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ACUTE EFFECTS OF ADVOCARE SPARK® ENERGY DRINK ON REPEATED
SPRINT PERFORMANCE AND ANEROBIC POWER IN NCAA
DIVISION I FOOTBALL PLAYERS

by

Nnamdi Gwacham

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Health and Human Movement

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Logan, Utah
2011

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ABSTRACT

Acute Effects of AdvoCare Spark® Energy Drink on Repeated Sprint Performance and Anaerobic Power in NCAA Division I Football Players

by

Nnamdi I. Gwacham, Master of Science

Utah State University, 2011

Major Professor: Dr. Dale R. Wagner
Department: Health, Physical Education and Recreation

Consumption of supplements and energy drinks is common among athletes; however, there is a lack of research on the efficacy of energy drink consumption before and during short-duration, intense exercise. The purpose of this research was to investigate the acute effects of a low-calorie, caffeine-aurine, energy drink (AdvoCare Spark®) on repeated sprint performance and anaerobic power in National Collegiate Athletic Association Division I football players. Twenty well-trained Division I football players (age: 19.7 ± 1.8 years, height: 184.9 ± 5.3 cm, weight: 100.3 ± 21.7 kg) participated in a double-blind, randomized crossover study in which they received the energy drink or an isoenergetic, isovolumetric, noncaffeinated placebo. The two trials were separated by 7 days. The Running Based Anaerobic Sprint Test (RAST), consisting of six 35-m sprints with 10 s of rest between each sprint, was used to assess anaerobic power. Sprint times were recorded with an automatic electronic timer. On average, there

was no statistically significant difference between the placebo ($15.06 \pm 3.80 \text{ W}\cdot\text{s}^{-1}$) and beverage ($15.3 \pm 4.18 \text{ W}\cdot\text{s}^{-1}$) measurements of fatigue index. Neither were there statistically significant main effects of the beverage treatment on power $F(1, 18) = 3.84, p = 0.066$; or sprint time $F(1, 18) = 3.06, p = 0.097$. However, there was a significant interaction effect between caffeine use and the beverage for sprint times ($F = 4.62, p = 0.045$), as well as for anaerobic power ($F = 5.40, p = 0.032$), indicating a confounding effect. In conclusion, a caffeine-aurine energy drink did not improve the sprint performance or the anaerobic power of collegiate football players, but the level of caffeine use by the athletes likely influenced the effect of the drink.

(70 pages)

Public Abstract

Acute Effects of AdvoCare Spark® Energy Drink on Repeated Sprint Performance and Anaerobic Power in NCAA Division I Football Players

Sports drinks, such as Gatorade and Powerade, have been designed to refuel athletes during and after their performance. Specifically they are designed to have optimal levels of carbohydrates to replenish electrolytes and prevent dehydration. In contrast, energy drinks are reported to increase mental alertness and physical performance during exercise. These drinks are designed to have substantial levels of caffeine as the main ingredient. For some years, energy drinks have become widespread both in recreational and trained athletes, because of their presumed influence on physical performance. A variety of energy drinks are currently on the market today and are purported to increase the energy level of the individuals consuming them.

The effect of caffeine on endurance performance is well known. However, comparatively less research has been conducted on its ability to improve anaerobic performance such as in sprinting. Some studies showing no effect of caffeine on performance used non-athletic people and study designs often not conducive to observing any physical improvement. However, recent studies incorporating trained athletes and specifically aimed at discontinuous sports activity (football, hockey, rugby) support the notion that caffeine can improve anaerobic exercise to an extent.

The purpose of this study was to investigate the acute effects of a commercially available caffeine-containing energy drink on repeated sprint performance and anaerobic power in college football players. Twenty well-trained Utah State University football players participated in the study in which they received the energy drink (AdvoCare Spark®) or a placebo without caffeine.

The Running Based Anaerobic Sprint Test (RAST), consisting of six 35-m sprints with 10 seconds of rest between each sprint, was used to assess anaerobic power. Sprint times and analysis of anaerobic power were used to understand the effects of acute ingestion of the energy drink. Sprint times increased from 5.11 seconds for the first sprint to 6.90 seconds for the sixth sprint on the placebo with almost exactly the same change for the energy drink (5.10 seconds to 6.90 seconds). In short, the energy drink did not improve sprint speed or change the rate of fatigue with repeated sprints. Through the analysis, a better understanding was gained of how caffeinated energy drinks impact physical performance in trained athletes.

DEDICATION

This thesis is dedicated to my parents, Edwin and Caroline Gwacham, who instilled a deep appreciation for the value of opportunities, who modeled the hard-working citizen, and who encouraged me each and every day to take advantage of every opportunity. Thanks, Mom, for believing I could do whatever I set out to accomplish, for reminding me each day that I am special, for knowing exactly what to say to keep me motivated. Dad, you taught me to love learning, and to reach for the stars and for that I am grateful.

This and other achievements I may realize are dedicated to my supportive and encouraging family – Adaobi, Chikodili, & Ifunanya, my sisters; and my brother, Obumneke. You will reach your stars, too.

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First and foremost, I would like to thank God. In the process of putting this thesis together, I realized how much He has blessed me with. You have given me the power to believe in my passion and pursue my dreams.

I would like to thank Dr. Dale Wagner for the countless hours he devoted to reading and editing many drafts of my proposal and thesis. I would also like to thank my committee members, Drs. Edward Heath, Gerald Smith, and Korry Hintze, for their support, direction, and guidance. I would also like to thank the twenty Utah State football players that woke up early in the morning to run sprints for the sake of science.

A special thanks to my fellow researchers, Ryan Porter, Josh Nagao, Scott Hadley, Anna Fukunaga, and Adam Raikes, for showing up early each day to help with the data collection. I give a special thanks to my family, and friends for their encouragement, moral support, and positive attitude as I worked my way from the proposal stages to this final document. I could not have done it without all of you.

Nnamdi I. Gwacham

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CHAPTER 1

INTRODUCTION

The dietary supplement industry dramatically impacts collegiate athletes who are continually seeking a competitive edge. A number of collegiate athletes today are taking vitamin and mineral supplements. In addition to vitamins and minerals, athletes are experimenting with the latest supplemental trends and ergogenic aids such as creatine, caffeine, hydroxyl-methyl-butyrate (HMB), ephedrine, and androstenedione. Ergogenic aids refer to substances that increase the capacity for bodily or mental labor, especially by eliminating fatigue symptoms. Nutritional ergogenic aids refer to substances that enhance performance and are either nutrients, metabolic by-products of nutrients, food (plant) extracts, or substances commonly found in foods (e.g., creatine & caffeine) that are provided in amounts more concentrated than commonly found in the natural food supply (Tarnopolsky, 2008). So all of these are packaged carefully into one bottle and sold to the unbeknownst student-athlete as an energy drink.

Energy drinks are one of the most popular supplements besides multi-vitamins in the American young adult population. Many collegiate athletes use them for their potential ergogenic effect. They believe that using high energy supplements prior to performance will result in greater focus, reaction time, sustained energy, and power. Several papers, including one by Forbes, Candow, Little, Magnus, and Chilibeck (2007), have been published showing that ingestion of a pre-exercise, high energy supplement can delay fatigue and/or improve the quality of a resistance training workout. A recent study showed that a pre-exercise high energy supplement consumed 10 min prior to

resistance exercise enhanced acute exercise performance by increasing the number of repetitions performed and total volume of exercise (Hoffman et al., 2008). The improved exercise performance resulted in a significantly greater increase in both growth hormone and insulin concentrations, indicating an amplified anabolic hormone response to this pre-exercise supplement.

Many pre-exercise high energy supplements consist of multiple ingredients that are proposed to either increase metabolic rate, enhance exercise performance, or both. One such supplement is known as AdvoCare Spark . It consists of various herbal and amino acid ingredients which include thiamine, L-tyrosine, riboflavin, niacin, pantothenic acid, inositol, and taurine. These ingredients are suggested to work synergistically to enhance exercise performance. Thus, it is the purpose of this study to examine the effect of this popular, over-the-counter high energy supplement on repeated sprint performance, mean anaerobic power, and fatigue index in Division I collegiate football players.

Research Questions

1. Will AdvoCare Spark® significantly increase anaerobic power in NCAA Division I football players?
2. Will AdvoCare Spark® significantly reduce sprint time in NCAA Division I football players during a repeated sprint test?
3. Will ingestion of AdvoCare Spark® significantly reduce the fatigue index in NCAA Division I football players?

Research Hypotheses

1. AdvoCare Spark® will significantly increase the mean anaerobic power in NCAA Division I football.
2. Ingestion of AdvoCare Spark® will significantly decrease sprint time in NCAA Division I football players.
3. Ingestion of AdvoCare Spark® will significantly reduce the fatigue index in NCAA Division I football players after a repeated sprint test.

Limitations

Limitations for this study included the small subject population; due to the repeated measures of the study and procedural constraints, only twenty subjects were tested. Also, we were not able to ensure compliance in the study. Factors such as rest, prior exercise, and over-the-counter medications may have affected the participants' response or metabolism of the energy drink. We did not ask the participants which treatment they thought they received or how they felt after each treatment. In addition, plasma or urinary caffeine concentrations were not measured.

