THE EFFECT OF ENERGY DRINK INGESTION ON 5-KM RUNNING PERFORMANCE IN RECREATIONAL ENDURANCE RUNNERS

by

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B.S., Georgia Southern University, 2009

M.S., Georgia Southern University, 2011

Submitted to the Graduate Faculty of

School of Education in partial fulfillment

of the requirements for the degree of

Doctor of Philosophy

University of Pittsburgh

2015

UNIVERSITY OF PITTSBURGH

SCHOOL OF EDUCATION

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March 30, 2015

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Introduction: The use of pre-exercise energy drinks has become a popular supplementation habit among recreational and competitive athletic populations. It is common for athletes to consume energy drinks prior to athletic competition, yet it is unresolved whether this is an effective strategy to increase performance, especially in short duration high intensity events. **Purpose:** The purpose of this study was to evaluate physiological and perceptual responses to exercise performance of recreational endurance runners after they ingested a commercially available energy drink (Red Bull) containing caffeine, glucose, and Taurine. **Methods:** Recreational endurance runners (n = 18, 13 men, 5 women, 20.39 ± 3.27 years, 71.25 ± 17.17 kg, 178.00 ± 7.57, 55.94 ± 7.66 VO_2max) participated in a double blind, crossover, repeated measures study where they were randomized to supplement with 500 ml of the commercially available energy drink Red Bull and non-caffeinated, sugar-free placebo 60 minutes before completing a 5-km time trial; separated by seven days. Heart rate, RPE (RPE-O; RPE-C; RPE-L), and affect were recorded at rest, 1-hr post ingestion, at 5-minute intervals during the 5-km time trial, and immediately post exercise. A Session RPE and session Affect were obtained 5 minutes following completion of the 5-km time trial. The distance covered at each 5 min interval

during the 5-km time trial was recorded. **Results:** Performance improved with ED compared with placebo (Red Bull: 1,413.2 ± 169.7 s vs. PLA: 1,443.6 ±179.2 s; $p = 0.016$), but there were no differences in ratings of perceived exertion, affect, session RPE, session affect, or the distance covered at 5 min splits between the two 5-km time trials ($p > 0.05$). **Conclusion:** These results demonstrate that consuming a commercially available ED before exercise can improve endurance performance. These results may have application for altering pre-exercise nutritional strategies in athletes and recreational runners.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PREFACE

I would like to thank the following for their contribution to this investigation:

- Dr. Goss: Thank you for all you assistance and guidance over the past couple of years. I have enjoyed your mentorship and am very appreciative of everything you have done.
- Dr. Nagle, Dr. Beals, Dr. Lovalekar, Dr. Robertson; Thank you for all your advice and help throughout this journey. Your assistance and advice has been greatly appreciated.

I would like to dedicate this dissertation to God and my family:

- God: Without you I would never have made it this far in my career. All glory and honor goes to you.
- My beautiful wife Shea: I love you very much and am eternally grateful for your love, support, and encouragement over the years. I thank God for blessing me which such a patient and selfless wife.
- Mom, Dad, Maryke: Thank you for all the sacrifices you have endured which have allowed me to pursue my education and build my career overseas. You are the best family a man could ask for. I love you all very much.

1.0 INTRODUCTION

The use of pre-exercise energy drinks has become a popular supplementation habit among recreational and competitive athletic populations. Athletes across the performance spectrums (endurance athletes to strength/power athletes) consume energy drinks on a regular basis. Due to their low cost, accessibility, and the relatively low frequency of deleterious side-effects derived from their consumption, caffeine-containing energy drinks have become the most popular supplement in the sports population, with a prevalence of 73% in American college athletes (Froiland et al, 2004), 75% in Canadian Varsity athletes (Kristiansen et al, 2005) and 42% in British elite athletes (Hoffman, 2010). Recent studies have indicated that among American adolescents and young adults energy drinks are second only to multivitamins in popularity (Froiland et al, 2004; Hoffman et al, 2008), with reports suggesting that 30% of this population group regularly consumes energy drinks (Hoffman et al, 2008). Another study indicated that 89% of athletes competing in the Ironman World Triathlon Championships admitted that they were planning on using caffeinated supplements prior to competition (Desbrow & Leveritt, 2006).

The main active ingredient in most energy drinks is caffeine (1,3,7-trimethylxanthine). Caffeine is a widely used drug, as about 90% of adults in the United States consume it daily (Burke 2008). American adults ingest an average of 3 mg/kg of body weight of caffeine daily in coffee, tea, caffeinated sodas, and many other drinks and food (Lieberman, 2003). Caffeine is

completely absorbed within the stomach and the small intestine 45 min after ingestion, and its half-life in the body is 3–4 h (Astorino & Roberson, 2010). Caffeine is one of the most widely used ergogenic aids, with acute caffeine ingestion increasing aerobic exercise endurance and reducing fatigue (Cox et al, 2002; Doherty & Smith, 2005; Kovacs et al, 1998). When consumed at least 60 minutes before exercise, caffeine is reported to increase aerobic exercise performance (Costill et al, 1978; Flinn et al, 1990) and decrease rating of perceived exertion (RPE) (Doherty & Smith, 2005; Hadjicharalambous et al, 2006), usually in a dose-dependent manner (Crowe et al, 2006). Energy drinks also contain ingredients such as taurine that have been found to elevate mood, alertness, and concentration (Mandel et al., 1985) and therefore might also contribute to endurance performance by changing perception of effort. There has been little research, however, to confirm the beneficial effects of such drinks, particularly when provided pre-exercise.

Caffeine has been shown to be an effective ergogenic agent by delaying fatigue and increasing time to exhaustion during endurance exercise (Bruce et al, 2000; Graham et al, 1998) (Graham & Spriet, 1995; Hoffman et al, 2007). Due to these properties, caffeine is frequently used as an ergogenic aid for recreationally active individuals as well as athletes (Desbrow and Leveritt 2007; Burke 2008). Caffeine has been proposed to improve physical performance by acting independently, or concurrently, through different mechanisms that include: an increase in free fatty acid oxidation (Spriet, 2002), serving as an adenosine receptor antagonist in the central nervous system (Crowe et al, 2006; Davis et al, 2002), increasing intracellular calcium mobilization (Lopes et al, 1983; Spriet, 2002), and enhancing plasma epinephrine concentrations (Norager et al, 2006). Early research by Costill et al. (1978) suggested that the ergogenic effect of caffeine with aerobic exercise was related to an increase in fatty acid oxidation and

subsequent sparing of muscle glycogen. However, recent research and reviews conclude that caffeine affects endurance performance largely through its antagonist effect on adenosine receptors in the brain (Davis et al, 2003; Kalmar & Cafarelli, 2004). Acting through this mechanism, caffeine may modulate central fatigue and influence ratings of perceived exertion, perceived pain, and levels of vigor, all of which may lead to performance improvements (Judelson et al, 2005; O'Connor et al, 2004).

Research has consistently demonstrated that caffeine ingestion (3-9 mg/kg body mass) produces significant improvements in endurance capacity as measured by time to exhaustion at a sub-maximal workload of 75-85% of maximal oxygen uptake (VO2max) (Costill, Dalsky, & Fink, 1978; Essig, Costill, & Vanhandel, 1980; Graham & Spriet, 1991, 1995; Greer, Friars, & Graham, 2000; Pasman, Van Baak, Jeukendrup, & De Haan, 1995; Ryu et al., 2001; Van Soeren & Graham, 1998; Doherty & Smith, 2004). There have been very few studies in which caffeine has been ingested using running-based protocols simulating competition, such as a time trial over a fixed distance rather than a time-to-exhaustion test (Schubert & Astorino, 2012). A time-to-exhaustion protocol may not be ideal because a small change in an individual's ability to increase power results in a large change in time to exhaustion and a high coefficient of variation (Hopkins et al, 2001). Therefore, improvements may be observed despite a large amount of measurement variability and inflation of type I error (Hopkins et al, 2001). A test to exhaustion does not elucidate the true performance effect of caffeine (Jeukendrup & Currell, 2005) because there is no endurance sport in which individuals win by going a longer distance or for a longer amount of time than their competitors, therefore these tests have minimal applicability for athletes. Endurance/aerobic sport require competitors to complete a set distance or amount of work in the shortest time possible (time trial).

Because most of the existing research has been conducted utilizing time to exhaustion protocols, there is a need for more ecologically valid approaches to studying the influence of caffeine on performance. Endurance capacity protocols used in previous research may indicate caffeine's potential as a training aid, but this information is limited with its application to absolute performance (unrestricted by fixed intensity or power output). During absolute performance, exercise intensity varies throughout, since pacing strategies, tactics and environmental factors influence the race. In protocols simulating performance, caffeine ingestion resulted in significantly increased work production of about 7.4% in a 2h cycling time trial (Ivy, Costill, Fink, & Lower, 1979), 3.4-5.3% in a 1 h cycling time trial (Kovacs, Stegen, & Brouns, 1998), a 1.8% reduction in 1500m swimming time (mean time ~1260 s; Macintosh & Wright, 1995) and indicated a slight improvement (1.7%) during 10km running (from 2808 to 2760 s), although the findings of the latter study were not statistically significant (Bell, Mclellan, & Sabiston, 2002).

Whereas the outcomes of caffeine ingestion (from natural sources and pills) are well known (Burke, 2008; Coso et al, 2008; Coso et al, 2009; Doherty & Smith, 2004), the effects of caffeine-containing energy drinks on sports performance have been the object of fewer studies. The most popular energy drink, Red Bull©, contains 80 mg of caffeine per serving, 110 kcals, as well as taurine and carbohydrate (Clauson et al. 2008) and has been used in many investigations. The first report concerning the effects of energy drinks on physical performance was carried out by Alford et al. in 2001 (Cox & Wescott, 2001). These authors found that ~1 mg of caffeine per kg of body weight (one 250-mL serving of Red Bull energy drink containing 80 mg of caffeine) improved reaction time, alertness and aerobic and anaerobic performance when ingested 30 min pre-trial compared to a placebo. In contrast, subsequent investigations using energy drinks have

shown that ~1 mg/kg of body weight of caffeine is not enough to enhance maximal oxygen uptake (Ferreira et al, 2004), peak power during three repetitions of the Wingate test (Forbes et al, 2007; Hoffman et al, 2009) or running velocity during 24 ‘‘all-out’’ sprints (Astorino et al, 2011). Previous results about the failure of energy drinks to improve performance (Ferreira et al, 2004; Forbes et al, 2007; Hoffman et al, 2009; Astorino et al, 2011; Candow et al, 2009) may be explained by the low dose of caffeine provided to the subjects. However, the ingestion of ~2 mg/kg of body weight (500 ml of Red Bull containing 160 mg of caffeine) enhanced performance during a cycling time trial (Ivy et al, 2009) but did not prolong time-to- exhaustion during a treadmill running test at 80% VO2max (Candow et al, 2009). In young men and women, ingestion of Red Bull containing 2 mg/kg of body weight caffeine improved bench press performance, but had no effect on peak or mean power (Forbes et al. 2007).

Another ingredient contained in Red Bull is taurine, and it has been shown to enhance exercise performance (Zhang et al. 2004), augment mood, alertness, and concentration (Ivy et al. 2009), and therefore could aid short-term performance by altering perception of effort and/or reducing reaction time. Geiss et al. (1994) studied the effect of a taurine-containing drink, “Red Bull”, on endurance performance. After 60 min of cycling at approximately 70% VO2max, 10 endurance athletes pedaled to exhaustion on a cycle ergometer. During each exercise trial, the participants ingested 500 ml of one of the following after 30 min submaximal cycling: 1) Red Bull without Taurine and glucuronolactone (U1), 2) Red Bull without taurine, caffeine and glucuronolactone (U2), and 3) Red Bull original drink containing taurine, caffeine and glucuronolactone (U3). Time to exhaustion was found to be longer with U3, than in U1 or U2 (Geiss et al, 1994). Consequently, the authors concluded that 1–2 servings of regular Red Bull

seem to be ergogenic for aerobic activities such as cycling and running, although its effects seem to be equivocal for high intensity activities dependent upon oxygen-independent metabolism.

The ergogenic effect of caffeine on endurance activities has been typically demonstrated with doses from 3 to 9 mg/kg of body weight (Graham & Spriet, 1995), while the ingestion of 1 mg/kg of body weight of caffeine does not improve performance (Jenkins et al, 2008). In many research settings, pure anhydrous caffeine in high doses is provided to participants 1 h before exercise in a capsule or as a powder to be mixed with a beverage (Astorino and Roberson, 2010). However, high doses frequently elicit side effects including anxiety and tremor, and this vehicle of caffeine intake is typically impractical to the recreational athlete who typically does not have access to pure caffeine. In this case, use of caffeine-containing energy drinks containing lower doses of caffeine (1–3 mg/kg body weight) is more practical due to their availability, minimal side effects, and low cost (Paton et al. 2010).

Only a few studies have investigated the potential effects of low-dose caffeine (<3 mg/kg of body weight) on exercise performance. When Cox et al. (2002) replaced a sports drink with a commercially available caffeinated soft drink (Coke: 1.3–1.9 mg/kg of body weight caffeine), cycling performance (time trial) was enhanced over placebo by 3.3%. Recently, Forbes et al. (2007) found that 2 mg/kg of body weight of caffeine ingestion (regular Red Bull energy drink) increased total bench press repetitions over 3 sets (Red Bull = 34 ± 9 vs. placebo = 32 ± 8) in young adults.

Numerous studies have established that ingestion of caffeine improves performance in low-intensity endurance events lasting several hours (Graham, 2001). It would appear that caffeine ingestion also enhances performance during single efforts of short-duration high-intensity exercise (Anselme et al, 1992), and during repeated sprint exercise (Paton et al, 2001).

However, there have been few studies of the effects of caffeine on shorter duration (10—30 min) high-intensity endurance exercise. In a recent study, Bridge and Jones (2006) reported that caffeine improved performance in an 8-km run by ~1.3% (Bridge & Jones, 2006). Research by O'Rourke et al (2007) revealed that the ingestion of 5mg/kg of body mass 1 h prior to a 5-km running time-trial significantly enhances performance by decreasing the time to completion in both recreational and well-trained runners. Additionally, well-trained and recreational runners experienced similar benefits following caffeine ingestion (~1%) on 5-km running performance. Therefore the mechanism by which caffeine affects performance appears unaffected by training status. Whether caffeine-containing energy drinks have a similar effect on running performance over shorter distances, such as 5 km is unclear. A number of athletes competing in 5-km races regularly consume caffeinated products, including energy drinks, with little scientific rationale for its ergogenic benefits at this distance.