REVIEW OF LITERATURE

Introduction

Energy drinks are over-the-counter soft drinks advertised as boosting energy. These drinks do not emphasize energy resulting from the calories they contain, but rather through a selected combination of caffeine, vitamins, and herbal supplements. Caffeine is the “main energy” ingredient in these drinks. Its ability to enhance performance, under certain conditions, has been well documented. Yet consuming too much caffeine often has negative effects on overall wellness. Elite athletes continually strive for enhanced performance, trying a variety of strategies to reach that goal. Incorporating energy drinks within a training regimen may be one such strategy. The amount of research that has been done using energy drinks as an ergogenic aid is vast, but each study utilizes a beverage new to the market with its own different mixture of ingredients. This literature review will examine: (a) history of the energy drink, (b) ingredients of the AdvoCare Spark® energy drink, (c) physiological effects of consumption, (d) consumption of energy drinks with alcohol, and (e) consumption related to exercise and athletic performance.

History of the Energy Drink

Energy drinks entered the North American beverage market with glamorous names, attractive slogans, and expensive marketing campaigns and now occupy a portion of the beverage industry. They are available in corner stores, gas stations, and bars, usually displayed alongside soft drinks, juices, and sports drinks. According to their

manufacturers, in addition to providing a boost of energy, the drinks promote wellness through curative properties (containing vitamins and/or ingredients like ginseng, guarana, and taurine). People drink them to keep up their energy during periods of intense physical activity or drink them after exercise to quench their thirst. But rather than re-hydrating their bodies, these drinks may actually lead to dehydration.

In a review article by Heckman, Sherry, and de Mejia (2010), energy drinks are characterized as functional beverages which encompass sports and nutraceutical drinks. Nutraceutical beverages are designed to promote and enhance health, usually containing bioactive compounds such as concentrated extracts from teas, fruits, and vegetables or herbs (Heckman et al., 2010). Additionally, some nutraceutical beverages are found to be fortified with vitamins and minerals and contain significant levels of antioxidants. In some instances, energy drinks could overlay into the nutraceutical beverage category depending on their ingredient composition (Heckman et al., 2010).

The term energy drink suggests activity, and the uninformed consumer may assume that such a drink would support physical exercise. Locating energy drinks on store shelves adjacent to traditional sports drinks like Gatorade™ and Powerade™ reinforces such an assumption of a positive relationship between their use and exercise. Caffeine, the main stimulant ingredient in most energy drinks, has been shown by research to offer questionable potential as a performance enhancer, in light of the broad variation in individuals' tolerance of it and the accompanying range of possible adverse effects (reproductive effects, links to cancer, anxiety, and mood changes).

Drinks providing high doses of caffeine are not a new concept. Lucozade Energy™, a forerunner to today's energy drink phenomenon, was originally introduced in the 1920s as a hospital drink for "aiding the recovery." In the early 1980s, it was promoted as an energy drink for "replenishing lost energy" (Retelny, 2007). The Red Bull™ energy drink, introduced to the United States in 1997, was the forerunner of the modern energy drink and remains the most recognizable brand in the industry (Retelny, 2007). However, it has considerable competition in today's marketplace; 500 new varieties of energy drink were introduced to the worldwide market in 2006 (Fornicola, 2007). According to Packaged Facts, the market research and analysis firm, the U.S. market for the drinks is estimated at \$5.4 billion in 2006, growing at an annual rate of 55% per year (Weise, 2008). The United States is the world's largest consumer by volume of energy drinks, roughly 290 million gallons in 2007, according to Zenith international, a British consulting group. Americans drink 3.8 quarts per person per year (Weise, 2008). It is also pointed out in the review article by Heckman et al. (2010) that the U.S energy drink industry is anticipated to more than double and reach \$19.7 billion in 2013, which is almost a 160% increase from 2008. Many companies continue to introduce new drinks, hoping to capture a share of the growing consumer base. Responding to the influx of new products with which they must compete, manufacturers push the boundaries, producing drinks with increasingly complex combinations of medicinal ingredients with even higher levels of caffeine and served in larger sizes (Fornicola, 2007).

Ingredients of AdvoCare Spark®

It seems energy drink companies are cramming more and more ingredients into their products. Consumers are left wondering what all the ingredients will do for their bodies. Content labeling has always been inconsistent across North America, and the steady stream of new products developed for the energy drink market further complicates the picture. The Food and Drug Administration (FDA), while it regulates caffeine content in soft drinks, does not regulate caffeine contained in energy drinks (Weise, 2008). In the United States, it is not required that manufacturers list the ingredients of energy drinks; therefore, consumers do not appreciate the amount of ingested caffeine in an energy drink. While the information is made known to the consumer if they contact the manufacturer, it is implausible that consumers are concerned about product ingredients to the point of calling the 1-800 number. Ingredients of the AdvoCare Spark® energy drink are listed in Table 1. The physiological influence that these ingredients have on the body and their proposed ergogenic benefits are summarized in Table 2.

Physiological Effects of Consumption

Ingestion of an energy drink may boost athletic performance. Caffeine is the only ingredient in energy drinks that has been studied in depth and that shows proven effects; short- and long-term effects of high doses of taurine and gluconorolactone require additional study. One study found that acute supplementation of 1.66 g of taurine 1 hr before 90 min of submaximal cycling followed by a 25-min time trial was not ergogenic.

Table 1. Supplement and ingredients in AdvoCare Spark®

Supplement Facts		
Serving Size: 1 pouch		
	Amt per serving	%DV ^a
Calories	45	
Total Carbohydrate	11g	4%
Vitamin A (as beta-carotene)	1,000 IU	20%
Vitamin C (as ascorbic acid)	180 mg	300%
Vitamin E (as d-alpha tocopheryl acetate)	300 IU	100%
Thiamine (as HCl)	3 mg	200%
Riboflavin	3.4 mg	200%
Niacin (as niacinamide)	60 mg	300%
Vitamin B-6 (as pyridoxine HCl)	15 mg	750%
Vitamin B-12 (as cyanocobalamin)	45 mcg	750%
Pantothenic acid (as calcium pantothenate)	50 mg	500%
Zinc (as zinc monomethionine)	3 mg	20%
Copper (as copper glycinate)	200 mcg	10%
Chromium (as chromium citrate)	24 mcg	20%
Choline (as bitartrate and citrate)	500 mg	^b
L-Tyrosine	500 mg	^b
Taurine	200 mg	^b
Caffeine	120 mg	^b
Glycine	100 mg	^b
Citrus flavonoids	50 mg	^b
Gamma-aminobutyric acid (GABA)	50 mg	^b
L-Carnitine (as tartrate)	10 mg	^b
Inositol	10 mg	^b

^a Percent Daily Values (DV) are based on a 2,000-calorie diet.

^b Daily Value not established

OTHER INGREDIENTS: Maltodextrin, citric acid, silicon dioxide, sucralose, natural flavors.

Table 2. Bodily functions and proposed ergogenic benefits of AdvoCare Spark ingredients (Antonio & Stout, 2001).

Nutrient	Bodily functions	Proposed ergogenic benefits
Vitamin A	Essential for vision as well as cellular differentiation, growth, reproduction, bone development, and the immune system.	No benefit, unless preexisting deficiency
Vitamin C	Synthesis of catecholamine neurotransmitters and collagen, essential for proper immune system function, synthesis & activation of thyroxin. Plays a role in conversion of cholesterol into bile acids & acts as an antioxidant	Optimizes ability of cells to maintain aerobic energy production (Gonzalez, Miranda, & Riordan, 2005)
Vitamin E	Acts as an antioxidant, essential nutrient for cell & tissue health, which may have a role in blood flow, immune function and blood cell functioning and in protecting against cellular stress.	No benefit, unless preexisting deficiency
Thiamine	Important for energy transformation reactions, synthesis of pentoses and NADPH. Needed for normal functioning of the nervous system and muscles, including heart muscle.	No benefit, unless preexisting deficiency
Riboflavin	An important component in coenzymes participating in many enzyme reactions; important for the metabolism of fat and carbohydrate; helps in red blood cell formation; promotes the release of energy from foods; essential in nervous system function	No benefit, unless preexisting deficiency
Niacin	Important in all steps essential for energy production and utilization, tissue and organ function; involved in making important tissue and body components. Niacin also promotes release of energy from foods and proper nervous system functioning.	No benefit, unless preexisting deficiency
Vitamin B-6	Essential for protein metabolism, nervous system, & immune functions. Necessary for synthesis of hormones & red blood cells. Enhances muscle growth & decreases anxiety.	No benefit unless preexisting deficiency
Vitamin B-12	Necessary for processing carbohydrates, proteins & fats. Acts as a coenzyme in the synthesis & repair of DNA & enhances muscle growth	No benefit, unless preexisting deficiency