It is common for athletes to consume energy drinks prior to athletic competition (Hoffman, 2010), yet it is unresolved whether this is an effective strategy to increase performance, especially in short duration high intensity events. Many randomized, placebo-controlled, crossover studies have documented the effectiveness of energy drinks as thermogenic, ergogenic, or cognitive aids (Klepacki, 2010; Hoffman, 2010; Lieberman, 2003; Sokmen et al, 2008; Glade, 2010). However, many of these studies have used time-to-exhaustion protocols that are not an indication of absolute performance. The present investigation would be the first to study the ergogenic benefits of a commercially available energy drink on 5-km running time.

Limited data exist that examine the use of pre-exercise energy drink supplementation on high intensity short duration endurance exercise (5-km). Therefore the purpose of this study was

to evaluate physiological and perceptual responses to exercise performance of recreational endurance runners after they ingested a commercially available energy drink (Red Bull) containing caffeine, glucose, and Taurine. Based on the potential ergogenic properties of caffeine, it was hypothesized that acute energy drink ingestion would improve 5-km time trial running performance and cause perceived exertion (RPE) to be equivalent to the placebo condition. It was also hypothesized that the subjects in the energy drink condition would experience more pleasure when performing the 5-km time trial in comparison to the placebo group as evidenced by their Feeling scale rating.

1.1 SIGNIFICANCE

Running is one of the most popular forms of sport and recreation in the United States. In 2010, approximately 13 million people finished a road race in the United States: 4.7 million completed a 5-km race (3.1 miles), 1.4 million competed half-marathons (13.1 miles = 21.1 km), 1.3 million ran a 10 km (6.2 miles), and 500,000 finished a marathon (26.2 miles = 42.2 km) (Running USA, 2011). With such a large population of runners, identifying nutritional factors that can elicit small improvements in performance is merited. It is very difficult to consume appropriate amounts of supplements during running or cycling events that last 1 hour or less (for ex a 5-km race). Therefore, it becomes important to determine the most appropriate type of pre-exercise supplement to extend endurance and improve exercise performance. Traditional sports drinks composed of glucose and electrolytes might not be of much benefit in this regard. Conversely, unlike carbohydrate supplementation, caffeine appears to have a very positive effect on exercise performance when taken before exercise, as well as during exercise (Costill, Dalsky, & Fink,

1978; Graham & Spriet, 1991; Ivy, Costill, Fink, & Lower, 1979; Kovacs, Stegen, & Brouns, 1998; Pierno, De Luca, Camerino, Huxtable, & Camerino, 1998; Spriet et al., 1992).

1.1.1 Prevalence of energy drinks

Caffeine-containing energy drinks have become the most popular supplement in the sports population, with a prevalence of 73% in American college athletes (Froiland et al, 2004), 75% in Canadian Varsity athletes (Kristiansen et al, 2005), and 42% in British elite athletes (Hoffman 2010). Recent studies have indicated that among American adolescents and young adults energy drinks are second only to multivitamins in popularity (Froiland et al, 2004; Hoffman et al, 2008) with reports suggesting that 30% of this population group regularly consuming energy drinks (Hoffman et al, 2008). Another study indicated that 89% of athletes competing in the Ironman World Triathlon Championships admitted that they were planning on using caffeinated supplements prior to competition (Desbrow & Leveritt, 2006).

1.1.2 Energy drinks as a pre-exercise supplement

Many randomized, placebo-control, crossover studies have documented the effectiveness of energy drinks as thermogenic, ergogenic, or cognitive aids (Klepacki, 2010; Hoffman, 2010; Lieberman, 2003; Sokmen et al, 2008; Glade, 2010). Directly related to this application is the influence of a caffeine-containing energy drink (Red Bull) on time trial performance (5-km) and perceptual markers (RPE and Affect), as it relates to the efficacy of energy drink ingestion.

1.1.3 Efficacy of caffeine-containing energy drinks

Several studies have investigated the effects of energy drink ingestion prior to aerobic exercise (Ivy et al, 1979; Candow et al, 2009; Cox & Wescott, 2001; Wlash et al, 2010). The most popular energy drink, Red Bull, contains 80 mg of CAF per serving as well as taurine and carbohydrate (Clauson et al, 2008) and has been used in many investigations. In the earliest of these studies, Alford and colleagues (2001) investigated the effects of ingesting a commercial energy drink on aerobic endurance. Significant improvements in aerobic performance were reported for the commercial energy drink treatment. Aerobic performance was 8% and 14% longer after ingesting the commercial energy drink as compared to the carbonated water and no beverage treatment, respectively.

Geib et al (1994) investigated the effects an energy drink (Red Bull) on performance in endurance athletes. The results showed that heart rate and plasma catecholamines were significantly lower, and endurance time was significantly longer in the energy drink treatment compared to the placebo. The authors concluded that the effect of a caffeine-containing energy drink on hormonal responses leads to enhanced endurance performance. Research has shown that ingestion of caffeine-containing energy drinks improves performance in low-intensity endurance events lasting several hours (Ivy et al, 1979; Candow et al, 2009; Cox & Wescott, 2001; Wlash et al, 2010). However, there have been no studies of the effects of caffeine-containing energy drink on shorter duration (10—30 min) high-intensity endurance exercise.

1.1.4 Energy drink dosage

The ergogenic effect of caffeine on endurance activities has been typically demonstrated with doses from 3 to 9 mg/kg of body weight (Graham & Spriet, 1995), while the ingestion of 1 mg/kg of body weight of caffeine has been shown to not improve performance (Jenkins et al, 2008). Typically, pure anhydrous caffeine in high doses is provided to participants 1 h pre-exercise in a capsule or as a powder to be mixed with a beverage (Astorino & Roberson, 2010). However, high doses frequently elicit side effects including anxiety and tremor, and this vehicle of caffeine intake is typically impractical to the recreational athlete who typically does not have access to pure caffeine. In this case, use of caffeine-containing energy drinks containing lower doses of caffeine (1–3 mg/kg body weight) is more practical due to their availability, minimal side effects, and low cost (Paton et al, 2010).

1.1.5 Time-to-exhaustion protocols vs. time trial protocols

Research has consistently demonstrated that caffeine ingestion (3-9 mg/kg body mass) produces significant improvements in endurance capacity as measured by time to exhaustion at a sub-maximal workload of 75-85% of maximal oxygen uptake (VO_2max) (Costill, Dalsky, & Fink, 1978; Essig, Costill, & Vanhandel, 1980; Graham & Spriet, 1991, 1995; Greer, Friars, & Graham, 2000; Pasman, Van Baak, Jeukendrup, & De Haan, 1995; Ryu et al., 2001; Van Soeren & Graham, 1998; Doherty & Smith, 2004). *There have been very few studies in which caffeine has been ingested using running-based protocols simulating competition, such as a time trial over a fixed distance rather than a time-to-exhaustion test (Schubert & Astorino, 2012).*

Moreover, there is currently no research on the impact of Caffeine-containing ED (Red Bull) during a running-based time trial protocol. A time-to-exhaustion protocol may not be ideal because a small change in an individual's ability to increase power results in a large change in time to exhaustion and a high coefficient of variation (Hopkins et al, 2001). Therefore, improvements may be observed despite a large amount of measurement variability and inflation of type I error (Hopkins et al, 2001). A test to exhaustion does not elucidate the true performance effect of caffeine (Jeukendrup & Currell, 2005) because there is no endurance sport in which individuals win by going a longer distance or for a longer amount of time than their competitors. Therefore these tests have minimal applicability for athletes. Endurance/aerobic sports require competitors to complete a set distance or amount of work in the shortest time possible (time trial).

Because most of the existing research has been conducted utilizing time to exhaustion protocols, there is a need for more ecologically valid approaches to studying the influence of caffeine on performance. Endurance capacity protocols used in previous research may indicate caffeine's potential as a training aid, but this information is limited with its application to absolute performance (unrestricted by fixed intensity or power output). During absolute performance, exercise intensity varies throughout, since pacing strategies, tactics and environmental factors influence the race. In protocols simulating performance, caffeine ingestion resulted in significantly increased work production of about 7.4% in a 2h cycling time trial (Ivy, Costill, Fink, & Lower, 1979), 3.4-5.3% in a 1 h cycling time trial (Kovacs, Stegen, & Brouns, 1998), a 1.8% reduction in 1500m swimming time (mean time ~1260 s; Macintosh & Wright, 1995) and a slight non-significant improvement (1.7%) during 10km running (from 2808 to 2760 s) (Bell, Mclellan, & Sabiston, 2002). *Whereas the performance outcomes of caffeine ingestion*

(from natural sources and pills) are well known (Burke, 2008; Coso et al, 2008; Coso et al, 2009; Doherty & Smith, 2004), the effects of caffeine-containing energy drinks on sports performance have been the object of fewer studies. Therefore, it is unclear whether caffeine-containing energy drinks will have the same ergogenic effect as caffeine, which is an important scientific question with significant clinical and performance implications.

1.1.6 Influence of energy drink ingestion on perceived exertion

The majority of the literature reveals attenuated RPE in response to caffeine. In a review article, Doherty and Smith (2005) examined 21 studies, and data revealed lower RPE during prolonged constant-load exercise, and this effect explained 29% of the improved performance with caffeine intake. The trend for a reduced RPE with caffeine ingestion, suggests that caffeine may elicit a central nervous system effect by reducing the perception of effort and fatigue. A study by Umana-Alvarado and Moncada-Jiménez (2004) indicated the RPEs in male endurance runners were lower when energy drinks were ingested compared to a placebo. These blunted RPE values may be due to many factors such as the taste of the beverage, carbohydrate and caffeine concentration. *However, there is paucity of research on the effect of energy drink ingestion and perceived exertion, and whether or not energy drink intake will attenuate perceived exertion.*

1.1.7 Influence of energy drink ingestion on affect

Traditionally, dimensions of affect have not been assessed in nutritional manipulation studies. Instead, the focus has been on "what" a person feels, as measured by the Rating of Perceived

Exertion (RPE) scale (Borg 1982). There is very little research on the influence of caffeine on the dimensions of affect during exercise. Backhouse et al. (2011) required male cyclists to exercise for 1.5 h at 70% VO_2max after ingestion of caffeine (6 mg/kg of body weight) or placebo. Every 15 minutes during exercise, RPE was assessed using the Borg 6–20 scale and affect was measured using the Feeling Scale. During exercise, positive ratings of affect were maintained in the caffeine trial compared to the placebo trial with significantly more positive ratings at 15, 30 and 75 min. The authors concluded that based on the results from this study a moderate dose of caffeine ingested 1 h prior to exercise results in the maintenance of a more positive subjective experience during prolonged cycling. This observation may partially explain the ergogenic benefits of caffeine. In another study, Acevedo et al. (1996) demonstrated that a favorable affective state benefited prolonged running performance. *However, Energy drinks were not included as a component of these studies. Thus, it is unclear whether energy drink ingestion would significantly improve affective state.*

1.1.8 Innovation

This study is innovative and of significance for a variety of reasons:

1. A unique aspect of this study is the inclusion of a caffeine-containing energy drink using a running-based time trial protocol. This is important for the following reasons:
    a. It is anticipated that findings from this study will inform runners (recreational and well-trained), athletes, trainers, and coaches regarding the use of caffeine containing energy drinks ingestion as a pre-exercise supplement.

b. Athletes will benefit if the energy drink supplementation can improve running time during the 5-km time trial.

2. We are using ratings of perceived exertion and affective response, to examine the influence of energy drink ingestion on perceptual measures. This is important for the following reasons:
    a. If energy drink supplementation is found to attenuate perceived exertion and result a in a more favorable affective state (i.e. more pleasurable) during 5-km running, then athletes can adopt this technique to lessen the intensity of effort, stress, discomfort, and displeasure that is felt during high intensity short duration continuous exercise.
    b. Collectively such potential benefits of energy drink supplementation can improve performance during training and contribute to improved sport performance.

1.2 SPECIFIC AIMS

The use of pre-exercise energy drinks has become a popular supplementation habit among recreational and competitive athletic populations. Athletes across the performance spectrums (endurance athletes to strength/power athletes) consume energy drinks on a regular basis. Due to their low cost, accessibility, and the relatively low frequency of deleterious side-effects derived from their consumption, caffeine-containing energy drinks have become the most popular supplement in the sports population, with a prevalence of 73% in American college athletes (Froiland et al, 2004), 75% in Canadian Varsity athletes (Kristiansen et al, 2005) and 42% in British elite athletes (Hoffman 2010). Recent studies have indicated that among American

adolescents and young adults energy drinks are second only to multivitamins in popularity (Froiland et al, 2004; Hoffman et al, 2008), with reports suggesting that 30% of this population group regularly consuming energy drinks (Hoffman et al, 2008). Another study indicated that 89% of athletes competing in the Ironman World Triathlon Championships admitted that they were planning on using caffeinated supplements prior to competition (Desbrow & Leveritt, 2006).

Whereas the performance outcomes of caffeine ingestion (from natural sources and pills) are well known (Burke 2008; Coso et al, 2008; Coso et al 2009; Doherty & Smith 2004), the effects of caffeine-containing energy drinks on sports performance have been the object of fewer studies. Numerous studies have established that ingestion of caffeine improves performance in low-intensity endurance events lasting several hours (Graham 2001). It would appear that caffeine ingestion also enhances performance during single efforts of short-duration high-intensity exercise (Anselme et al, 1992), and during repeated sprint exercise (Paton et al, 2001). However, there have been few studies of the effects of caffeine on shorter duration (10—30 min) high-intensity endurance exercise. In a recent study, Bridge and Jones (2006) reported that caffeine improved performance in an 8-km run by ~1.3%. Research by O'Rourke et al (2008) revealed that caffeine ingestion of 5mg/kg of body mass 1 h prior to a 5-km running time-trial significantly enhances performance by decreasing the time to completion in both recreational and well-trained runners. Additionally, well-trained and recreational runners experienced similar benefits following caffeine ingestion (~1%) on 5-km running performance. Therefore the mechanism by which caffeine affects performance appears unaffected by training status. Whether caffeine-containing energy drinks have a similar effect on running performance over shorter distances, such as 5 km is unclear. A number of athletes competing in 5-km races

regularly consume caffeinated products, including energy drinks, with little scientific rationale for its ergogenic benefits at this distance.

It is common for athletes to consume energy drinks prior to athletic competition (Hoffman 2010), yet it is unresolved whether this is an effective strategy to increase performance, especially in short duration high intensity events. Many randomized, placebo-controlled, crossover studies have documented the effectiveness of energy drinks as thermogenic, ergogenic, or cognitive aids (Klepacki 2010; Hoffman 2010; Lieberman 2003; Sokmen et al, 2008; Glade 2010). However, many of these studies have used time-to-exhaustion protocols that are not an indication of absolute performance. This investigation was designed to test the efficacy of a commercially available energy drink utilizing a short duration high intensity exercise (5-km) running time trial on both physiological and perceptual markers.

1. The primary aim of this study was to evaluate physiological and perceptual responses to exercise performance of recreational endurance runners after they ingest a commercially available energy drink (Red Bull) containing caffeine, glucose, and Taurine. NOTE: We will compare Energy Drink (Red Bull) vs. Placebo.
2. Variables that was measured are (a) 5-km running time, (b) RPE, (c) heart rate, (d) affect, (e) session RPE and (f) session affect
3. The experimental design used was intended to examine the effect of the independent variable (Energy drink vs. Placebo ingestion) on the following dependent variables: 5-km time trial, heart rate, affect, RPE, session RPE and session affect.
4. Based on the potential ergogenic properties of caffeine, it was hypothesized that acute energy drink ingestion compared to the placebo will:
5. Improve 5-km time trial running performance

6. Cause perceived exertion (RPE) to be equivalent between the two experimental trials
7. Result in increased pleasure during the 5-km time trial as evidenced by the Feeling scale rating
8. Result in a greater mean heart rate response
9. Result in an attenuation of perceived exertion for the entire exercise session
10. Result in an attenuation of affect for the entire exercise session

1.3 HYPOTHESIS

1. It was hypothesized that acute energy drink ingestion will improve 5-km time trial running performance compared to the placebo.
2. It was hypothesized that energy drink ingestion will cause perceived exertion (RPE) to be equivalent to the placebo condition.
3. It was hypothesized that the subjects in the energy drink condition will experience more pleasure when performing the 5-km time trial in comparison to the placebo group as evidenced by their Feeling scale rating.
4. It was hypothesized that energy drink ingestion will result in a greater mean heart rate response during the 5-km time trial in comparison to the placebo group.
5. It was hypothesized that energy drink supplementation will result in a comparatively greater attenuation of perceived exertion for the entire exercise session (Session RPE) when compared to the placebo condition.

6. It was hypothesized that energy drink supplementation will result in a comparatively greater attenuation of affect for the entire exercise session (Session Affect) when compared to the placebo condition.

2.0 LITERATURE REVIEW

2.1 INTRODUCTION

Running is one of the most popular forms of sport and recreation in the United States. In 2010, approximately 13 million people finished a road race in the United States: 4.7 million completed a 5-km race (3.1 miles), 1.4 million competed half-marathons (13.1 miles = 21.1 km), 1.3 million ran a 10 km (6.2 miles), and 500,000 finished a marathon (26.2 miles = 42.2 km) (Running USA, 2011). With such a large population of runners, identifying nutritional factors that can elicit small improvements in performance is merited. It is very difficult to consume appropriate amounts of supplements during running or cycling events that last 1 hour or less (for ex a 5-km race). Therefore, it becomes important to determine the most appropriate type of pre-exercise supplement to extend endurance and improve exercise performance. Research has consistently documented improved endurance performance in athletes using carbohydrate beverages, compared with water or other placebo beverages (Coyle, Coggan, Hemmert, & Ivy, 1986; Ivy et al., 1983; Ivy, Res, Sprague, & Widzer, 2003; Sherman et al., 1989; Yaspelkis, Patterson, Anderla, Ding, & Ivy, 1993). The effect of carbohydrate supplementation when provided before exercise, however, is contradictory, with a few studies demonstrating a positive effect (Kirwan, O'Gorman, & Evans, 1998; Sherman et al., 1989) but most studies indicating a reduced (Foster,

Costill, & Fink, 1979) or no performance-enhancing effect (Hargreaves, Costill, Fink, King, & Fielding, 1987; Kuipers, Fransen, & Keizer, 1999; Sherman et al., 1989).

Conversely, unlike carbohydrate supplementation, caffeine appears to have a very positive effect on exercise performance when taken before exercise, as well as during exercise (Costill, Dalsky, & Fink, 1978; Graham & Spriet, 1991; Ivy, Costill, Fink, & Lower, 1979; Kovacs, Stegen, & Brouns, 1998; Pierno, De Luca, Camerino, Huxtable, & Camerino, 1998; Spriet et al., 1992). Supplements of caffeine containing 3–9 mg/kg body weight provided 1 hour before exercise have been found to be effective in increasing exercise time to exhaustion at exercise intensities of 70–80% VO2max (Graham & Spriet, 1995; Kovacs et al, 1998; Pasman, van Baak, Jeukendrup, & de Haan, 1995).

Energy drinks are often used by athletes as a pre-exercise or pre-game supplement to either enhance the quality of their workout or improve athletic performance. The basic active ingredient in these energy drinks is caffeine. Caffeine itself is only a mild central nervous system stimulator (Sawynok, 1995). Therefore, additional ingredients (e.g., β- adrenergic receptor stimulators) are often combined with caffeine to increase the stimulatory response and provide additional ergogenic benefits. The synergistic effect of these ingredients has been demonstrated to increase subjective feelings of alertness, focus and energy (Hoffman et al, 2009; Scholey & Kennedy, 2004), and improve reaction time to both auditory and visual stimuli (Hoffman et al, 2009).

2.2 ENERGY DRINK SALES

The consumption of caffeinated energy drinks by both competitive and recreational athletes has increased dramatically since the introduction of Red Bull to the United States in 1997 (Reissig et al, 2009). Since its inception, the energy drink market has grown exponentially, with nearly 500 new brands launched worldwide in 2006 (Johnson, 2006), and 200 new brands launched in the U.S. in the 12-month period ending July 2007 (Packaged Facts, 2007). The United States is the world's largest consumer of energy drinks by volume, roughly 290 million gallons in 2007, or 3.8 qt per person per year (Weise, 2008). Consumption of energy drinks is most common among those aged 11 to 35 years, and 24% to 57% of this age group reported that they drank an energy drink within the past few months (Ballard et al, 2010; Heckman et al, 2010). The total U.S. retail market value for energy drinks was estimated to be $5.4 billion in 2006, $6.6 billion in 2007, $6.7 billion in 2010 (Packaged Facts, 2007), and is expected to surpass $20 billion in 2017 (Klineman, 2010), with industry leader Red Bull commanding more than 50% of all revenues (Clauson et al, 2008) (Figure 1).

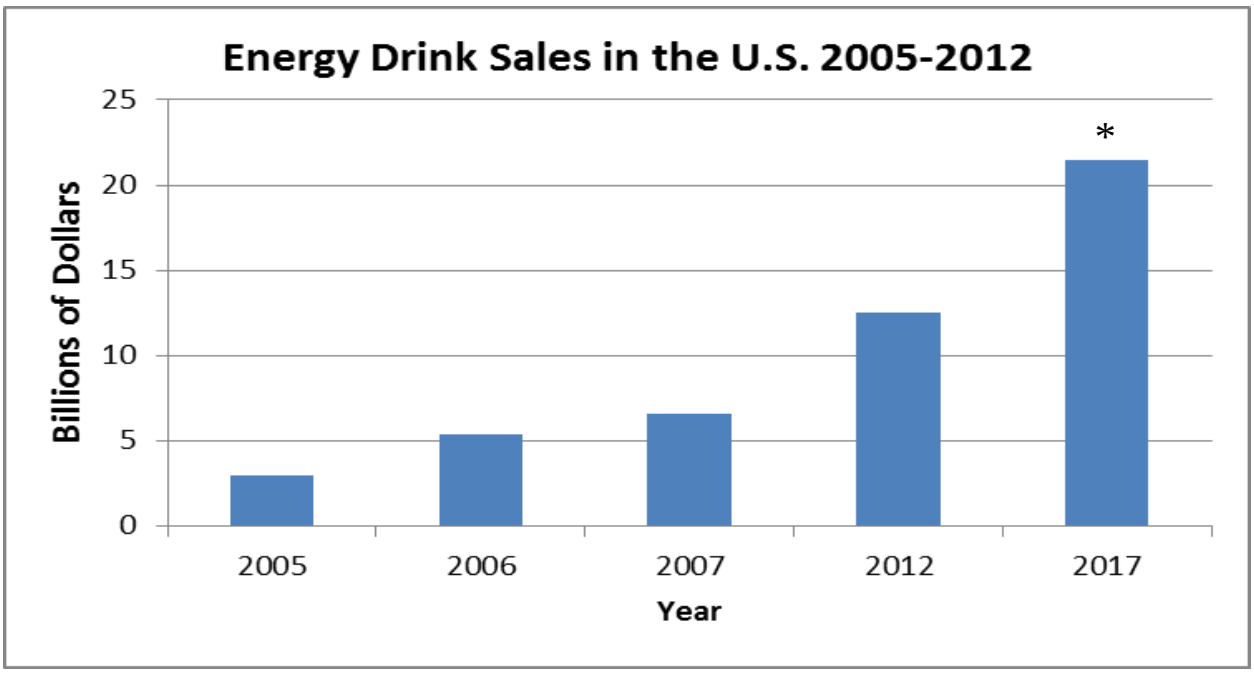

Figure 1. Energy drinks sales in billions of dollars in the United States from 2005 to 2012. ***** = expected sales.

2.3 REGULATION OF ENERGY DRINKS IN THE UNITED STATES

Regulation of energy drinks, including content labeling and health warnings differs across countries, with some of the laxest requirements existing in the United States (Weise, 2008). In the United States, most energy drink manufacturers package and market their products so as to ensure the energy drinks are classified as dietary supplements. By doing so, manufacturers are not required to disclose the quantities of active ingredients in their products (U.S Food and Drug Administration, 2009). In addition, unlike manufacturers of soft drinks, which, in the United States, are classified as a food product and regulated by the Food and Drug Administration, manufacturers of energy drinks are not limited to a maximum dose of caffeine in a given volume

or serving (U.S Food and Drug Administration, 2009). No energy drinks are banned in the United States, and energy drink companies can say whatever they want regarding energy and performance effects. This absence of oversight has resulted in aggressive marketing of energy drinks, targeted primarily toward young men and openly promoting psychoactive, performance-enhancing, and stimulatory effects (Reissig et al, 2009; Ballard et al, 2010). Several case reports (Machado-Vieira et al, 2001; Berger & Alford, 2009; Worthley et al, 2010) have associated the consumption of high volumes of energy drinks with manic, seizure, or cardiac episodes that resolved following cessation of the product's ingestion. It has also become increasingly common for younger adults to mix energy drinks and alcohol (Malinauskas et al, 2007; Oteri et al, 2007).

2.4 MARKETING CLAIMS AND USAGE

A recent study has shown that 3 out of 4 elite athletes consume caffeine prior to competing, based on the post-exercise urinary caffeine concentrations of 20,686 urine samples obtained for doping analysis (Coso et al, 2011). The manner in which athletes consume caffeine is diverse. Caffeine can be artificially synthesized and included in food and drinks, like energy drinks. These drinks vary widely in both caffeine content (ranging from 50 to 505 mg per can or bottle) and caffeine concentration (ranging from 2.5 to 171 mg per fluid ounce) (Weise, 2008) (Table 1). In addition to caffeine energy drinks also contain carbohydrates, taurine, glucoronolactone , B-group vitamins and various herbal derivatives (Aranda & Morlock, 2006; Clauson et al, 2008).

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 (Carvajal-Sancho, 2005). In a recent survey of 115 male and 88 female athletes at a large NCAA Division I Midwest university, 73% reported that they regularly consumed energy drinks, including Red Bull, and that the main reasons for using these types of drinks were for fluid replacement and increased energy during practice (Froiland et al, 2004). Energy drink manufacturers focus advertising on the perception that energy drink consumption will enhance performance, boost mental alertness, improve endurance and energy, decrease fatigue, enhance metabolism, and improve overall performance. Advertising of energy drinks is targeted primarily towards the younger population, with alluring product names such as "Full Throttle", "AMP Energy" and "Cocaine". These advertising campaigns promote the psychoactive, performance-enhancing, and stimulant effects of energy drinks. Although energy drinks have been sold worldwide for more than a decade, few studies have apparently been published to test the effectiveness of these beverages in endurance performance in athletes.