Nutrient	Bodily function	Proposed ergogenic benefit
Zinc	Plays a role in the growth & development of many cells, tissues, & the immune system, helps support healthy eye function, may improve glucose tolerance by increasing insulin	No benefit
Pantothenic Acid	Involved in the metabolism & efficient utilization of fats, hormones, and components necessary for immune function. Involved in the breakdown of carbohydrates & formation & breakdown of fatty acids.	May hold benefit for exercise that is limited by lactate production, thus enhancing exercise recovery (Antonio & Stout, 2001).
Copper	Functions as enzyme cofactors, and as an intermediate in electron transfer, and, plays a role in iron metabolism, melanin synthesis, and central nervous system function.	No benefit
Chromium	Involved in metabolism of carbohydrates, lipids, & proteins. Increases muscle cell's sensitivity to insulin. Certain forms decrease insulin levels & improve glucose disposal in obese populations.	Niacin bound chromium has been proven to improve power output in sprint cycling (Frank & Baer, 2002). Chromium supplementation during strength training programs can result in greater gains in muscle mass & concurrent losses in fat weight than training alone (Antonio & Stout, 2001)
Choline	Aids in formation of a number of important substances in the body essential for nerve function & protection, muscle control, & memory. Utilized in producing phospholipids involved in brain & heart functions & energy utilization.	Choline supplementation ameliorates the decrease in plasma free choline & can be utilized as an ergogenic aid when exercising continuously for two hours or more (Buchman, Awal, Jenden, Roch, & Kang, 2000)

Nutrient	Bodily function	Proposed ergogenic benefit
Caffeine	Exhibits stimulatory actions in the central nervous system, cardiovascular system, and muscles. Also amplifies lipolysis. Affects the brain and results in elevated mood, decreased fatigue, and increased attentiveness. Increases norepinephrine excretion and enhances neural activity. Increases heart rate, blood flow, respiratory rate, and metabolic rate.	A number of research articles have concluded that caffeine improves time-trial endurance performance by release & mobilization of free-fatty acids (Ganio, Klau, Casa, Armstrong, & Maresh, 2009). Studies incorporating trained subjects and paradigms specific to intermittent sports activity support caffeine's ergogenic benefits with anaerobic exercise ranging in duration from 60 to 180 s (Davis & Green, 2009)
L-Tyrosine	Improves mental energy & focus by serving as a precursor for the neurotransmitters epinephrine, norepinephrine, & thyroid hormones	Tyrosine supplementation significantly increases plasma tyrosine levels, but has no significant ergogenic effects on aerobic endurance, anaerobic power, or muscle strength (Sutton, Coll, & Deuster, 2005)
Taurine	Aids in stabilizing cells & tissues through antioxidative properties, protects the nervous system. Helps maintain blood lipid levels & stabilizes blood platelets.	Can induce increases in VO_{2max} and cycle ergometer exercise time to exhaustion (Zhang et al., 2004).
Glycine	Participates in several important reactions, including the biosynthesis of heme, an important constituent of hemoglobin.	No benefit
Citrus Flavonoids	Acts as an antioxidant by donating electrons. Also associated with anti-inflammatory activity, vitamin C sparing action, beneficial effects on blood flow and anti-allergenic interactions with immune cells	No benefit

Nutrient	Bodily function	Proposed ergogenic benefit
GABA	Directly responsible for the regulation of muscle tone, acts as a “balancer” in the brain, balancing the excitation of neurons with their inhibition	No benefit
L-Carnitine	Essential for the transport of fatty acids into the mitochondrion for conversion into energy by oxidation. Increases blood flow by improving fatty acid oxidation in the artery walls.	Carnitine supplementation has been shown to demonstrate a benefit in high intensity activities when consumed either just before the activity or for several days (Brass, 2004).
Inositol	Helps establish healthy cell membranes and maintain proper electrical energy and nutrient transfer across the cell membrane. Also involved in the conversion of fat into other useful products.	No benefit

The researchers also found that taurine had no effect on the normal physiological responses (heart rate and rate of perceived exertion) to exercise (Rutherford, Spriet, & Stellingwerff, 2010).

Athletes have long used caffeine prior to training sessions and competitions, but most nevertheless do not understand how the drug works. For example, as a diuretic, caffeine is capable of setting off the dehydration athletes may experience during competition. The scientific literature itself provides mixed messages about caffeine's performance-enhancing capability and its value prior to exercise. Beck, Housh, and Schmidt (2006) stated that the ingestion of caffeine resulted in a significant increase in strength training. Forbes et al. (2007) reported a significant increase in muscular endurance with energy drink consumption. In contrast, Fornicola (2007) stated that no real need exists to use energy drinks for performance advantage, and the quick caffeine fix is not a very intelligent strategy. Seidl, Peyrl, Nicham, and Hauser (2000) demonstrated that cognitive performance and well being are stimulated with use of caffeine and taurine. The same study attributed those effects on caffeine's action on purigenic (adenosinergic) receptors and taurine modulation of receptors.

Carefully controlled studies have demonstrated an ergogenic effect of caffeine during endurance exercise performance (Greer, Friars, & Graham, 2000; Rahnama, Gaeini, & Kazemi, 2010). The traditional hypothesis has been that caffeine ingestion may enhance time to exhaustion because of its implication in increasing lipolysis from adipose tissue and thus enhancing fat oxidation resulting in spared stored glycogen during intense and prolonged exercise (Hoffman, 2010; Laurent et al., 2000; Rahnama et al., 2010).

However, several studies have raised doubts that the ergogenic effect of caffeine is due to the aforementioned metabolic effects (Greer et al., 2000). In a review paper by Ganio, Klau, Casa, Armstrong, and Maresh (2009), it was mentioned that the ergogenic effect of caffeine, especially in non-glycogenic-limiting exercise, is thought to be more central in nature and not metabolic. Kruskall and Miracle's (2009) review mentions that although free fatty acid release increases with caffeine ingestion, free fatty acid oxidation is not increased nor is glycogen spared. The authors suggest that the ergogenic benefit may be related to caffeine's role as a central nervous system stimulant. Klepacki's (2010) review article mentions a study in which free fatty acid concentrations were significantly elevated up to 180 min post ingestion, while glycerol values were significantly elevated only 60 min post ingestion.

Furthermore, although the effects of caffeine on short term, high intensity exercise performance have produced inconsistent results (Bell, Jacobs, & Ellerington, 2001), the traditional theory used to explain the ergogenic effect of caffeine would not account for improved endurance reported in shorter duration, higher intensity exercise protocols (Greer, Morales, & Coles, 2006). Candow, Kleisinger, Grenier, and Dorsch (2009) found that sugar-free Red Bull™ energy drink did not significantly improve high-intensity run time-to-exhaustion in young healthy adults. The authors noted a possible reason for the results was due to the lack of carbohydrates in the treatment condition. Davis and Green (2009) stated that most studies failing to show ergogenic potential in anaerobic performance have incorporated untrained subjects (not specifically accustomed to intermittent-sprint exercise). They also went on to conclude that caffeine does provide

an ergogenic benefit when the testing protocol more closely mimics athletic competitions with trained subjects accustomed to intermittent-sprint bouts.

Potential influences of caffeine during short-term, high-intensity exercise include a direct effect on skeletal muscle, an impact on excitation-concentration coupling affecting neuromuscular transmission, and an increased mobilization of intracellular calcium from the sarcoplasmic reticulum (Laurent et al., 2000). It has been demonstrated that caffeine potentiates twitch and tetanic tension in directly stimulated isolated muscle and indirectly stimulated isolated nerve-muscle preparations in both fatigued and non-fatigued states both *in vitro* and *in vivo* (Tarnopolsky, 2008). However, caffeine's ergogenic effects on voluntary neuromuscular performance are more ambiguous. While some studies have reported that maximum voluntary contraction and muscular endurance are not affected by the administration of caffeine (Crowe, Leicht, & Spinks, 2006), others report an ergogenic effect on these variables (Forbes et al., 2007).

One hypothesis to explain caffeine's direct impact on skeletal muscle is an increase in calcium release at the sarcoplasmic reticulum, making calcium more available to the contractile mechanism (Tarnopolsky, 2008). However, the effects of caffeine on intracellular calcium and force production observed *in vivo* require millimolar concentrations of caffeine which would be toxic to humans. There are some human studies that have reported delayed fatigue and enhanced recovery of contractile properties after fatiguing electrical stimulation (Tarnopolsky, 2008), thus the possibility that caffeine may directly affect skeletal muscle in some instances cannot be discounted. At present, it is unclear how these alterations in neuromuscular function might affect human

performance during high-intensity dynamic exercise. It may be that acute caffeine ingestion changes motor unit recruitment and discharge characteristics.

It has been found that caffeine inhibits the brain's adenosine receptors (Davis et al., 2003). In a recent review of caffeine use in sports, Sökmen et al. (2008) stated that caffeine affects the central nervous system by stimulating the secretion of serotonin in the cerebral cortex, enhancing the action of the sympathetic system, and diminishing the activity of inhibitory neurons. They went on to propose that this mechanism greatly affects the user's cognition and mood. This review by Sökmen et al. (2008) cited several studies that demonstrate, depending on timing, quantity of dose, and habituation to caffeine, the positive effects of acute caffeine intake include decreased tiredness, increased mental alertness, mood improvement, and energetic arousal as a result of caffeine on the central nervous system. These cognitive effects; however, depended on the quantity of acute caffeine intake, tolerance to caffeine, and cessation from caffeine.