Table 1. Energy drinks in the United States

	Ounces per bottle or can	Caffeine concentration (mg/oz)	Total caffeine (mg)
Top selling energy drinks			
Red Bull	8.3	9.6	80
Monster	16	10	160
Rockstar	16	10	160
Full throttle	16	9	144
No Fear	16	10.9	174
Amp	8.4	8.9	75
SoBe Adrenaline Rush	8.3	9.5	79
Tab Energy	10.5	9.1	95
Higher caffeine energy drinks			
Wired X505	24	21	505
Fixx	20	25	500
BooKoo Energy	24	15	360
Wired X344	16	21.5	344
SPIKE Shooter	8.4	35.7	300
Viso Energy Vigor	20	15	300
Cocaine Energy Drink	8.4	33.3	280
Jolt Cola	23.5	11.9	280
NOS	16	16.3	250
Redline RTD	8	31.3	250
Blow (Energy Drink Mix)	8	30	240
Lower caffeine energy drinks			
Bomba Energy	8.4	8.9	75
HiBall Energy	10	7.5	75
Airforce Nutrisoda Energize	8.5	5.9	50
Whoop Ass	8.5	5.9	50
Vitamin Water (Energy Citrus)	20	2.5	50
High concentration energy drinks			
RedLine Power Rush	2.5	140	350
Ammo	1	171	171
Powershot	1	100	100
Fuel Cell	2	90	180
Classic soft drinks			
Coca-Cola Classic	12	2.9	34.5
Pepsi Cola	12	3.2	38
Dr Pepper	12	3.4	41
Mountain Dew	12	4.5	54

2.5 MECHANISMS

Although caffeine has been used as an ergogenic aid for many years, consistent benefits have only been seen during endurance activities, in which time to exhaustion is often reported to increase (Doherty & Smith, 2004, Graham et al, 1998; Bruce et al, 2000; Graham et al, 1998; Graham & Spriet, 1995; Hoffman et al, 2007; Hogervorst et al, 2008). Plausible theories for the beneficial effects of caffeine include an increase in central nervous system activity (stimulates the cardiovascular system) (Birnbaum & Herbst, 2004; Graham, 2001), acting as an adenosine receptor antagonist (caffeine prevents adenosine from binding in the brain and thus reduces drowsiness) (Crowe et al, 2006; Davis et al, 2002), increasing calcium release and uptake to the sarcoplasmic reticulum (Lopes et al, 1983), and enhancing plasma epinephrine concentrations (Norager et al, 2006). For example, Graham and Spriet (1995) showed that caffeine supplementation (3 and 6 mg/kg body weight) consumed 60 minutes before running at 85% VO2max significantly improved run time-to-exhaustion (increases of 22 ± 9 and 22 ± 7%, respectively) over the placebo time (49.4 ± 4.2 minutes). In addition, caffeine ingestion (6 mg/kg body weight) 90 minutes before cycling exercise at 80% VO2max increased exercise time-to-exhaustion compared with placebo (caffeine: 41.2 ± 4.8 minutes, placebo: 32.6 ± 3.4 minutes) (Graham, 2001).

The mechanisms by which energy drinks improved performance is not immediately clear. It is well established that providing carbohydrate during prolonged aerobic exercise increases endurance and exercise performance (Coyle et al., 1986; Ivy et al., 1983, 2003; Yaspelkis et al., 1993). This improvement in exercise performance is believed to be related to maintaining an

adequate glucose supply to the active muscles (Coyle et al, 1986). Research indicates, however, that providing carbohydrate 30–60 min before exercise will increase the plasma insulin concentration before exercise and that this causes a rapid decline in blood glucose because of the suppression of liver glucose output and increase in muscle glucose uptake. Elevated plasma insulin also inhibits lipolysis and therefore increases reliance on muscle glycogen as a fuel source. Not surprisingly, providing carbohydrate 30–60 min before exercise generally has not been found to enhance endurance performance (Foster et al., 1979; Hargreaves et al., 1987; Kuipers et al., 1999; Sherman et al., 1989) even when participants have previously fasted for 12 hr. Therefore, it is unlikely that energy drinks consumed before exercise increase performance by simply providing additional calories or maintaining blood glucose availability.

Another potential mechanism by which caffeine increases endurance performance is its effect on the perception of effort. There is support both for (Doherty et al., 2002; Rodrigues et al., 1990) and against (Bell et al., 2002; Bruce et al., 2000) reductions in RPE after caffeine ingestion. The trend for a reduced RPE, suggests that caffeine may elicit a central nervous system effect by reducing the perception of effort and fatigue. A recent meta-analysis critiquing the effects of caffeine and RPE suggests that there is no difference in RPE between caffeine and placebo after exhaustive exercise (Doherty & Smith, 2005).

However, previous research has shown a reduction in RPE with much higher doses of caffeine (5 mg/kg body weight) after treadmill running at 70% VO2max (Birnbaum & Herbst, 2004) and cycling at 80% VO2max (Bell & McLellan, 2002). Also, Ivy et al. (1979) reported that, with caffeine participants were able to exercise more intensely than with the placebo but with the same perception of effort. Similarly, Cole et al. (1996) observed that compared with placebo, 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. 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 (Gambert et al., 1981; Laurent et al., 2000). In this regard, Laurent et al. (2000) reported that after 2 hr of cycling to exhaustion, plasma β-endorphin levels were significantly elevated when participants consumed 6 mg caffeine/kg body weight 90 min before exercise.

Another study by Umana-Alvarado and Moncada-Jiménez (2004) indicated the RPEs in male endurance runners were lower when energy drinks were ingested compared to a placebo (Umana-Alvarado & Moncada-Jiménez, 2004). These blunted RPE values may be due to many factors such as the taste of the beverage, carbohydrate and caffeine concentration. Utter et al. (1999) indicated a physiological link between a lower RPE and carbohydrate substrate availability as well as selected hormonal regulation during prolonged running and cycling at 75% VO2max. A lower RPE was associated with a higher level of carbohydrate oxidation, higher plasma glucose and insulin levels, and lower plasma cortisol and growth hormone levels (Utter et al, 1999). Backhouse et al (2005) reported the influence of regular carbohydrate beverage ingestion on increased feelings of pleasure during and decreased RPE following prolonged cycling. Utter et al. (2002) found that marathoners consuming carbohydrate compared to placebo beverages could run at a higher intensity, so that no significant difference was observed in RPEs during a competitive race (Utter et al, 2002). Doherty and Smith (2005), demonstrated that caffeine reduces RPE during constant load exercise and upon termination of exhausting exercise and this may partly explain the subsequent ergogenic effects of caffeine on performance, so that caffeine improved exercise performance by 11.2% (Doherty & Smith, 2005).

Recent research and reviews conclude that caffeine affects endurance performance largely through its antagonist effect on adenosine receptors in the brain (Davis et al, 2003; Kalmar & Cafarelli, 2004; Crowe et al, 2006). It is also possible that caffeine improves exercise response during exercise by increasing or maintaining a high central nervous system drive. It has been found that caffeine inhibits the brain's adenosine receptors (Davis et al., 2003). During exercise adenosine levels increase in skeletal muscle and blood in proportion to the rate of ATP hydrolysis. Although it has not been determined how adenosine levels change in the brain during exercise, adenosine can cross the blood–brain barrier (Latini & Pedata, 2001). On binding to its receptors, adenosine lowers brain dopamine levels (Feuerstein, Hertting, & Jackisch, 1985; Hauber & Münkle, 1997). This lowers the seritonin:dopamine ratio, resulting in sensations of weariness and central nervous system fatigue (Garrett & Griffiths, 1997; Myers & Pugsley, 1986). 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).

2.6 ENERGY DRINK INGESTION PRIOR TO ENDURANCE EXERCISE

Several studies have investigated the effects of energy drink ingestion prior to aerobic exercise (Ivy et al, 2009) (Candow et al, 2009; Cox & Wescott, 2001; Walsh et al, 2010). In the earliest of these studies, Alford and colleagues (Cox & Wescott, 2001) investigated the effects of ingesting a commercial energy drink on aerobic endurance. In a repeated measures, crossover design, young healthy participants ingested 250 mL of a commercial energy drink (containing 80 mg of caffeine and 26 grams of carbohydrate), a carbonated water beverage, or no beverage at all 30

minutes prior to performing an endurance exercise bout. Aerobic performance was analyzed by the amount of time that exercise could be maintained at 65-75% of maximum heart rate on a cycle ergometer. Significant improvements in aerobic performance were reported for the commercial energy drink treatment. Aerobic performance was 8% and 14% longer after ingesting the commercial energy drink as compared to the carbonated water and no beverage treatment, respectively.

In one of only two studies that have investigated the effects of ingesting a sugar/carbohydrate-free energy drink on performance capacity, Candow and colleagues (2009) reported no improvements in high intensity run time-to-exhaustion performed at 80% of VO_2max on a treadmill in physically active college-aged participants. The sugar-free energy drink contained 2 mg/kg body weight caffeine and was ingested one-hour prior to the exercise bout (Candow et al, 2009). In contrast, Walsh and colleagues (2010) reported significant improvements in treadmill run time to exhaustion following ingestion of a carbohydrate-free energy drink. In this randomized cross-over investigation, 15 recreationally active participants ingested an energy drink 10-minutes prior to engaging in a treadmill run-to exhaustion test at 70% VO2max (Walsh et al, 2010). The energy drink utilized in this study did not contain any carbohydrate, and unlike other energy drink products, contained nearly eight grams of the amino acids L-leucine, L-isoleucine, L-valine, L-arginine and L-glutamine. Unfortunately, the published study did not disclose the precise amount of caffeine contained in the energy drink, but instead referred to a ~2 g "proprietary blend" of caffeine, taurine, and glucoronolactone. The placebo used as a comparison was sweetened water that was similar in color and volume. It was reported that participants consuming the energy drink were able to run 12.5% longer than during the placebo treatment (Walsh et al, 2010).

A study in 1994 investigated the effects of the taurine-enriched drink Red Bull on performance in endurance athletes. The subjects received 500 mL of a test drink after 30 minutes of submaximal cycling: Red Bull without taurine, without Glucuronolactone (U1); Red Bull without taurine, without glucuronolactone, without caffeine (U2); and Red Bull original drink containing taurine, glucuronolactone, and caffeine (U3). The results showed that heart rate level was significantly lower in U3 15 minutes after application. The plasma catecholamine's increased slightly from beginning of exercise to 15 minutes after application of the drinks in all trials but remained on a significantly lower level in U3. Endurance time was significantly longer with ''Red Bull'' original in U3 (Geib et al, 1994). The authors concluded from the data that there is a positive effect of a taurine-containing drink on hormonal responses, which lead to a higher endurance performance. This study did not differentiate if taurine or caffeine alone caused the increase in exercise capacity.

In a double-blind crossover study, 13 endurance-trained participants performed an exhaustive bout of endurance exercise at 3 different times (Baum & Weiss, 2001). Before the exercise, they ingested the original Red Bull drink, a similar drink without taurine but containing caffeine, and a placebo drink without caffeine or taurine. Echocardiography was performed before ingestion of the drinks, before exercise, 40 minutes after ingestion, and in the recovery period after exercise. Stroke volume was significantly influenced only in the Red Bull group (80±21 mL before ingestion vs 98±26 mL in the recovery period), mainly because of reduced end-systolic volume. Baum and Weiss suggested that increases in stroke volume might occur due to the potential effect of the caffeine and taurine-containing energy drink (Red Bull) on cardiac contractility (Baum & Weiss, 2001).

2.6.1 Summary

Energy drinks containing approximately 2 mg/kg body weight caffeine consumed 10 to 60 minutes prior to aerobic exercise improve cycling and running performance in both trained cyclists and recreationally active participants.

2.7 ENERGY DRINK INGESTION PRIOR TO ANAEROBIC EXERCISE

Several recent studies have demonstrated that a pre-exercise energy supplement can also improve the quality of a resistance training workout (Hoffman et al, 2007; Hoffman et al, 2008; Ratamess et al, 2007). In 2007, Forbes et al. (2007) conducted the first Red Bull study that examined the immediate effects of the energy drink Red Bull on repeated Wingate cycle performance and bench press muscular endurance. The results show that Red Bull energy drink significantly increased total bench press repetitions over 3 sets (Red Bull = 34 ± 9 versus placebo = 32 ± 8) in young physically active men and women who were non-habitual caffeine users. Clearly, Red Bull significantly does increase upper-body muscle endurance even with the trivial amount of caffeine that it contains. However, the drink had little or no effect on anaerobic peak or average power during repeated Wingate cycling tests (Red Bull = 701 ± 124 W versus placebo = 700 ± 132 W, Red Bull = 479 ± 74 W versus placebo = 471 ± 74 W, respectively) (Forbes et al, 2007). No adverse side effects were seen in either the control group or the PLA group. These findings indirectly suggest that a caffeine dose ~2 mg/kg body weight may be effective for increasing upper body muscle endurance but has no impact on Wingate performance (Forbes et al, 2007).

In a similarly designed study, a commercially available energy drink (providing an average of 2.1 mg of caffeine per kg of body mass) given to physically active male and female participants 45 minutes prior to exercise resulted in a significant increase in leg press total lifting volume (12% increase as compared to a carbohydrate placebo) but had no effect on bench press total lifting volume (Campbell et al, 2010) or multiple 20-second Wingate-type cycle sprints (Campbell et al, 2010). Hoffman and colleagues (2009) gave male strength/ power athletes an energy drink containing an average of 1.8 mg/kg body weight of caffeine or a placebo beverage that was similar in taste and appearance but contained only inert substances. Following the ingestion of the energy drink, three separate 20-second Wingate tests separated by about 15 minutes were performed. Results revealed that there were no significant differences between trials in any anaerobic power measure. In a recent publication, 12 healthy male and female non-resistance trained participants ingested a commercially available energy drink standardized at 1 or 3 mg/kg body weight of caffeine or a placebo beverage (containing no caffeine) in a randomized, repeated measures design (Del Coso et al, 2012). Sixty minutes following beverage ingestion, each participant completed 10-to-100% 1RM power-load tests for the bench press and half-squat. Ingestion of the energy drink with 1 mg/kg body weight of caffeine was not enough to raise the power output during the power-load tests. However, the ingestion of an ED with 3 mg/kg body weight of caffeine increased maximal power output by 7% in both the half-squat and bench-press as compared to the ingestion of a placebo (Del Coso et al, 2012). A recent study by Gonzalez and colleagues (2011) indicated that an energy matrix consisting of caffeine, taurine and glucoronolactone consumed 10-min prior to a workout resulted in an 11.9% improvement in the number of repetitions performed during 4 sets of the squat or bench press exercise using 80%

of the subject's 1-RM. In addition, the average power output for the workout was significantly higher for subjects consuming the energy drink compared to subjects consuming the placebo.

In addition to resistance and high intensity anaerobic exercise, the effects that energy drinks exert on speed/agility performance has also been investigated. Collegiate female soccer players ingested an energy drink containing 1.3 mg/kg body weight of caffeine and 1 gram of taurine or a caffeine and taurine-free placebo 60 minutes prior to repeated agility t-tests (Astorino et al, 2012). No difference in agility t-test performance between the energy drink and placebo groups was reported. Specifically, the highest difference reported between the two groups was during the third set of eight agility t-tests, and the difference reached only 1.15% between the groups. It is unlikely that the carbohydrate content alone in energy drink is responsible for improvements in resistance exercise performance. In support of this view, the majority of studies in which supplemental carbohydrate was ingested prior to a resistance-training bout did not report improvements in resistance training performance (Haff et al, 2000; Kulik et al, 2008; Lambert et al, 1991).