In a study by Ragsdale et al. (2009), it was found that consumption of Red Bull™ was accompanied by an increase in the saliva caffeine concentration 60 and 120 min post-prandial. The elevation in saliva caffeine reflected a change in the plasma caffeine concentration of the subjects. The researchers also found no changes in blood pressure and heart rate following consumption of the energy drink in comparison to a placebo. However, an increase in pain tolerance was observed that could be attributed to consumption of the energy drink. This may allow athletes to work-out harder and longer thereby leading to enhanced performance.

During exercise, adenosine levels increase in skeletal muscle and blood in proportion to the rate of adenosine triphosphate hydrolysis. Although it has not been determined how adenosine levels change in the brain during exercise, adenosine can cross the blood-brain barrier. Adenosine binds to adenosine receptors and slows nerve cell activity, whereas caffeine blocks adenosine receptors and speeds up the activity of the cells (Sökmen et al., 2008). On binding to its receptors, adenosine lowers brain dopamine levels. This lowers the serotonin:dopamine ratio, resulting in sensations of weariness and central nervous system fatigue. By blocking the adenosine receptors, it is believed that caffeine is able to maintain alertness and vigor and delay sensation of fatigue (Davis et al., 2003).

Many studies examining the effect of caffeine on body weight are difficult to interpret because caffeine is usually combined with another substance. Hoffman's (2010) review mentions that caffeine alone has been demonstrated to be effective in enhancing lipolysis, fat oxidation, and reducing glycogen breakdown; however, when it is combined with other thermogenic agents (i.e., ephedrine), its effectiveness appears to be magnified. Caffeine, in combination with ephedra, has been shown to be an effective supplement for increasing metabolic rate and stimulating fat loss (Kruskell & Miracle, 2009). Although the research that reports positive effects of caffeine use on body weight are scarce, even fewer studies have examined the role of caffeine in weight maintenance and those few have reported conflicting results (Kruskell & Miracle, 2009). The effect of prolonged consumption of energy drinks on weight loss has shown some promising results. Hoffman (2010) cited a study that reported significant decreases in body mass and body

fat, with positive alterations to lipid profiles following 6 months of using an ephedrine and caffeine supplement. In consideration of the large obesity epidemic within the United States, additional research appears warranted to determine whether energy drinks can play a significant role, in combination with dietary and exercise intervention, in the treatment options associated with weight loss.

Consumption with Alcohol

The concept of sobering up after a rough night of drinking by loading up with caffeine is a time-honored tradition. The newer activity of ingesting energy drinks that contain alcohol to maintain the feeling of alertness potentially increases the risk of physical and social harm (Weldy, 2010). Weldy (2010) mentioned that caffeine alone is associated with sensation seeking and impulsivity among college students, including sexual activity, marijuana use, seatbelt omission, taking a dare, smoking, alcohol problems, illicit prescription drug use, and “identity and masculinity behaviors” associated with sports.

The consumption of energy drinks along with alcohol lessens the subjective sense of intoxication (O’Brien, McCoy, Rhodes, Wagoner, & Wolfson, 2008). This means one can consume more alcohol than usual because one does not feel intoxicated. In addition, the alcohol-induced fatigue that normally tends to limit further alcohol consumption may be masked by the caffeine in the energy drink (Reissig, Strain, & Griffiths, 2009). The packaging of the combination drinks is nearly identical to energy drinks without alcohol, resulting in the sale of these products to minors or unsuspecting parents (Weldy, 2010).

Although energy drink companies may caution consumers against mixing the products with alcohol, young people, especially, do so. Combining a depressant (alcohol) with a stimulant (energy drink containing caffeine) clearly could exacerbate the typical risks of alcohol consumption. The practice, combined with the tendency of collegiate athletes to binge on alcohol, should raise concern. O'Brien et al. (2008) indicated that

students who reported consuming alcohol mixed with energy drinks had had significantly higher prevalence of alcohol-related consequences, including being taken advantage of sexually, taking advantage of another sexually, riding with an intoxicated driver, being physically hurt or injured, and requiring medical treatment. (p. 456)

The physiologic and psychological response to alcohol depends on well-known factors, including body weight, sex, sleep status, general health, hepatic health, nutrition, and medication. Therefore, the quantities of caffeine, alcohol, and other ingredients in alcoholic energy drinks, as well as the ratios needed to produce alertness despite impairment from intoxication, are dependent on the individual, and their previous exposure to and tolerance of alcohol and caffeine (Weldy, 2010). Curry and Stasio (2009) found that consumption of an alcohol-laden energy drink impaired neuropsychological functioning, as measured by the Repeated Battery for the Assessment of Neuropsychological Status. More results of the combination of caffeine and alcohol include: a more rapid absorption of alcohol, a greater total volume of alcohol absorbed, greater physical impairment, and a significantly reduced perception of intoxication in oneself as well as others (Curry & Stasio, 2009). This, in part, prevents one from recognizing impairment or risky behavior in others, such as not recognizing that one's driver is drunk, and may enhance risk-taking behavior by young individuals who are

known to have a baseline of less mature judgment concerning sexual activity and motor vehicle use. An increased sense of immortality, and disregard for the risks of pregnancy, sexually transmitted infections, accidents, and injury can also be factors (Weldy, 2010).

Consumption Related to Exercise and Athletic Performance

Each generation of athletes is better than the previous one, and each generation seeks new methods to improve performance. Some of today's athletes believe that energy drinks can be used to enhance their performance during training and competition due to their potentially ergogenic ingredients such as carbohydrates, caffeine, sodium, and taurine, among others. Consumption of sports drinks is recommended for many athletic endeavors and not all of the sport beverages are the same. They differ in type and concentration of carbohydrates, electrolytes, flavors, and other constituents. Some simply replace carbohydrates and electrolytes; others provide added protein, specific amino acids, and even fat, while still others provide herbs, vitamins, and caffeine.

Energy drinks (e.g., Red Bull™, Monster™, Rockstar™, Full Throttle™, Amp™, and AdvoCare Spark®) are beverages designed and consumed for purposes other than for improving athletic performance; for instance, to reduce the depressant effects of alcohol on the central nervous system. On the other hand, sports and fluid-electrolyte replacement beverages (e.g., Gatorade and Powerade) are designed and consumed to enhance athletic performance or to reduce the deleterious effects of dehydration during athletic competitions. It should be noted that, although energy drinks have been sold worldwide for more than a decade, unfortunately only a few studies have been published to test the

effectiveness of these beverages on the physical or cognitive performance in collegiate athletes.

Alford, Cox, and Wescott (2001) investigated the effects of an energy drink (Red Bull™) on psychomotor, anaerobic, and aerobic performance, and reported that the Red Bull group improved aerobic and anaerobic performance by 9% and 24%, respectively. Anaerobic performance was measured by a 20-s cycle ergometer test. In another study the influence of a multivitamin/mineral supplement on anaerobic exercise performance (a 30-s cycle sprint test and one set of squat exercise) was examined by Fry and colleagues (2006), and a decreased rate of fatigue was noted for both exercise tests.

In a recently published study, Ivy et al. (2009) found that ingesting an energy drink containing carbohydrates, taurine, gluconorolactone, caffeine, and several B-vitamins 40 min before exercise improved performance on a 1-hr cycling time trial. The improvement averaged 4.7%, with 83% of participants demonstrating a positive effect. The mechanism by which energy drinks improved performance was not immediately clear. It is possible that caffeine improved exercise response during the energy drink trial by increasing or maintaining a high central nervous system drive. It is well established that providing carbohydrates during prolonged aerobic exercise increases endurance and exercise performance (Ivy, Res, Sprague, & Widzer, 2003). This improvement in exercise performance is believed to be related to maintaining an adequate glucose supply to the active muscles. Research indicates, however, that providing carbohydrate 30-60 min before exercise will increase the plasma insulin concentration of liver glucose output and

increase muscle glucose uptake (Ivy et al., 2009). Elevated plasma insulin also inhibits lipolysis and therefore increases reliance on muscle glycogen as a fuel source.

Ivy et al. (2003) reported that caffeine increased self-selected exercise intensity early in exercise and that, relative to exercise intensity, rating of perceived exertion was lowered by caffeine. That is, with caffeine, participants were able to exercise more intensely than with placebo but with the same perception of effort. Similarly, Cole et al. (1996) observed that a greater amount of work was performed at predetermined levels of perceived exertion after participants consumed 6 mg caffeine/kg body weight 1 hr before exercise compared with a placebo. This ability to influence the psychological state and alter pain perception can significantly affect exercise performance. During high levels of physical activity, an increase in the release of β -endorphins has been proposed to limit discomfort and pain, invoke euphoria, and reduce sensation of effort (Laurent et al., 2000). There is a lack of research concerning the effect of these high energy drinks on the fatigue index. In one study, Fry et al. (2006) noted a decreased rate of fatigue following multi-vitamin/mineral supplementation.

Summary

Given the proliferation of energy drinks and their growing popularity despite possible negative effects, coaches and athletic department administrators should take the initiative in educating student-athletes about the products. Energy drinks are aggressively marketed to college students with messages touting the performance and other benefits of consuming the beverages. Students are urged to be energy drink consumers, and for the

uninformed student-athlete, the trend's influence may produce negative consequences. While the proposed benefits of the taurine and gluconorolactone in energy drinks are unproven, potential positive and negative effects of another common ingredient, caffeine, are well documented. The choice to use caffeine prior to training or competition should belong to the individual, based on adequate knowledge of the pros and cons and on past experiences with caffeine. Student-athletes who choose to use caffeine should be encouraged to do so in moderation. They should also be provided information about levels of caffeine contained in various foods and beverages, in order to monitor their uptake. Most energy drinks do not contain more caffeine than a cup of coffee, but there is a noticeable trend toward selling the beverages in larger containers – meaning more servings and more caffeine.