2.7.1 Summary

Energy drinks (containing approximately 2 mg/kg body weight caffeine) consumed 45 to 60 minutes prior to anaerobic/resistance exercise may improve upper- and lower- body total lifting volume, but has no effect on repeated high intensity sprint exercise, or on agility performance.

2.8 MOOD/REACTION TIME/ALERTNESS

Given the rising popularity and widespread use of energy drinks, a number of studies have examined the potential ergogenic effects of commercially available energy drinks, particularly Red Bull, on reaction time, concentration/focus, memory, mood, verbal reasoning and alertness (Cox, 2001; Scholey & Kennedy, 2004; Seidl et al, 2000; Warburton et al, 2001) and have reported beneficial effects compared to placebo.

Reaction time, concentration, alertness, and subjective feelings of energy/vitality are important in many competitive activities such as hitting a baseball, returning a serve in tennis, and dodging strikes and kicks in a mixed martial arts competition. Strategies to improve these attributes are often sought after by individuals competing in certain athletic endeavors. Over the past several years, research has investigated the effects that energy drink ingestion has on these (and other) variables.

Seidl and coworkers (2000) conducted a study utilizing three common ingredients (i.e., caffeine, taurine, glucuronolactone) typically found in energy drinks and compared it to a placebo. Participants were evaluated at night to see if ingestion of these nutrients affected mood and motor function in fatigued participants. Interestingly, the investigators found that at the end of the experiment, reaction time was significantly longer in the placebo group, but remained unchanged in the group that consumed the energy drink ingredients. Similarly, vitality scores, feelings of well-being, and social extrovertedness were all significantly decreased in the placebo group, but did not change in the energy drink group (Seidl et al, 2000).

Scholey and colleagues (2004) investigated the effects of an energy drink (containing primarily caffeine, glucose, ginseng and ginkgo biloba drink) or a placebo beverage on five

aspects of cognitive performance and mood. Thirty minutes after consuming the energy drink, two of the five variables (i.e., “secondary memory” and “speed of attention”) were significantly improved as compared to the placebo beverage (Scholey et al, 2004). Other investigators also reported that when caffeine was combined with carbohydrates in a carbonated beverage, performance and mood were improved and/or maintained during fatiguing and cognitively demanding tasks relative to placebo (Smit et al, 2004). Similarly, energy drinks containing caffeine and glucose have also been shown to enhance event related potentials (i.e., a measure of brain activity in real time obtained from an electroencephalogram), which may translate to improvements in reaction time (Rao et al, 2005).

Hoffman et al. (2009) reported that an energy drink containing caffeine and a number of additional herbal and botanical compounds that included evodiamine, N-acetyl-L-tyrosine, hordenine, 5-hydroxytryptophan, potassium citrate, N-methyl tyramine, sulbutiamine, vinpocetine, yohimbine HCL, and St. John’s wort extract (marketed as Redline Extreme; Vital Pharmaceuticals, Inc., Davie, FL) significantly increased focus, alertness, and reaction time. Improvements in reaction time were assessed through both visual and auditory stimuli. Interestingly, despite a significant improvement in reaction ability, no significant improvements were noted in anaerobic power performance as assessed by repeated Wingate anaerobic power tests.

Research by Cox & Wescott (2000) has shown that energy drinks increase exercise performance at moderate intensity levels but also help combat fatigue and drowsiness as well as increase alertness (Cox & Wescott, 2000). This is particularly important to persons engaging in longer activities. Ingestion of an energy drink significantly improved subjective feelings of focus and energy as well as increased levels of alertness and decreased fatigue (Horne & Reyner,

2001). Also, an energy drink can significantly reduce sleep related driving incidents and is beneficial in reducing sleepiness for drivers (Horne & Reyner, 2001; Roberts et al, 2007).

Howard and coworkers (2010) evaluated the effects of acute ingestion of a glucose containing energy drink on behavioral control. In this study, 80 participants were randomly assigned to consume 1.8, 3.6, or 5.4 ml/kg body weight of an energy drink, a placebo, or no drink in a counterbalanced manner. Participants completed a behavioral control task and subjective measures of stimulation, sedation, and mental fatigue before and 30-minutes after ingestion of the assigned drinks. Results revealed that those consuming the energy drink decreased reaction times on the behavioral control task, increased subjective ratings of stimulation and decreased ratings of mental fatigue. The greatest improvements in reaction times and subjective measures were observed with the lower dose and improvements diminished as the dose increased.

2.8.1 Summary

To date, most studies on energy drinks have reported improvements in mood, reaction time, and/or markers of alertness, even though the relative importance of the various ingredients is not fully understood. The primary ergogenic value appears to be due to the caffeine and/or carbohydrate contained in these drinks. Individuals looking to enhance reaction time, mental alertness, and/or focus may benefit from consuming energy drinks prior to exercise.

2.9 TIME-TO-EXHUASTION VS TIME TRIAL PROTOCOLS

The two most common protocols used to assess aerobic performance when using energy drinks are time to exhaustion at a given exercise intensity (e.g., exercise at 70% of maximum oxygen uptake until exhaustion) and time trial performance for a set distance (e.g., 40 km time trial). Time trials have greater validity than time to exhaustion because they provide a good physiological simulation of actual performance and correlate with actual performance (Currel & Jeukendrup, 2008; Laursen et al, 2007). Ivy and colleagues (2009) were the first research group to utilize a time trial component in conjunction with energy drink consumption. In this investigation, trained male and female cyclists completed two trials in a repeated measures crossover design separated by one week. After a 12 hour fast, the cyclists ingested 500 ml of a commercially available energy drink (Red Bull) providing approximately 160 mg of caffeine or an artificially colored, flavored, and sweetened-water placebo 40-minute prior to the exercise bout. Performance during the exercise bout was measured as the time to complete a standardized amount of work equal to 1 hr of cycling at 70% of maximal power output. Results revealed a significant difference between the treatments in relation to performance with the energy drink treatment completing the time trial ~4.7% faster than the placebo treatment (Ivy et al, 2009). The performance improvements after the energy drink ingestion are consistent with those found by Alford, Cox, and Wescott (2001), in whose study performance was indirectly measured as the length of time participants exercised and maintained HR within 65–75% of HRmax, and Geiß, Jester, Falke, Hamme, and Waag (1994), in whose study performance was directly measured as time to exhaustion.

A recent literature review by Ganio et al (2009) examined the effect of caffeine on time-trial endurance performance and found that the mean improvement in performance with caffeine ingestion was 3.2 ± 4.3%. O'Rourke et al (2008), demonstrated that consuming 5 mg/kg of caffeine significantly improved 5-km track performance in well-trained (-10s, 1.0%) and recreational runners (-11s, 1.1%). Bell et al (2002) found a non-significant 1.7% improvement in 10-km treadmill performance in moderately trained subjects wearing 11-kg of military gear with 4 mg/kg body weight of caffeine. In trained runners, Bridge & Jones (2006) reported improved performance with 5 mg/kg body weight caffeine versus placebo during an 8-km track race.

2.10 CAFFEINE AND RUNNING

2.10.1 Caffeine and middle-distance running (400 – 5000 m)

Caffeine use has been shown to be ergogenic in middle-distance running (400 – 5000 m), longer middle distance events (3000 – 5000 m), and long distance running (8 – 10 km to 42.2 km). In middle-distance running (400–5,000 m), metabolic acidosis and neuromuscular fatigue are detrimental to performance. Caffeine has been shown to alter neural function via reducing the inhibitory effects of adenosine (Davis et al, 2003) and potentially augmenting motor unit recruitment (Meyers & Cafarelli, 2005; Walton et al, 2002). An ergogenic effect of caffeine intake on 1,500-m treadmill performance was revealed by Wiles et al. (1992) in trained runners. Data revealed that 3 g of caffeinated coffee (containing 2.5 mg/kg/BM caffeine as reported by Ganio et al. (2009) improved time trial performance vs. placebo by 4.2 seconds, representing a

1.5% improvement in performance. Other data showed improved sprint cycling performance (Paton et al, 2010; Wiles et al, 2006) and 2,000-m rowing performance in athletes (Bruce et al, 2000). Although these activities are not running, they were at similar relative intensities and durations to middle-distance running.

2.10.2 Caffeine and longer middle distance events (3,000–5,000 m)

In addition to the fatigue caused by acidosis, fatigue in longer middle distance events (3,000–5,000 m) is caused by a complex interaction of physiological and psychological systems (Brooks et al, 2005). Others (O'Rouke et al, 2008) demonstrated that consuming 5 mg/kg body weight of caffeine significantly improved 5-km performance in well-trained (-10 seconds, 1.0%) and recreational runners (-11 seconds, 1.1%).

2.10.3 Caffeine and long-distance running (8–10 km to 42.2 km)

Long-distance running (8–10 km to 42.2 km) has a great dependence on oxidative phosphorylation of carbohydrate and fats to provide a constant source of fuel for working muscle. Causes of fatigue can vary for these distances, with mechanisms of fatigue in 8- to 10-km races similar to those of middle-distance running, whereas fatigue in half marathons and marathons is generally because of carbohydrate depletion. In trained runners, Bridge and Jones (2006) reported improved performance with 5 mg/kg body weight of caffeine (-24 seconds; 1.2%) vs. placebo during an 8-km track race, whereas Bell et al. (2002) found a non-significant 1.7% improvement in 10-km treadmill performance in subjects wearing 11 kg of military gear

with 4 mg/kg of caffeine. Studies have examined the combined effect of caffeine and carbohydrate on performance, with a recent meta-analysis indicating a small but worthwhile improvement of 6% compared with carbohydrate alone (Conger et al, 2011).

2.11 CAFFEINE AND HEART RATE

Caffeine is a CNS-stimulating drug that acts as an adenosine receptor antagonist in the brain (Smit and Rogers, 2000). Additionally, adenosine antagonism has been implicated as a contributor to some of the physiological effects associated with caffeine consumption, such as a direct cardioacceleratory effect, and increased blood pressure and respiration rate (Suleman and Siddiqui, 1997–2004). Consumption of caffeine increases cardioacceleratory signals, which should increase heart rate (Suleman and Siddiqui, 1997–2004). During exercise caffeine ingestion normally results in a significant increase in mean heart rate (Graham, 2001; Bridge & Jones, 2006). In a study by Bridge & Jones (2006), caffeine ingestion resulted in an increase in mean heart rate (2 beats/min). The authors suggested that the participants were able to work at a higher percentage of their maximal heart rate during the caffeine trial. This finding is in line with Kovacs et al (1998) who found a mean increase in heart rate (4 beats/min). The higher mean heart rates could be attributed to the direct effects of caffeine as a stimulant or due to caffeine's effects upon central perceptions of effort (Graham, 2001). Numerous studies, however, have shown that caffeine consumption can cause heart rate to decline through pressure-induced reflex bradycardia (Suleman and Siddiqui, 1997–2004). Caffeine-induced heart rate decline may also result from direct central vagal stimulation (Whitsett et al., 1984).

2.12 POTENTIAL ERGOGENIC NUTRIENTS CONTAINED IN ENERGY DRINKS THAT MAY AFFECT PERFORMANCE

Energy drinks typically contain caffeine, taurine, water, carbohydrates, vitamins, minerals, and proprietary blends of various nutrients purported to increase energy, alertness, metabolism, and/or performance. Therefore, ingestion of energy drinks prior to, during, and/or following exercise could have some ergogenic value (Table 2).

Table 2. Potential stimulants contained in energy drinks that may affect performance capacity

Ingredient	Potential Ergogenic Value	Scientific Support
Caffeine	Stimulant. Increases metabolism and lipolysis (Bonati et al, 1982; Hoffman, 2010; Graham et al, 1998).	Increases alertness, mood, cognitive function (Bonati et al, 1982; Hoffman, 2010; Graham et al, 1998). Increases fat oxidation, spares glycogen utilization, improves exercise (Goldstein et al, 2010; Graham et al, 1998).
Taurine	Improved mental focus, concentration, serves as antioxidant, glucose homeostasis (Franconi et al, 2006; Dawson et al, 2002; Zhang et al, 2004).	Some supportive evidence with ED and fed animals (Bakker & Berg, 2002; Bichler et al, 2006).
Glucuronolactone	May favor the body's natural defense mechanism for eliminating carcinogens and tumor promoters and their effects (Zoltaszek et al, 2008).	Little research has been done in humans, and the current body of knowledge on this substance is scant. Therefore, conclusions on whether this compound is harmful or beneficial cannot be made.
B-Groups Vitamins	Required for proper cell function, especially mitochondrial function and energy production (Depeint et al, 2002).	There is little evidence that ingestion of these vitamins and minerals in the amounts found in energy drinks would provide any ergogenic benefit during exercise performance in well-nourished individuals (Rodriguez et al, 2009; Kreider et al, 2010).
Sucrose and Glucose	Carbohydrate feeding during exercise of about 45 minutes or longer can improve endurance capacity and performance (Jeukendrup et al, 1997; Jeukendrup, 2004).	Maintaining blood glucose levels, maintaining high levels of carbohydrate oxidation, and the sparing of liver and possibly skeletal muscle glycogen (Coyle et al, 1986)
Alpine Spring Water	N/A	N/A

2.12.1 Caffeine

Caffeine, an adenosine receptor antagonist, is a stimulant that can influence the activity of neuronal control pathways in the central and peripheral nervous systems (Jones, 2008). Caffeine is the most common ingredient utilized in energy drinks. After ingestion, caffeine is quickly absorbed and increases in plasma concentrations are generally observed between 30 – 60 minutes following ingestion (Goldstein et al, 2010; Quilan et al, 1997). Caffeine is a strong cardiovascular stimulant that increases epinephrine output to a greater extent when ingested via its anhydrous formulation when compared to an equal amount of brewed or instant caffeinated coffee (Graham et al, 1998; McLellan & Bell, 2004). In addition, caffeine's half-life ranges from approximately 2 to 10 hours with 0.5% - 3.5% of its content excreted unchanged in urine and select amounts eliminated via perspiration (Kovacs et al, 1998).

Caffeine has global effects on the central nervous system (CNS) and on hormonal, metabolic, muscular, cardiovascular, pulmonary, and renal functions during rest and exercise. It stimulates bronchodilation of alveoli, vasodilation of blood vessels, neural activation of muscle contraction, blood filtration in the kidneys, catecholamine secretion, and lipolysis (Graham & Spriet, 1991; Leonard et al, 1987). These metabolic, physiologic, and hormonal effects of caffeine lower the respiratory exchange ratio, peripheral fatigue, rating of perceived exertion (RPE), and the threshold for exercise-induced cortisol and B-endorphin release; they also increase oxygen uptake, cardiac output, ventilation, circulating levels of epinephrine, metabolic rate, and fat oxidation during endurance exercise in trained and untrained individuals (Doherty et al, 2004; Engels et al, 1999).

Caffeine binds to the adenosine class of G protein–coupled receptors on the surface of heart muscle cells, which begins a second messenger system with cyclic adenosine monophosphate inside the cells and mimics the effects of epinephrine (Piirainen et al, 2010). The rate of glycolysis increases, which increases the amount of adenosine triphosphate available for muscle contraction and relaxation (Mayo Clinic Staff, 2009). This can result in a stronger and faster heartbeat. Caffeine immediately increases blood pressure and peripheral vascular resistance, in part because of sympathetic stimulation. One group of investigators showed a significant effect of drinking caffeinated coffee on arterial tone and function, suggesting that caffeine immediately increases arterial stiffness, with the effect being more pronounced on aortic systolic and diastolic blood pressures than on the brachial artery (Mahmud & Feely, 2001).

Recent reviews conclude that caffeine's primary mode of action involves adenosine receptor antagonism in the central nervous system (Graham, 2001; Keisler & Armsey, 2006; Paluska, 2003). The stimulation of the sympathetic nervous system by caffeine acts on multiple metabolic pathways to improve endurance performance. Until recent years, the mechanism for improved endurance performance was considered to be improved lypolysis from adipose and intramuscular triglyceride and conservation of carbohydrate stores (i.e., glycogen sparing effects of caffeine) for later use during endurance exercise (Doherty et al, 2004; Engels et al, 1999; Graham & Spriet, 1995). Caffeine mobilizes fat stores and stimulates working muscles to use fat as a fuel, which delays depletion of muscle glycogen and allows for prolonged exercise (Laurent et al, 2000). The critical period in glycogen sparing appears to occur during the first 15 minutes of exercise, when caffeine has been shown to decrease glycogen utilization by as much as 50%. Thus, glycogen saved at the beginning is available during the later stages of exercise (Laurent et al, 2000). However, Davis et al. (2003) proposed a mechanism by which caffeine delays fatigue

through its effects on the CNS. Recently, this mechanism has gained popularity because of previously known effects of caffeine as a CNS stimulant, through its action as an adenosine receptor antagonist, and its analgesic effects on CNS.

Caffeine affects the CNS by stimulating the secretion of serotonin in the cerebral cortex, enhancing the action of the sympathetic system, and diminishing the activity of inhibitory neurons (Griffiths & Woodson, 1988; Leonard et al, 1987) as a result of the binding and blocking of adenosine receptors. Caffeine is able to cross the blood-brain barrier and is a powerful antagonist of adenosine receptors in the central nervous system (Biaggioni et al, 1991). Adenosine and caffeine work opposite of one another with respect to cellular regulations. Adenosine, a neuromodulator, binds to adenosine receptors and slows nerve cell activity, whereas caffeine blocks adenosine receptors and speeds up the activity of cells (Griffiths & Woodson, 1988; Leonard et al, 1987). This mechanism greatly affects the user's cognition and mood. Several studies show that, the positive effects of acute caffeine intake include decreased tiredness, increased mental alertness, mood improvement, and energetic arousal as a result of the effects of caffeine on the CNS (Davis et al, 2003; Evans & Griffiths, 1999). In addition, caffeine significantly enhanced concentration, visual vigilance, choice reaction time, and self-reported fatigue (i.e., after a period of exercise, work, and a long period of sleep deprivation) in a dose-dependent manner (Lieberman et al, 2002; McLallan et al, 2005).

Because of the potential importance of adenosine receptors on central fatigue, it is important to understand factors that may change or modulate adenosine receptor number or sensitivity. Changes in adenosine receptor number or sensitivity may play a role in the effect that caffeine has on exercise performance. Chronic caffeine consumption in animal models results in up-regulation of the number and an increase in the affinity of adenosine receptors within the

central nervous system (Kaplan et al, 1993). This may result in an increased amount of caffeine needed to have the same antagonist activity on the receptors (termed ‘‘caffeine habituation’’).

The ergogenic effects of caffeine on athletic performance have been shown, and its broad range of metabolic, hormonal, and physiologic effects has been described (Ganio et al, 2009; Sokmen et al, 2008). Caffeine has been shown to be an effective ergogenic aid for endurance athletes when ingested before and/or during exercise in moderate quantities (3-6 mg/kg of body mass). It is not known exactly how many days an endurance athlete should abstain from caffeine to maximize its ergogenic effects, but animal studies show that increases in adenosine receptor number and affinity are maximized in 7 days (Kaplan et al, 1993). This should allow for withdrawal symptoms (which may negatively affect performance) to subside and allow sufficient time for adenosine receptor down-regulation to occur (Kaplan et al, 1993), thus possibly maximizing the ergogenic effects of caffeine.

It is generally agreed that as little as 40–60 mg of caffeine can exert positive effects on cognitive function (Lieberman et al, 1987; Smith et al, 1999; Durlach, 1999), with larger doses, which typically exceed 200 mg or about 3 mg/kg body weight, required to enhance physical performance when the dose is ingested about 1 h before exercise (Graham & Spriet, 1995). Caffeine content for a single serving of an energy drink ranges from a low of 50 mg to a high of 500 mg. Certainly one serving of any of these drinks would be sufficient to impact cognitive function (Lieberman et al, 1987; Smith et al, 1999; Durlach, 1999). Two servings of Red Bull and most of the other energy drinks 1 h prior to exercise would also approach a dose of caffeine that could impact physical performance (Graham & Spriet, 1995). Several factors, such as history of use, genetic variation in the expression of the cytochrome P450 enzyme or the adenosine A2a receptor, and whether an individual is rested or fatigued, can influence the

magnitude of the physical and cognitive effects to a given dose of caffeine (Lieberman et al, 2010).

2.12.2 Carbohydrate

Another common ingredient in most energy drinks is some type of carbohydrate source (e.g., glucose, sucrose, maltodextrin, etc.). In examining the effects of caffeine (0, 150, 225, 320mg/L) and carbohydrate (68.8 g/L) containing solutions on exercise performance, Kovacs et al. (1998) found that the combination of caffeine and carbohydrates significantly improved cycling exercise performance in young male athletes. Furthermore, the ingestion of a commercially available caffeinated, carbohydrate-containing soft drink (i.e., Coke) improved cycling exercise performance by 3.3% over a carbohydrate containing solution in young trained male athletes (cyclists, triathletes; (Cox et al, 2002)). In 2 previous studies investigating the effects of regular Red Bull (i.e., caffeine and carbohydrates) energy drink on exercise performance, it was shown that bench press muscle endurance (defined as the total number of repetitions over 3 sets; (Forbes et al, 2007)) and maximum cycling velocity (65–76% heart rate maximum (Alford et al, 2000)) increased when Red Bull was consumed compared with a non-caffeinated, carbohydrate containing placebo (Forbes et al, 2007). Although it is difficult to compare the results across studies, it appears that the ergogenic effects of commercially available soft drinks and energy drinks may only be observed when the treatment contains both caffeine and carbohydrates.

It is well documented that endurance exercise performance can be extended if carbohydrates are included in the fluid consumed at regular intervals (Coyle et al, 1983; Coyle et al, 1986; Jeukendrup et al, 1997; Jeukendrup, 2004). Mechanisms by which carbohydrate feeding

prior to and during exercise improves endurance performance include maintaining blood glucose levels, maintaining high levels of carbohydrate oxidation, and the sparing of liver and possibly skeletal muscle glycogen (Coyle et al, 1986). The American College of Sports Medicine (Rodriguez et al, 2009) and the International Society of Sports Nutrition (ISSN) (Kreider et al, 2010) recommends ingesting carbohydrate in a 6-8% solution (6-8 grams per 100 ml of fluid) during endurance exercise. Optimal concentrations of 6–8% can provide an exogenous source of carbohydrate oxidation at rates approximating 60 g/h for each liter of fluid consumed (Coyle, 2004). Sport drinks, such as Gatorade, are designed to provide these optimal concentrations of carbohydrate, whereas the sugar content of most energy drinks are closer to 11–12% by volume. Ingesting higher percentages (>10%) of carbohydrate in fluids has been reported to delay gastric emptying and increase gastrointestinal distress (Maughan & Leiper, 1999; Coyle, 2004).

Energy drinks contain approximately 25-30 grams of carbohydrate per 240 mL (8 fluid ounces) serving. This amount nearly meets the lower value of 30 grams/hour recommended during endurance exercise, but falls short of the upper range of 60 g/hr. A teaspoon of sugar weighs about 4 g, so a typical energy drink contains about 13 teaspoons, or just more than ¼ cup, of sugar. So while the total carbohydrate content of typical energy drinks is quite high, a shortcoming exists in regards to the concentration of commercially available energy drinks.

Given the independent ergogenic effects of carbohydrate or caffeine ingestion, several investigators have studied the interactive effects of these substances when they are concomitantly ingested. Hulston and Jeukendrup (2008) examined the impact of 0.7 g/min of carbohydrate ingested alone or in combination with 5.3 mg/kg body weight of caffeine during 105 min of steady-state exercise at approximately 60% of maximal aerobic power, followed by a time trial lasting about 45 min. Rates of appearance and disappearance of glucose were significantly higher

with carbohydrate ingestion but were unaffected by the additional ingestion of caffeine. Time trial performance was improved significantly by almost 5% when caffeine was ingested with the carbohydrate, implying that this additional ergogenic effect was due to the independent effect of the caffeine. Unfortunately, these authors did not include an experimental condition that involved only the ingestion of the 5.3 mg/kg body weight of caffeine.

Other studies have found that caffeine co-ingested with a carbohydrate (CHO) solution has been shown to have no additive effects on substrate use and exercise performance (Hunter et al, 2002; Jacobson et al, 2001). However, caffeine has also been shown to improve 1-hour time trial cycling performance in a dose-dependent manner, when added to a 7% CHO–electrolyte drink, without having any effects on fat oxidation (Kovacs et al, 1998). A recent study showed that caffeine may exert ergogenic properties during exercise, when ingested in combination with a CHO solution, perhaps by increasing exogenous CHO oxidation or intestinal absorption (Yeo et al, 2005).

There is also substantive evidence supporting the independent effects of glucose and caffeine on cognitive performance. Following a night of restricted sleep totaling 5 h, a 2-h driving simulator test conducted the next afternoon from 14:00 to 16:00 h under three double-blind and randomized conditions was used to study the effect of a glucose (30 g of sugar) or glucose (65 g) and caffeine (46 mg) drink on performance (Horne & Anderson, 2005). Sleep-related incidents, defined from video recordings as due to eye closure or vacant staring ahead, were the lowest over the 2-h test with the glucose and caffeine drink. Based upon their own previous research that tested driver sleepiness following the consumption of one can of Red Bull (Reyner & Horne, 2002), the authors concluded that the impact on driver performance was due to the caffeine rather than the glucose content of the drink.

In another study by Scholey & Kennedy (2004) a modified version of the Cognitive Drug Research assessment battery was used to assess the effects of an energy drink and its caffeine, glucose, and herbal fractions on memory and attention (Scholey & Kennedy, 2004). Following a familiarization session, subjects performed five double-blind and randomized tests in the morning that consisted of baseline testing, the consumption of a 250 mL drink, and additional testing with the cognitive battery that began 30-min post-ingestion. The drinks were placebo (water plus artificial sweeteners) provided alone or together with 75 mg caffeine, 37.5 g of glucose, 12.5 mg of ginseng, and 2 mg of Ginkgo biloba extract or the complete energy drink containing all of the ingredients. Performance on the tests administered to provide an outcome score for secondary memory (such as the delayed word and picture recognition and the immediate and delayed word recall tests) and on tests used to indicate speed of attention were significantly improved following ingestion of the entire energy drink. It was concluded that the combination of glucose with caffeine in an energy drink, rather than either ingredient alone, was essential to produce a positive effect on cognitive performance.

The glucose content in energy drinks is not designed to optimize absorption of fluid and carbohydrates during exercise, as is the case for sport drinks, such as Gatorade (Coyle, 2004). There is some evidence to support the beneficial effects of the glucose in energy drinks for improving cognitive performance for up to 60 min post-ingestion (Scholey & Kennedy, 2004), with the addition of caffeine enhancing and sustaining the effects of glucose for up to 2 h post-ingestion (Horne & Anderson, 2005; Scholey & Kennedy, 2004).

2.12.2.1 Carbohydrate-free energy drinks effect on performance

There have been some studies that have looked at the effects on performance using a carbohydrate free energy drink. In one of only two studies that have investigated the effects of ingesting a sugar/carbohydrate-free energy drink on performance capacity, Candow and colleagues (2009) reported no improvements in high intensity run time-to-exhaustion performed at 80% of VO2max on a treadmill in physically active college-aged participants. The sugar-free energy drink contained 2 mg/kg body weight caffeine and was ingested one-hour prior to the exercise bout (Candow et al, 2009). In contrast, Walsh and colleagues (2010) reported significant improvements in treadmill run time to exhaustion following ingestion of a carbohydrate-free energy drink. In this randomized cross-over investigation, 15 recreationally active participants ingested an energy drink 10-minutes prior to engaging in a treadmill run-to exhaustion test at 70% VO2max (Walsh et al, 2010). The energy drink utilized in this study did not contain any carbohydrate, and unlike other energy drink products, contained nearly eight grams of the amino acids L-leucine, L-isoleucine, L-valine, L-arginine and L-glutamine. Unfortunately, the published study did not disclose the precise amount of caffeine contained in the energy drink, but instead referred to a ~2 g "proprietary blend" of caffeine, taurine, and glucoronolactone. The placebo used as a comparison was sweetened water that was similar in color and volume. It was reported that participants consuming the energy drink were able to run 12.5% longer than during the placebo treatment (Walsh et al, 2010).