If consuming an energy drink before a competition improves mood and concentration, it would be difficult to suggest that it poses significant danger. Non-using athletes who are considering caffeine as an ergogenic aid will be unaccustomed to its cognitive and physiological effects. Nonusers therefore should test its effects before implementing a caffeine strategy for training and competition (Sökmen et al., 2008). Although deaths associated with energy drink consumption and sport have been reported, they seem to be isolated cases involving multiple servings with high levels of caffeine (Nordqvist, 2004). While it is important to provide student-athletes with accurate information on energy drinks and caffeine, as these affect athletic performance, of greater concern to athletic departments should be the growing trend of combining energy drinks and alcohol. Take the not uncommon pattern of student-athletes, dehydrated by the effort

of playing a game, gathering after that game to consume alcohol. If the alcohol is mixed with caffeinated energy drinks, the student-athletes are subjected to a double diuretic effect, since alcohol, like caffeine, has diuretic properties. Thus they further compromise hydration.

Caffeine ingestion can benefit high-volume or intense endurance training. Three or four days of consecutive low levels of caffeine intake, during the period of heavy training days, can serve as the “washout period” prior to using caffeine during a competition (Sökmen et al., 2008). Caffeine seems to be ergogenic during high intensity exercise, depending on the model. Davis and Green (2009) concluded that exercises examining isokinetic peak torque, isometric maximal force, muscular endurance for upper body musculature, and 1RM show equivocal results, with caffeine having minimal ergogenic effect within these areas.

Earlier research examining the effects of caffeine on performance typically employed untrained subjects with methodologies not specific to high-intensity intermittent sport activities. Davis and Green (2009) stated that these designs and subject characteristics potentially contributed to the conclusion that caffeine may not be beneficial in this model. Caffeine seems to be the most beneficial for trained subjects accustomed to the severity of the tested protocols (Davis & Green, 2009). The reason for such differences in training status between subjects is currently unclear. Speed endurance (60-180 s) seems to be highly affected by caffeine. High intensity exercise (e.g., sprinting and sprint cycling) seems to be favorably affected with methodologies employing protocols that mimic sport activities (i.e., 4-6 s), while agility performance remains

unclear (Davis & Green, 2009). Therefore, sports such as soccer, rugby, lacrosse, and football would seem to be favorably affected by caffeine.

METHODS

Energy drinks are among the most popular supplements being used by young adult and athletic populations today. Although caffeine is the primary active ingredient in these drinks, the combinations of various other ingredients including herbal and botanical compounds make it quite difficult to provide a general statement of efficacy for energy drinks. The answer regarding the efficacy and risk associated with an energy drink is specific to the ingredients within each respective supplement. The purpose of this study was to examine the effect of AdvoCare Spark® on physical performance, anaerobic power, and fatigue in Division I collegiate football players. This chapter will discuss the participants used in the study, the procedure, as well as the statistical analyses.

Participants

Twenty male student athletes from the Utah State University football team volunteered to participate in the study. The athletes were informed that their participation was voluntary and not a requirement for being on the team. In order to be eligible to participate in the study, participants had to be a member of the Utah State football team and train for competition at least 4 days per week (approximately 60 min in each session). The participants signed an informed consent (Appendix A), outlining risks involved, before participating in the study. The nature of the study was explained to everyone involved and any questions were answered. The Institutional Review Board of Utah State University approved the study.

Procedure

The study utilized a double blind, counterbalanced cross-over design such that each participant received both the energy drink and a placebo during two trials. One week prior to data collection, the participants were instructed on how to perform the Running-based Anaerobic Sprint Test (RAST). The participants were instructed to avoid alcohol, nicotine, and other stimulants and sudden changes in food consumption (including any nutritional supplementation products) the day before the experiment. In addition, they were asked to maintain regular physical activities during the days prior to the experiment. Moreover, they were asked to wear comfortable, loose fitting clothing and get an adequate amount of sleep (6 to 8 hr) the night before the test. The clothing, shoes, as well as all equipment used, was consistent for each subject.

The participants arrived at the Dale Mildenerger Sports Medicine Complex in a fasted state where a standardized breakfast (approximately 400 kcal) was served. After breakfast, the participants were randomly divided into two groups (AdvoCare Spark® and placebo). Each athlete received one serving size (1 pouch made 8 fl oz) of related beverages. The beverages were served cooled, and the staff ensured that the participants consumed the entire amount. Citrus flavored water mixed with maltodextrin was consumed as the placebo. Information about the participants – body mass and height was taken. The participants also filled out a food frequency questionnaire to gain knowledge about their caffeine intake (Appendix B). The participants were then taken to Romney Stadium (where the RAST was performed). Due to the intensity of the RAST, the participants warmed up for at least 25 min. The warm-up was standardized for all of the

participants and consisted of: jumping jacks, seal jacks, stationary spidermans, inchworms, scorpions, lying leg kicks, bent leg rotations, sit and reach rollovers, figure-four stretch, hip flexor stretch, a-skips, high knee run, straight leg skips, leg kicks, lateral bounds, backwards stride run, and power skips. The RAST was performed (46.6 ± 6.30 min for placebo, and 46.2 ± 6.59 min for beverage) following the dynamic warm-up.

The RAST test was developed to test an athlete's anaerobic performance. The RAST consists of six 35-m discontinuous sprints and was conducted on the SprinTurf® surface of Merlin Olsen Field at Romney Stadium. Two 35-m sprint zones were sectioned off using cones (Figure 1).



Figure 1. Field setup at Romney Stadium for the RAST.

Each sprint represented a maximal effort with 10 s allowed between each sprint for turnaround. The time taken for each sprint was recorded to the nearest hundredth of a second. The participant sprinted at maximum speed through the cones each time. The time between each sprint was designed to allow the participant to recover and return to the start line after running through the marker, to record the time, and reset the timer. Each participant ran the sprints individually. Data were collected using the data collection sheet (Appendix C). The RAST was chosen primarily due to its reliability in relation to the Wingate test, and also because this test required minimal equipment and training of the assessors. The RAST was first investigated by Zacharogiannis, Paradisis, and Tziortzis (2004), who verified significant correlations between the RAST and the Wingate Anaerobic Test for peak power, and mean power variables ($r = 0.82$ and $r = 0.75$, respectively) and related that the RAST could be used to measure anaerobic power (P), and fatigue index (FI) as follows:

$$\text{P} = \frac{\text{Work}}{\text{Time}} \quad (1)$$

$$\text{FI} = \frac{\text{Time} - \text{Time}_0}{\text{Time}_0} \quad (2)$$

The RAST is also sport-specific in that it is a field-based anaerobic activity of an intermittent nature. It is easy to perform, provides scores that are easily reproduced and can be used to successfully estimate anaerobic power (Zacharogiannis et al., 2004).

During the RAST test, the time of each repetition and the rest interval were measured by an automatic timing system (Nike Sparq XLR8 Digital Timing, Beaverton,

Oregon). Wind speed was also measured with a wind gauge (Gill Athletics Compact Wind Gauge, Champaign, IL). Seven days later, the same procedure was followed with each participant receiving the treatment they did not receive the week before. The 7 day counterbalance ensured no treatment contamination, and it also allowed the participants adequate recovery between exercise tests.

Statistical Analyses

Descriptive data including means and standard deviations of age, height, and weight were each reported. A 2x6 repeated-measures analysis of variance (ANOVA) was conducted to determine if the differences in sprint time and anaerobic power were significant between the AdvoCare Spark® and placebo across all six trials. A global caffeine score calculated from the participants' responses to the caffeine inventory (Appendix B) was used as a covariate in an attempt to account for the potential influence of caffeine habituation. Subjects' caffeine history was evaluated by assigning a "caffeine score" to each participant based on their daily consumption of caffeinated beverages during the month prior to the test. This score was obtained by multiplying the subjects' serving size (1 = small, 2 = medium, 3 = large) by the number of times each caffeinated beverage was consumed. A paired samples *t* test was conducted to determine if the difference in fatigue index was significant between the AdvoCare Spark® and placebo trials. Statistical significance was set at $p < 0.05$. Statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS, version 19.0, IBM, Somers, NY).

CHAPTER 4

RESULTS

The purpose of this study was to investigate the acute effects of a low-calorie, caffeine-aurine, energy drink (AdvoCare Spark®) on repeated sprint performance and anaerobic power in NCAA Division I football players. Twenty well-trained Division I football players (age: 19.7 ± 1.8 years, height: 184.9 ± 5.3 cm, weight: 100.3 ± 21.7 kg) were tested in the RAST; once with a placebo and once with the treatment beverage. Figure 2 shows a comparison of the average sprint time through the six trials for both placebo and beverage. Figure 3 shows a comparison of the average anaerobic power between the placebo and AdvoCare Spark® through the sprint trials. Repeated-measures ANOVA with a caffeine-use score as a covariate was performed to determine whether significant mean differences existed between beverage and placebo values of anaerobic power and sprint time. Table 3 displays the results of the ANOVA. Data were normalized to the first sprint bout and charted accordingly (Figures 4 & 5).