2.12.3 Taurine

Although caffeine is the main purported ergogenic ingredient in Red Bull and many other popular energy drinks, this commercially available energy drink also contains other potential ergogenic ingredients, like Taurine. Taurine is often combined with caffeine in energy drinks. Although its mechanism of action is not well understood, previous studies have shown that taurine by itself can improve endurance performance (Miyazaki et al, 2004; Zhang et al, 2004). For example, taurine supplementation has been shown to increase exercise time-to-exhaustion in both humans and rats (Zhang et al, 2004), possibly by increasing muscle hyperexcitability and calcium availability (Bakker & Berg, 2002; Zhang et al, 2004). Research suggests that taurine doses of 2–6 g are required to be beneficial (Baum & Weis, 2001; Zhang et al, 2004).

Taurine is a non-essential amino acid found in high concentrations in the brain, heart, and skeletal muscle (Huxtable, 1992). In addition, Taurine is the most abundant intracellular amino acid in humans and a normal constituent of the human diet (Gaull, 1989). Taurine is important in multiple metabolic processes, like osmoregulation to anti-oxidation to glycolysis (Babu et al, 2008). Taurine modulates skeletal muscle contractile function and may attenuate exercise-induced DNA damage, with some evidence showing the ability to improve exercise capacity and performance (Ballard et al, 2010). Taurine has numerous other biological and physiologic functions, including bile acid conjugation and cholestasis prevention, antiarrhythmic, inotropic, and chronotropic effects, central nervous system neuromodulation, retinal development and function, endocrine or metabolic effects, and anti-inflammatory properties (Lourenco & Camilo, 2002). Taurine also assists in cell membrane stabilization and detoxification (Zoltaszek et al, 2008).

In a study by Ivy et al. (2009) the amount of caffeine consumed averaged only 2.35 mg/kg body weight (500ml of Red Bull energy drink), which is at the lower end of caffeine dosage found to be effective. The authors speculated that the caffeine was working in combination with the other functional ingredients in the energy drink and that this combination is required to obtain the improvement in exercise performance observed. For example, Taurine is known to modulate mood and enhance the positive effects of caffeine on alertness (Mandel et al., 1985). It might also help improve performance by enhancing skeletal-muscle contractility (Pierno et al., 1998; Warskulat et al., 2004). Geiß et al. (1994) compared energy drink with and without taurine and found that when caffeine was held constant, the drink containing taurine elicited better performance.

When combined with caffeine and glucuronolactone, the ergogenic benefits of taurine have been confirmed in some investigations (Hoffman et al, 2008; Ratamess et al, 2007), but not others (Candow et al, 2009). Zhang et al. (2003) found significant increases in VO2max, time to exhaustion and maximal workload in exercise test with consumption of Taurine supplementation for one week. Results indicated that taurine may attenuate exercise-induced DNA damage and increase the capacity of exercise because of its cellular protective properties (Zhang et al, 2003).

The potential benefits of taurine supplementation in humans before or during exercise have been attributed to its antioxidant effect in young men following a 6 g/day dosing regimen for 7 days (Zhang et al, 2004) and increases in plasma concentrations in males following long-duration submaximal runs, implying a release from skeletal muscle (Ward et al, 1999). Contrasting these reports, Galloway et al (Galloway et al, 2008) reported that following 7 days of 5 g/day supplementation, there was no change in resting skeletal muscle taurine content and no change in the muscle taurine response to 2 h of cycling exercise at 60% of maximal aerobic

power. Furthermore, there were no effects on muscle metabolism during the exercise; this was despite the fact that plasma taurine increased fivefold for up to 4 h following the 1.66 g of the supplement that was taken three times daily with meals. Further, the acute ingestion of 1.66 g of taurine 1 h prior to 90 min of submaximal exercise had no effect on subsequent time-trial performance (Rutherford et al, 2010).

Taurine, in dosages of 1,000 mg per serving, has shown to significantly increase stroke volume over a placebo without taurine and caffeine mainly because of a reduced end-systolic diameter and volume (Baum & Weib, 2001). With the increase in stroke volume, the heart is able to pump more oxygenated blood each beat to the rest of the body thus potentially increasing aerobic performance.

The effects that 1 or 2 weeks of 4 mg/bodyweight caffeine or 15 mg/bodyweight taurine supplementation, either alone or in combination, had on the treadmill running performance of mice was examined by Imagawa et al (2009). Treadmill exercise began 4 h after the final drug administration and included 90 min of running at 10 m/min followed by increases in treadmill speed of 5 m/min every 15 min, to the point where the mice stopped running despite electro-stimulation. After 1 week, the group fed caffeine alone or in combination with taurine significantly increased their treadmill running distance, whereas no difference was observed in the control group or in those fed taurine alone. After 2 weeks of supplementation, there were no further improvements for the mice fed caffeine alone, but significant improvements were found for the group fed taurine alone and further additional increases in running performance were noted for the group fed both caffeine and taurine. The findings from this study suggest there is an additive effect of taurine supplementation with caffeine that becomes evident after a period of

2weeks in rodents. However, the translation of these data obtained using an animal model to human performance is not a straightforward undertaking.

One of the first and most popular energy drinks, Red Bull, contains 1 g of taurine in each 250 mL can. A number of studies have compared the effects of a placebo drink or one or more cans of Red Bull on physical and cognitive performance (Ferreira et al, 2004; Ferreira et al, 2004). Research examining taurine ingestion within energy drinks has shown to improve exercise performance. Although the majority of the findings from these studies demonstrate the efficacy of Red Bull, they do not identify which ingredient alone or in combination in this energy drink explains the positive effects observed. Geiß et al (1994) were the first to examine the effects of some of the ingredients of Red Bull on exercise performance. They performed a double-blind study that involved the following three experimental trials: 500 mL (2 cans) of Red Bull (the test drink); Red Bull without taurine, glucuronolactone, and caffeine (the placebo trial that contained glucose and sweetener); or Red Bull without taurine and glucuronolactone (the control trial that contained 160 mg caffeine, glucose, and sweetener). The drinks were consumed after 30 min of exercise at 70% of maximal aerobic power. The submaximal exercise continued for a further 30 min, after which the power output was increased by 50W every 3 min to exhaustion. Interestingly, compared with the control condition, the time to exhaustion during the incremental exercise test was significantly greater in the other conditions, i.e., 2.8 min longer during the Red Bull trial and 1.7 min longer during the placebo trial; the former improvement represented the completion of an additional 50W of exercise, requiring the equivalent of an additional 600 mL of oxygen consumption (or 7.5 mL/kg for those subjects who were described as endurance-trained athletes). These findings add to the growing prevalence of energy drinks

being utilized in the sport and exercise science domain as a means of improving exercise performance.

Marketing claims that taurine will increase physical and cognitive performance are not supported by the available evidence. And the precise mechanisms underpinning how TA may affect human endurance performance are still largely unclear (Galloway et al. 2008). Findings by Galloway et al (2008) conclusively showed that taurine supplementation for 7 days had no effect on muscle taurine levels and no effect on muscle metabolism during submaximal exercise. In addition, despite observed elevations in plasma levels following acute supplementation (Galloway et al, 2008), transport across the blood-brain barrier is tightly regulated, so taurine levels in the brain would likely be unaltered from normal levels (Kang et al, 2002).

There is clearly a lack of definitive evidence-based support in humans to justify the addition of taurine to a caffeinated energy drinks with the claim that the taurine will cause greater improvements in physical and cognitive performance than can be attributed to the effects of caffeine alone. In addition, the most conclusive studies, to date, have shown that acute or chronic taurine supplementation has no effect on muscle concentration or metabolism during submaximal endurance exercise (Galloway et al, 2008; Rutherford et al, 2010).

2.12.4 Glucuronolactone

Energy drinks also typically contain glucuronolactone, an ingredient which is involved in ascorbic acid synthesis and is metabolized into xylulose (Oka et al, 1976). Glucuronolactone is a naturally occurring metabolite formed from glucose in the liver (Storey, 1950). Ingested Glucuronolactone is readily absorbed, and then hydrolyzed and excreted in the urine as

glucuronic acid (Dowben, 1956). This is a naturally occurring substance produced in small amounts within the body. Supplementation with D-glucarates, including glucuronolactone, may favor the body's natural defense mechanism for eliminating carcinogens and tumor promoters and their effects (Zoltaszek et al, 2008).

An early study, which involved the injection of 100 mg/kg body weight of Glucuronolactone or other sugar carbon complexes, such as glycogen, glucose, galactose, fructose, or pyruvate, three times daily in rats during rest periods that preceded swimming tests to exhaustion, revealed positive effects on swim performance, blood glucose, and liver glycogen during the second and third tests following glucuronolactone injection (Tamura et al, 1968). This 100 mg/kg dose of Glucuronolactone three times daily would equate to the consumption of 35 cans of Red Bull for a 70-kg individual, given the amount of glucuronolactone in each 245 mL serving.

Evidence to support the addition of Glucuronolactone to energy drinks is nonexistent. No studies, to date, have appropriately tested the effects of glucuronolactone alone on physical and cognitive performance. Unfortunately, little research has been done in humans, and the current body of knowledge on this substance is scant. Therefore, conclusions on whether this compound is harmful or beneficial cannot be made. This is one ingredient for which evidence-based studies are needed to justify its popularity in various energy drinks.

2.12.5 Vitamins

Most energy drinks contain varying amounts of B vitamins and make unsubstantiated claims that these ingredients will increase the body's energy level. The B vitamins are water-soluble

vitamins required as coenzymes for proper cell function, especially mitochondrial function and energy production (Depeint et al, 2006). Because energy drinks contain large amounts of sugar, these vitamins are touted as ingredients necessary to convert the added sugar to energy. Hence, the B vitamins are the "key" needed to unlock all the energy provided by the simple sugars in energy drinks, and this is the extra energy that energy drink companies claim their product can provide.

B vitamins include thiamine, riboflavin, niacin, pantothenic acid, pyridoxine hydrochloride, biotin, inositol, and cyanocobalamin. The reduced form of nicotinamide adenine dinucleotide (NADH) is synthesized from niacin (vitamin B3). This coenzyme is required to supply protons for oxidative phosphorylation and plays a major part in energy production in cells (Sauve, 2008). It also stimulates the production of such neurotransmitters as l-dopa, dopamine, serotonin, and norepinephrine. Pantothenic acid (vitamin B5) is required for coenzyme A, α-ketoglutarate, and pyruvate dehydrogenase formation, as well as fatty acid oxidation (Depeint, 2006). Pyridoxine hydrochloride (vitamin B6) is a coenzyme involved in amino acid and homocysteine metabolism, glucose and lipid metabolism, neurotransmitter production, and DNA and RNA synthesis (Spinneker et al, 2007). Specifically, pyridoxine hydrochloride is involved in protein and red blood cell metabolism, is important for immune system function, and is needed to convert tryptophan to niacin. Cyanocobalamin (vitamin B12) helps maintain nerve cell function, is needed for production of DNA, and is important in red blood cell formation (Depeint, 2006).

For young, healthy adults, a balanced nutritious diet will provided sufficient quantities of the vitamin B complex without the need to supplement intake through the consumption of energy drinks (Williams, 2004; Rosenbloom, 2007). In addition, there is no evidence to support the

claims that additional supplementation with the vitamin B complex will enhance physical and cognitive performance.

2.13 SAFETY ISSUES RELATED TO ENERGY DRINK CONSUMPTION

The top selling energy drinks have caffeine levels that range from 75 to 174 mg per serving, while in some of the higher caffeine energy drinks, levels may exceed 500 mg per serving (Reissig et al, 2009). Adverse effects typically manifest with ingestion higher than 200 mg of caffeine (Clauson et al, 2008). The adverse effects seen with caffeine in these doses include insomnia, arrhythmia, nausea, nervousness, headache, and tachycardia (Clauson et al, 2003; Calamaro et al, 2009). In comparison, an 8-oz cup of coffee contains 110 to 150 mg for drip, 65 to 125 mg for percolated, and 40 to 80 mg for instant; caffeinated beverages contain about 50 to 100 mg of caffeine (Clauson et al, 2008). A recent discussion of the safety issues associated with energy drinks suggested that the products that are generally added to these supplements such as guarana, ginseng, and tuarine are in concentrations that are far below the amounts associated with adverse events (Clauson et al, 2003).

Several case reports have indicated that energy drinks may increase the risk for ventricular tachycardia (Nagajothi et al, 2008) or myocardial ischemia (Berger & Alford, 2009). However, a European study has reported no association between caffeine consumption and cardiac conduction abnormalities (Katan & Schouten, 2005). A health concern has been raised if energy drinks are consumed with alcohol. A recent study has reported a blunted cardiac autonomic control in healthy subjects consuming energy drinks mixed with alcohol (Wiklund et

al, 2009). Although no significant arrhythmias were reported, the authors suggested that individuals who were predisposed to arrhythmias may be at an increased risk for a significant adverse event if they combine alcohol with an energy drink.

A recent review article reported that caffeine does not promote ventricular arrhythmia, contrary to popular belief (Katan & Schouten, 2005). One large Danish study with 48,000 participants yielded no association between caffeine consumption and atrial fibrillation. Another recent meta-analysis included 17 studies and concluded that there is a decreased risk for myocardial infarction in moderate caffeine users (Peters et al, 2001). Caffeinated and decaffeinated coffee are rich sources of antioxidants, which have been linked to a number of potential health benefits, including protection against heart disease and type 2 diabetes mellitus (Katan & Schouten, 2005; Peters et al, 2001; Yen et al, 2005).

A concern that energy drinks can increase the risk for dehydration and cause poor athletic performance was raised based on evidence that caffeine can induce diuresis and natriuresis (Riesenhuber et al, 2006). However, in several well-designed studies, caffeine consumption has not been shown to impair hydration, exacerbate dehydration, or impair thermoregulation (Del Coso et al, 2009; Grandjean et al, 2000). The common belief that caffeine leads to dehydration and causes poor athletic performance apparently is not factual (Armstrong, 2002; Armstrong et al, 2005; Fiala et al, 2004). A recent study observed no changes in body fluid indices during 11 days of controlled caffeine ingestion and during exercise on the 12th day (Armstrong et al, 2005; Roti et al, 2006). In chronic consumers (3 and 6 mg/kg body weight per day), acute caffeine ingestion did not alter fluid–electrolyte and physiologic responses during exercise in heat (37.7^0C), when compared to a placebo (Roti et al, 2006).