Table 3. *Repeated-measures ANOVA (2x6) with caffeine use as a covariate for sprint time and power.*

	Sums of squares	df	Mean square	f	p
Treatment (power W)	23506.691	1	23506.691	3.843	0.066
Treatment*caffeine score	33040.395	1	33040.395	5.401	0.032*
Treatment (sprint)	0.363	1	0.363	3.057	0.097
Treatment*caffeine score	0.548	1	0.548	4.618	0.045*

* Denotes statistical significance

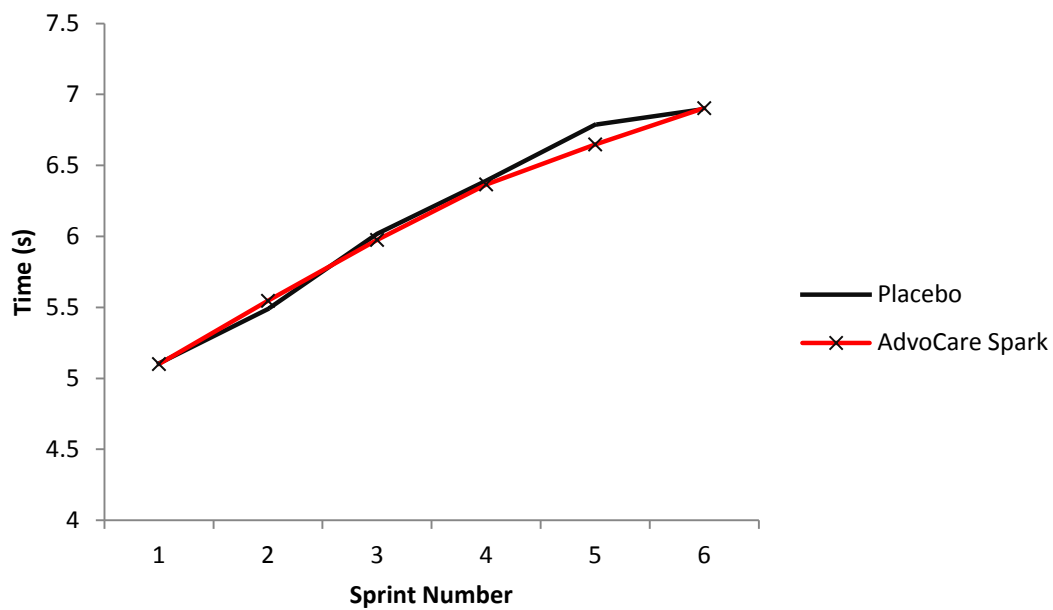


Figure 2. Comparison of average sprint times through sprint trials

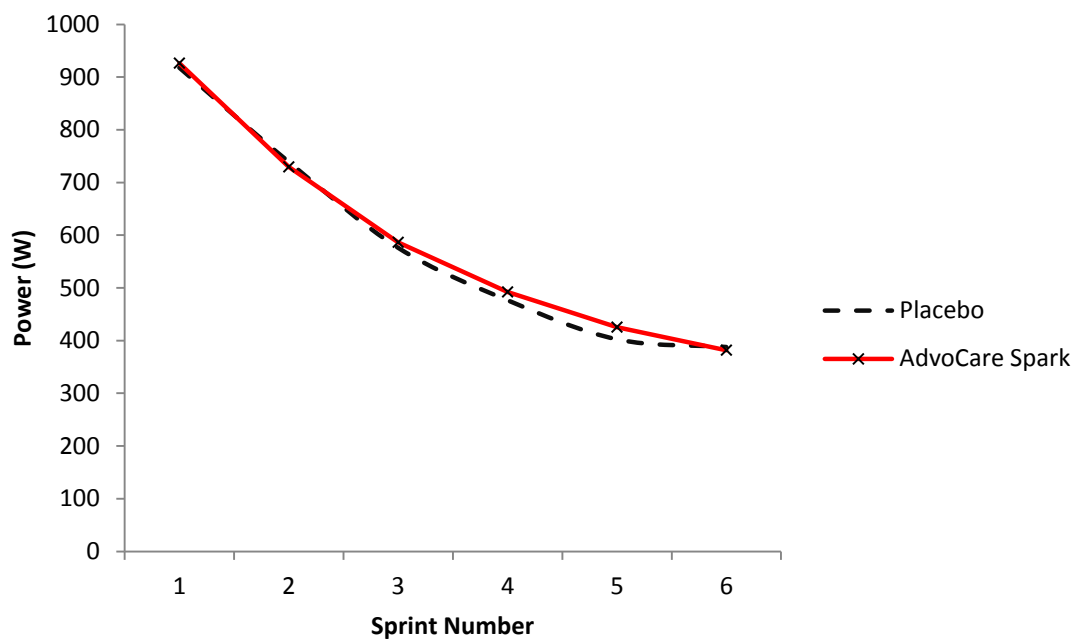


Figure 3. Comparison of average anaerobic power through sprint trials

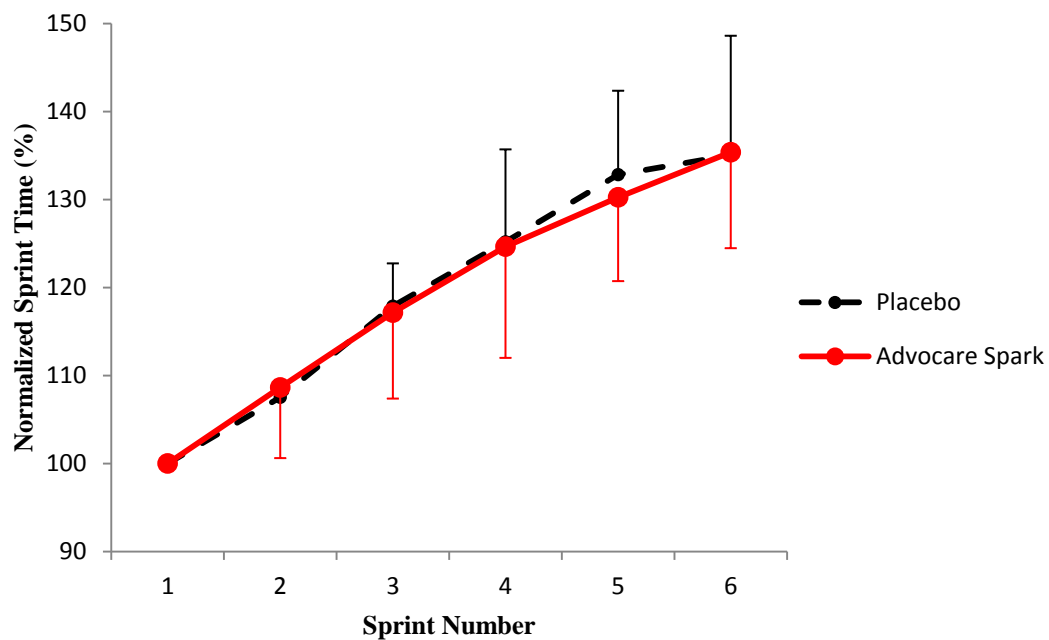


Figure 4. Comparison of normalized average sprint time through sprint trials

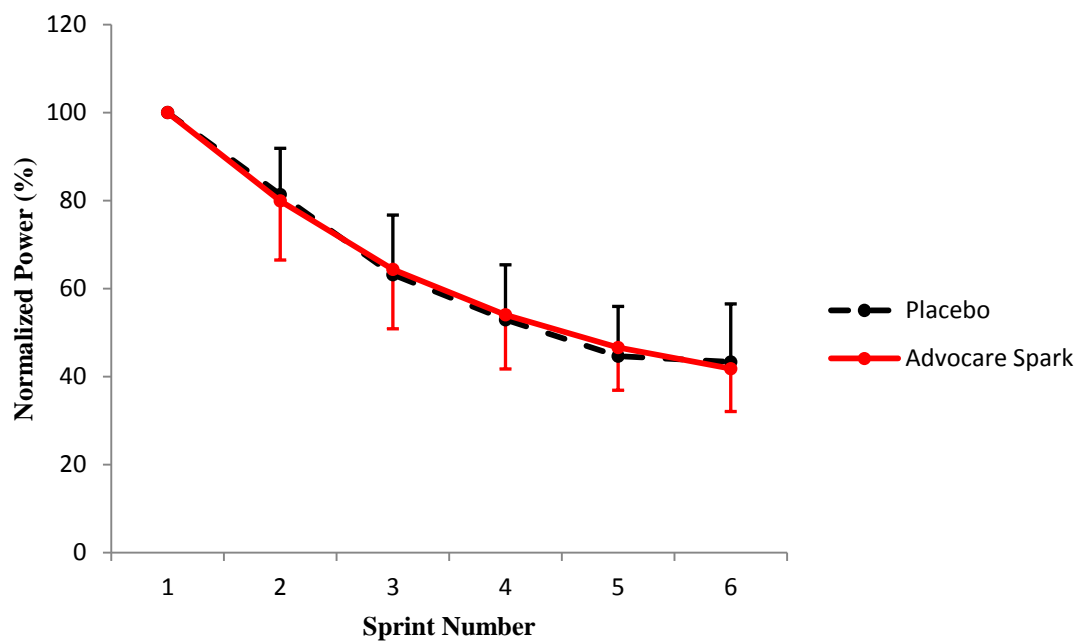


Figure 5. Comparison of normalized average anaerobic power through sprint trials

Results of the repeated-measures ANOVA showed no significant statistical difference for the main effect of the beverage treatment (Spark® versus placebo) for either the sprint time or anaerobic power, indicating that the energy drink did not affect performance. The main effect of the sprint trial was significant ($p < 0.001$) for both time and power. Post-hoc analysis revealed that each of the six sprints was significantly slower (see Figure 2) with less anaerobic power produced (see Figure 3) than the previous sprint, with the exception of sprint 6 not being statistically significantly worse than sprint 5 (sprint time: $p = 0.053$; power: $p = 0.064$). There was a significant interaction effect between caffeine use and the beverage treatment for both sprint times ($F = 4.62, p = 0.045$), as well as anaerobic power ($F = 5.40, p = 0.032$) indicating a confounding effect, such that athletes not habituated to caffeine were more likely to receive an improvement from the energy drink than those who regularly consumed caffeine. None of the other interactions (sprint trial x caffeine use, beverage treatment x sprint trial, and beverage treatment x sprint trial x caffeine use) were significant ($p > 0.05$). There were no statistically significant differences in the placebo scores ($15.06 \pm 3.80 \text{ W}\cdot\text{s}^{-1}$) and beverage scores ($15.3 \pm 4.18 \text{ W}\cdot\text{s}^{-1}$) for the measurement of fatigue index. Finally, although there was a statistically significant main effect for wind speed ($F = 10.84, p < 0.001$) indicating that the wind varied from one sprint to the next, the mean wind speed was negligible ($0.039 \text{ m}\cdot\text{s}^{-1}$) and it did not differ between the placebo and Spark® trials ($p = 0.668$) nor was there a beverage treatment x wind interaction ($p = 0.7$).

CHAPTER 5

DISCUSSION

The purpose of this study was to investigate the acute effects of a low-calorie, caffeine-containing energy drink on repeated sprint performance and anaerobic power in NCAA Division I football players. The procedures were designed to measure the sprinting ability of 20 Utah State University football players on two test conditions using the RAST. Sprint time was recorded and anaerobic power was calculated from the sprint time results. Repeated-measures ANOVA results showed no significant statistical difference in either sprint time or anaerobic power between the energy drink and the placebo. There were also no significant statistical differences between drinks on the fatigue index. There was, however, a significant interaction effect between the subjects' history of caffeine use and the treatment beverage for both sprint times and anaerobic power.

The main active ingredient in AdvoCare Spark® energy drink is caffeine. Although the mechanisms explaining the ergogenic effects of caffeine are not fully known, plausible theories include the antagonism of adenosine receptors leading to an increase in central nervous system activation and plasma epinephrine concentrations, enhanced calcium release and reuptake from the sarcoplasmic reticulum affecting skeletal muscle excitation-contraction coupling, and the alteration of plasma potassium concentrations (Crowe et al., 2006).

Over the last 25 years, caffeine has been one of the most widely studied ergogenic aids by sport scientists. During this time, there has been an almost unequivocal support

for the beneficial effects of oral caffeine ingestion on prolonged submaximal exercise (Bell et al., 2001; Greer et al., 2000). In addition, there is now growing evidence that caffeine can improve performance in short term high-intensity exercise (i.e., an exercise intensity requiring $> 100\% \text{ VO}_{2\text{max}}$) lasting from several seconds up to ~ 7 min (Davis & Green, 2009). Whether or not caffeine augments anaerobic power may depend on the dose of caffeine used, the timing of caffeine administration, the subjects' fed state (fasting versus non-fasting), their level of training, their habitual use of caffeine, or a combination of any of these factors.

Only limited research has examined the impact of caffeine during high-intensity, team-sport field performance exercises. While Bell et al. (2001) showed that $6 \text{ mg}\cdot\text{kg}^{-1}$ of caffeine enhanced short duration, high intensity exercise, forming a basis for the hypothesis of the present study, this absolute amount of caffeine was not effective in enhancing sprint performance. Studies have shown that 250 to 300 mg of caffeine can enhance supramaximal cycling (Anselme, Collomp, Mercier, Ahmaidi, & Prefaut, 1992), swimming (Collomp, Ahmaidi, Chatard, Audran, & Prefaut, 1992), and reaction time (Hoffman et al., 2009). Similar to our study, these researchers used an absolute dose of caffeine (i.e., one serving size of an energy drink). As a result, lighter subjects received more caffeine relative to body weight than heavier subjects, thereby making an interpretation of the findings difficult. This study utilized an absolute amount (one serving) rather than relative because it is more practical and resembles the typical serving size a student-athlete is likely to have before practice or competition.

In this study, we administered the supplement approximately 60 min prior to exercise, a common protocol used by researchers based on peak blood concentrations observed 30-60 min post-ingestion. We also provided a standardized breakfast for the subjects (bagels and orange juice) prior to testing. Other studies of anaerobic performance have required a fast ranging from 3 (Forbes et al., 2007) to 12 hr (Woolf, Bidwell, & Carlson, 2009) before testing. Few studies have addressed the effect of caffeine supplementation prior to exercising in a fasted versus a fed state. In the present study, one participant vomited almost immediately after each testing session.

Our study involved collegiate anaerobically trained athletes. Other studies involving untrained athletes have failed to show an ergogenic effect of caffeine supplementation on anaerobic power as measured by the Wingate Anaerobic Test (Forbes et al., 2007; Greer et al., 2006). When anaerobically trained athletes have been studied, ergogenic effects of caffeine on anaerobic power have been observed. For instance, Collomp et al. (1992) showed that caffeine ingestion prior to 2 x 100-m freestyle swims improved swim times in trained swimmers but not in untrained subjects. Similarly, Schneiker, Bishop, Dawson, and Hackett (2006) reported a significant enhancement in 18 x 4 s sprints with 2 min active recovery after ingestion of 6 mg·kg⁻¹ of caffeine. These results seem promising; however, future studies are warranted. These studies utilized caffeine in its pure form. Yet pure caffeine is not widely available to coaches or athletes. In contrast, caffeine-containing energy drinks and supplements are quite available to the consumer. Improved anaerobic performance (Alford et al., 2001) and muscular endurance (Forbes et al., 2007) after Red Bull™ ingestion were demonstrated in randomized

placebo-controlled studies in recreationally active subjects. There are limited data examining the effectiveness of various products containing caffeine, specifically to enhance short-term exercise performance, so further investigation is merited, especially in competitive athletes. Considering the 2008 Summer Olympics 100 m freestyle final for gold and silver was separated by 0.11 seconds and bronze by 0.46 seconds, if caffeine could elicit similar results shown with trained subjects as Stuart, Hopkins, Cook, and Cairns (2005) showed on sprint performance (0.5-2.9%), a competitive advantage is plausible.

Well trained athletes are likely to perform more reliably than untrained subjects in any chosen performance task, especially if their training is specific to the test, or employs aspects of fitness specifically being tested. They also are likely to have greater motivation to perform fatiguing exercises and can provide more consistent performance day-to-day, which may reduce variability and thus increase statistical power. Paton, Hopkins, and Vollebregt (2001) had 16 team sport athletes (e.g., basketball, hockey, rugby) perform 10 x 20-m sprints with 10 seconds recovery between sprints. Bouts were completed following 6 mg·kg⁻¹ caffeine consumption and placebo. Similar to our results, the researchers did not find significant improvement with caffeine using team-sport athletes. However, historic use of caffeine was not reported in their study.

Stuart et al. (2005) simulated a rugby game with Australian rugby players performing seven circuits in each 2 x 40-min half, with 10 min half-time rest after consuming 6 mg·kg⁻¹ of caffeine. Skill tasks assessed included agility, power generation, passing accuracy, and sprinting. Eleven stations were performed per circuit with 30 s

intervals between stations, and two stations consisted of straight-line sprinting (20-30 m sprints). It was found that $6 \text{ mg}\cdot\text{kg}^{-1}$ caffeine significantly improved sprint time by 0.5-2.9% for the entire trial; specifically, performance improved in the first half for 20-30 m (0.5 - 2.3%) and second half for 20-30 m sprints (1.4 - 3.4%). It was also reported that all the participants were regular consumers of caffeine in their diets. Reasons for equivocal results between Stuart et al. (2005) and Paton et al. (2001) are unclear. Although distances were relatively the same, recovery duration between sprints was different (10 s vs. 30 s). The rest:work ratio we employed was similar to that of Paton et al. (2001) and that could have had a dramatic effect on recovery, which may have prevented any observation of ergogenic effects. Thus, the effect of rest:work might play a crucial role in allowing caffeine to magnify its effect. Future studies should investigate to what extent rest:work or total volume plays on allowing caffeine to elicit its effect on performance.

In some studies (Glaister et al., 2008; Woolf et al., 2009), subjects were low-caffeine consumers (<100 mg per day), which may potentiate the ergogenic effect of the drug compared with subjects tolerant to the effects of caffeine. In a systematic review by Astorino and Roberson (2010), the authors added an additional explanation, saying that, like creatine, there may be individual “responders” and “nonresponders” to the effects of caffeine during short-term exercise. The study by Forbes et al. (2007) was the only one found which had differentiated subjects on the basis of caffeine use. The researchers found that subjects who regularly consumed caffeine did not differ from caffeine-naïve subjects for repeated Wingate tests and bench press muscular endurance.

Caffeine seems to be ergogenic during high intensity exercise, depending on the paradigm. Speed endurance (i.e., 60-180 s in duration) seems to be highly affected by caffeine. High intensity exercise seems to be favorably affected (i.e., sprinting, sprint cycling) with methodologies employing protocols that mimic the duration of the activities (i.e., 4-6 s). Therefore, sports such as soccer, rugby, lacrosse, and football would seem to be favorably affected by caffeine ingestion.

Earlier research examining the effects of caffeine on performance typically involved untrained subjects with methodologies not specific to high-intensity intermittent sport activities. These designs and subject characteristics potentially contributed to the conclusion that caffeine may not be beneficial in this paradigm. However, researchers have started to study trained subjects accustomed to the rigor of the protocols tested. Therefore, caffeine seems to be most beneficial for trained subjects, with the majority of studies showing little to no effect on untrained subjects. The reason for differing results dependent on training status is still unclear.

Acute ingestion of a caffeinated energy drink (AdvoCare Spark®) did not statistically improve repeated sprint times, fatigue index, and anaerobic power as measured by the RAST test. AdvoCare Spark® is commonly ingested in the hope that it will increase exercise performance. The potential to improve short-term, high intensity exercise performance may be small and difficult to measure. Our participants were both caffeine users and non-users. Thus, more research is needed that compares the effect of caffeine in caffeine naïve versus habituated caffeine consumers in anaerobic exercise performance. More research is needed examining the effect of caffeine during field tests

specific to the athletes' competition or training regimen. Different relative doses of caffeine should be examined. Future research is also needed to determine whether a longer duration of testing in which participants exercise for a long amount of time before repeated sprint testing, will benefit the fatigue index.

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APPENDICES

Appendix A: Informed Consent

Informed Consent

ACUTE EFFECTS OF ADVOCARE SPARK® ENERGY DRINK ON ANAEROBIC POWER IN NCAA DIVISION I FOOTBALL PLAYERS

Before making a decision about participating in this research study, it is important that you read the following explanation of this study. Please carefully read this information and ask the researcher if there is anything that is not clear or if you want more information.

Introduction/Purpose

The purpose of this research is to determine if the energy drink AdvoCare Spark® will improve repeated sprint performance in NCAA division I football players. Nnamdi Gwacham and Dr. Dale Wagner of the Health, Physical Education, and Recreation Department at Utah State University are conducting research to better understand the effects that this beverage may have on athletic performance. The study will include approximately 70 eligible football players.

Explanation of Procedures.

If you decide to participate, you will be required to complete two sprint tests with seven days between each test. The sprint test involves running as fast as possible for 35 m (about 38 yards), six times, with only 10 seconds rest between each effort. You will receive instruction on how to perform this test and see a demonstration of the test one week before the study begins. About 40 minutes before one of the tests you will be given 8 oz of the energy drink AdvoCare Spark®. For the other test you will be given flavored water. You will not know which beverage you are receiving. Detailed instructions and guidelines include:

- 1) maintaining your regular physical activities in the days before and between the two tests
- 2) avoiding alcohol, nicotine, and other stimulants as well as big changes in your diet (including nutritional supplements) the day before each test
- 3) getting an adequate amount of sleep (6 to 8 hours) the night before each test
- 4) wearing the same comfortable, loose-fitting clothing for each test
- 5) coming to the Dale Mildenerger Sports Medicine Complex in the morning without having eaten breakfast; a standardized breakfast (about 400 calories) will be served
- 6) consuming 8 oz of either flavored water or the AdvoCare Spark® energy drink at the conclusion of the breakfast
- 7) getting weighed
- 8) completing 25 minutes of warm-up drills (i.e., jogging, shuffling, back-peddling, etc.)
- 9) completing the sprint test (six 35m sprints with 10 seconds rest between each) to the best of your ability.

Risks and Discomforts

As with any maximal effort exercise test, certain risks and discomforts apply. You will be asked to sprint as fast as possible several times, and this may cause nausea or put you at risk for a pulled muscle. Additionally, the energy drink contains caffeine. Although the caffeine dose used in this study is similar to those encountered in everyday life, over-the-counter supplements have the potential for minor side effects. Side effects for caffeine may include the possibility of headache, dizziness, nausea, and muscle tremor. Individuals who do not consume caffeine on a regular basis may be more prone to side effects than those who are habitual caffeine users.

Benefits

There may or may not be any direct benefit to you by participating in this study. However, we believe that the benefits to both the participants and researchers in this study are a greater understanding of the effects of an energy drink (AdvoCare Spark®) on anaerobic power and repeated sprinting performance.

Questions

If you have any questions concerning this research study or believe that you have been injured as a result of your participation in this study, you can contact Dr. Dale Wagner (principal investigator) at 435-797-8253 or by email at dale.wagner@usu.edu or Nnamdi Gwacham (student researcher) at 909-438-6658 or by email at nnamdi.gwacham@usu.edu. If you have questions about your rights as a research participant or a concern or complaint about the study and would like to contact someone other than the researchers, you may contact the Institutional Review Board (IRB) Administrator at 435-797-0567 or email at irb@usu.edu.

Voluntary Participation and Withdrawal without Prejudice

Participation in this study is voluntary; refusal to participate will involve no penalty. Each participant is free to withdraw consent and discontinue participation in this project at any time without prejudice from the researchers or Utah State University.

Confidentiality

All information gathered from the study will remain confidential and kept in a locked drawer. Computer analysis of the data will be numerically coded; your name will not appear on the researchers' computers. Participant's individual scores will not be disclosed outside of the testing personnel without each participant's written permission. The results of this study may be published for scientific purposes, but participants' identities will not be revealed.

IRB Approval Statement

The Institutional Review Board (IRB) for the protection of human participants at USU has reviewed and approved this research study. If you have any questions or concerns about your rights you may contact the IRB Administrator at 435-797-0567 or email irb@usu.edu.

Copy of Consent

If you decide to participate in this study, you will be asked to sign two copies of this informed consent. Please retain one copy for your files.

Investigator Statement

“I certify that the research study has been explained to the individual, by me or my research staff, and that the individual understands the nature and purpose, the possible risks and benefits associated with taking part in this research study. Any questions that have been raised have been answered.”

Signatures of Principal Investigator & Student Researcher

 Dale R. Wagner, Ph.D.
 Principal Investigator
 435-797-8253
 dale.wagner@usu.edu

 Date

 Nnamdi Gwacham
 Student Researcher
 909-438-6658
 nnamdi.gwacham@usu.edu

 Date

Signature of Participant: By signing below, I agree to participate.

 Signature of participant

 Date

 Participant name (printed)

Appendix B: Caffeine Inventory

HOW OFTEN DO YOU DRINK THE BEVERAGE? (MARK ONE)										Amount			
	Never or less than once per month	1-3 per month	1 per week	2-4 per week	5-6 per week	1 per day	2-3 per day	4-5 per day	6+ per day	Medium Serving Size	S S=1	M M=2	L L=3
	Code=0	Code=1	Code=2	Code=3	Code=4	Code=5	Code=6	Code=7	Code=8				56
Decaffeinated coffee (instant & brewed)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	1 cup (8 oz)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Instant Coffee, not decaffeinated (including flavored types)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	1 cup (8 oz)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Brewed Coffee, not decaffeinated	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	1 cup (8 oz)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Decaffeinated espresso & espresso drinks (Latte, Mocha)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	1 shot of espresso	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Espresso & espresso drinks, not decaffeinated (Latte, Mocha)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	1 shot of espresso	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Herbal or decaffeinated tea (instant, bottled, & brewed)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	1 cup (8 oz)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Green tea (not decaffeinated-instant, bottled or brewed)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	1 cup (8 oz)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Black tea such as Lipton®, or Earl Grey (not decaffeinated-instant, bottled, and brewed)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	1 cup (8 oz)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Jolt®, Surge®, Mountain Dew®, Red Bull® & other highly caffeinated sodas	0	0	0	0	0	0	0	0	0	1 can (12 oz)	0	0	0
Regular colas & root beer (with caffeine, not diet)	0	0	0	0	0	0	0	0	0	1 can (12 oz)	0	0	0
Diet colas & diet root beer (with caffeine)	0	0	0	0	0	0	0	0	0	1 can (12 oz)	0	0	0
Regular colas & root beer (caffeine free, not diet)	0	0	0	0	0	0	0	0	0	1 can (12 oz)	0	0	0
Diet colas & diet root beer (caffeine free, not diet)	0	0	0	0	0	0	0	0	0	1 can (12 oz)	0	0	0

Appendix C: Data Collection