Some of the adverse health consequences of energy drinks include: Caffeine intoxication, caffeine dependence, caffeine withdrawal, and the combined use of energy drinks and alcohol. Common features of caffeine intoxication include nervousness, anxiety, restlessness, insomnia, gastrointestinal upset, tremors, tachycardia, psychomotor agitation (American Psychiatric Association, 1994) and in rare cases, death (Garriot et al, 1985; Kerrigan & Lindsey, 2005). The symptoms of caffeine withdrawal include headache, begin 12–24 h after the last dose of caffeine (Driesbach & Pfeiffer, 1943; Lader et al, 1996). In addition to headache, other caffeine withdrawal symptoms include tiredness/fatigue, sleepiness/drowsiness, dysphoric mood (e.g., miserable, decreased well-being/contentedness), difficulty concentrating/decreased cognitive performance, depression, irritability, nausea/vomiting, and muscle aches/stiffness (Griffiths et al, 1990; Juliano & Griffiths, 2004).

Additional recent concerns about energy drinks surround issues relating to dependence, withdrawal, and tolerance (Reissig et al, 2009). There is considerable debate whether caffeine can produce a dependence syndrome that is similar to that associated with a narcotic. A few studies have suggested that habitual caffeine users may fulfill diagnostic criteria for substance dependence (Hughes et al, 1998; Oberstar et al, 2002); however, there is no evidence to suggest such behaviors in individuals consuming energy drinks. Caffeine dependency seems to be almost entirely connected to withdrawal symptoms, which peak 28 to 48 hours before decreasing to baseline values in 4 to 7 days (Evans & Griffiths, 1992; Evans & Griffiths, 1999; Greden, 1974). Symptoms such as severe headache, tiredness/fatigue, sleepiness, and irritability are associated with caffeine withdrawal. The main symptom during caffeine withdrawal, frequent and severe headaches, is theoretically caused by vasodilation of cerebral blood vessels (Leonard et al, 1987). In one study, exercise performance significantly decreased 2 to 4 days after caffeine cessation

when a placebo was given; however, acute caffeine ingestion after 2 to 4 days of cessation resulted in performance similar to that achieved before withdrawal (Van Soeren & Graham, 1998).

The issue of tolerance is a major concern for athletes who use energy drinks on a regular basis during their competitive season. Tolerance to caffeine results from repeated exposure. Caffeine tolerance has been associated with increased adenosine receptor activity and a decrease of b-adrenergic activity (Corti et al, 2002; Greden, 1974). Lower caffeine doses are well tolerated by nonusers, who may develop complete tolerance in 5 or 6 days of moderate caffeine intake (Armstrong et al, 2005; Evans & Griffiths, 1992).

One of the big concerns regarding energy drinks is the combined use with alcohol. There is an association between the heavy use of caffeine and the heavy use of alcohol (Istvan, & Matarazzo, 1984; Kozlowski et al, 1993), and the ingestion of energy drinks in combination with alcohol is becoming increasingly popular (O'Brien et al, 2008; Oteri et al, 2007), with 24% of a large stratified sample of college students reporting such consumption within the past 30 days (O'Brien et al, 2008).

Lastly, energy drinks contain approximately 25-30 grams of carbohydrate per 240 mL (8 fluid ounces) serving. A teaspoon of sugar weighs about 4 g, so a typical energy drink contains about 13 teaspoons, or just more than ¼ cup, of sugar. Long-term exposure of the body to excesses of simple sugars is associated with the development of obesity and insulin resistance. Pancreatic beta cells increase insulin secretion in response to this reduction in insulin sensitivity. Over time, in many individuals, the beta cells become unable to secrete sufficient insulin to maintain normal blood glucose levels, leading to the development of diabetes (Tappy et al, 2010).

2.13.1 Summary

The indiscriminant use of energy drinks, especially if more than one serving per day is consumed, may lead to adverse events and harmful side effects. Diabetics and individuals with pre-existing cardiovascular, metabolic, and neurologic disease who are taking medications that may be affected by high glycemic load foods, caffeine, and/or other stimulants should avoid use of energy drinks unless approved by their physician. One can of an energy drink during one session is safe for most healthy individuals. However, excess consumption and consumption with other caffeine-containing beverages or alcohol may lead to adverse effects and possibly death. Ingestion of energy drinks before an event or during training can have serious adverse effects, most notably restlessness and irritability; can increase blood pressure; and may result in dehydration. The long-term effects of energy drinks on the human body have not been established.

2.14 PERCEIVED EXERTION

2.14.1 Ratings of perceived exertion

The perception of physical exertion is defined as the intensity of effort, strain, discomfort, and/or fatigue that is felt during exercise (Robertson & Noble, 1997). At the onset of exercise, physiological, psychological, and symptomatic mediators are integrated to create the sensation of effort, strain, discomfort, or fatigue throughout and effort continuum. The theoretical rationale

underlying the practical application of RPE relies on the functional interdependence of perceived exertion and physiological responses during exercise (Robertson, 2004). The three main effort continua involved in an individual's subjective response to exercise are physiological, perceptual, and performance (Robertson, 2001a). As the intensity of exercise increases, corresponding and interdependent increases occur in performance, perceptual (RPE), and physiological (VO2 and HR) processes (Borg, 1998; Robertson, 2004). Therefore, the relations between the effort continua indicate that perceptual responses provide the same information about exercise performance as physiological responses (Figure 2).

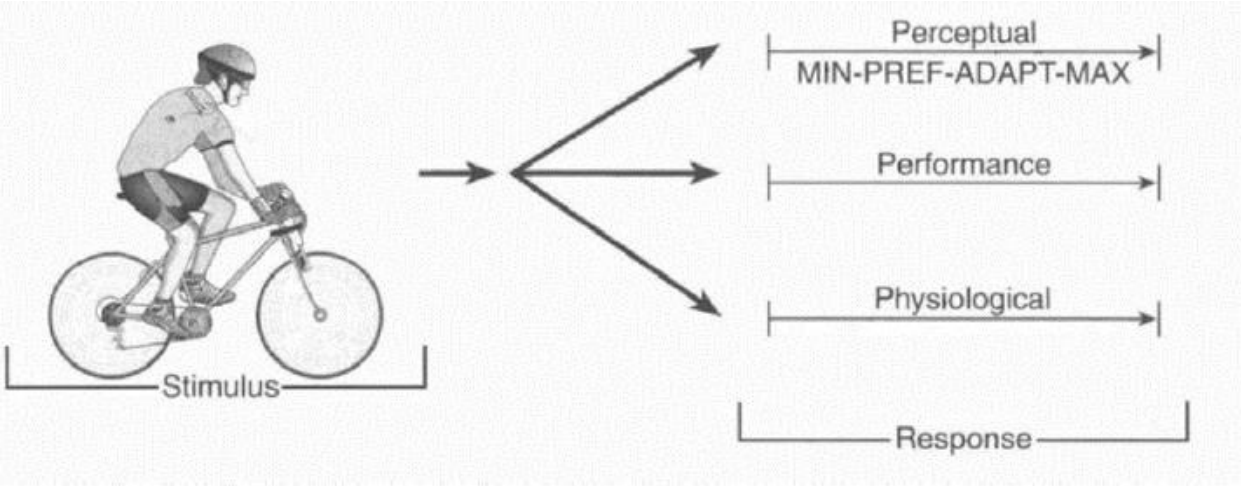

Figure 2. Effort continua model of perceived exertion (Borg, 1998; Robertson, 2004)

2.14.2 Physiological Mediators

Physiological processes that are subjectively monitored and evaluated in clinical, research, and health-fitness settings are important mediators in the application of perceived exertion. The physiological mediators of perceived exertion can be classified into three groups: 1) respiratory-

metabolic, 2) peripheral, and 3) nonspecific (Table 3) (Noble & Robertson, 1996; Robertson, 2004). Pulmonary ventilation (VE), VO2, carbon dioxide production (VCO2), HR, and blood pressure (BP) responses during exercise influence the respiratory-metabolic drive. The composition of localized skeletal muscles in the trunk and exercising limbs, and their contraction efficiency provide the peripheral contribution to the overall exertion signal. The nonspecific mediators of perceived exertion are generalized or systemic physiological responses that occur during exercise that are not directly linked to peripheral or respiratory-metabolic perceptual signals (Noble & Robertson, 1996).

Table 3. Physiological mediators of perceived exertion (Noble & Robertson, 1996; Robertson, 2004)

Respiratory-Metabolic	Peripheral	Non-Specific
Pulmonary Ventilation	Metabolic Acidosis	Hormonal Regulation
Oxygen Uptake	Blood Glucose	Temperature Regulation
Carbon Dioxide Production	Muscle Blood Flow	Pain
Heart Rate	Muscle Fiber Type	Cortisol/Serotonin
Blood Pressure	Free Fatty Acids	Cerebral Blood Flow
	Muscle Glycogen	

2.14.3 Effectiveness in Exercise Intensity Self-Regulation

An investigation by Koltyn and Morgan (1992) examined the effectiveness of using RPE, compared to HR, to monitor exercise intensity during aerobic dance classes in 76 female college students (20.0 ± 4.0 years of age). Subjects attended two 50-minute aerobic dance classes per week for 14 weeks. During these classes, one group regulated exercise intensity using the HRR

method (70 – 85 % HRR) while another group employed the Borg 6 – 20 RPE Scale at an intensity (13 – 15, "somewhat hard – hard") that typically corresponds to 70 – 80% HRR. Endurance performance was assessed by total distance covered during a 15-minute run at baseline, and following the intervention. Subjects in both groups significantly improved endurance performance ($p < 0.001$). However, the greatest improvement was observed in subjects who perceptually regulated exercise intensity (11%) compared to those who utilized the HRR method (6%). Therefore, RPE may be more effective in exercise intensity self-regulation than HR methods in improving health and fitness.

2.14.4 The OMNI scale of perceived exertion

The ACSM recommends the use of either the Borg 6 – 20 RPE Scale, or an OMNI scale to measure the perception of exertion (ACSM, 2010). The OMNI Picture System of Perceived Exertion is one of the latest contributions to the perceived exertion domain. The term OMNI is a contemporary abbreviation for the word omnibus, which refers to a perceptual scale that is applicable over a wide range of individuals and physical activity settings (Robertson, 2004). An OMNI scale includes pictures of an individual exercising at different intensity levels combined with verbal cues arranged along a numerical scale ranging from 0 – 10 (Figure 3).

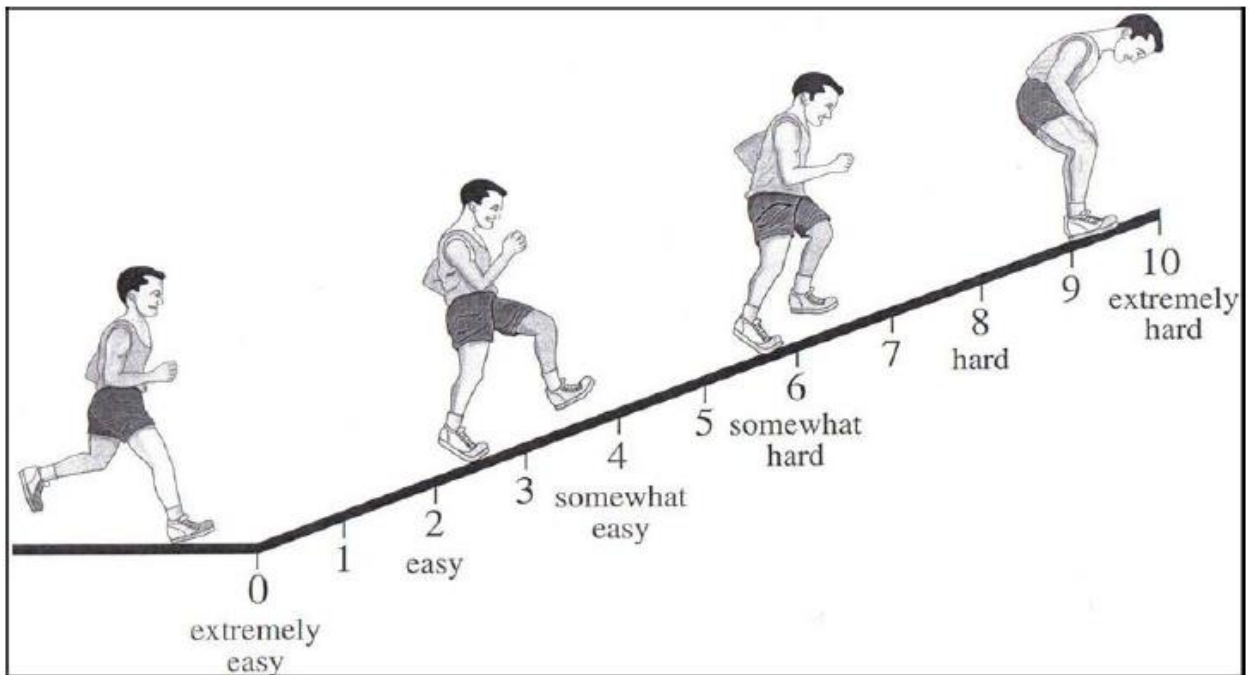

Figure 3. OMNI Scale of Perceived Exertion: Walk/Run RPE-Scale (Robertson, 2004)

There are several advantages of using the OMNI scale over other perceived exertion scales. The numerical range of the scale is narrow, ranging from 0 to 10. This range is similar to the category rating system used by individuals to evaluate most facets of their daily living making the scale easier to understand. The scale also utilizes a single set of verbal cues that are the same for all interchangeable picture cues. Previous perceived exertion scales only included verbal descriptors along a numerical range. The set of interchangeable pictures allows the scale to be used for exercise intensity assessment and prescription in individuals who vary in age, health status, fitness level, and exercise preference. In addition, the last picture on the upper right portion of the scale helps the individual recall a memory of, and improves their sense of maximal exertion. This allows for the individual to establish the high perceptual anchor prior to performing the exercise, and during a submaximal exercise test. Therefore, the OMNI scale has distinct advantages over other RPE scales.

2.14.5 Validation of the OMNI-Walk/Run RPE Scale

Concurrent and construct paradigms are used to establish measurement validity of RPE scales across populations. A concurrent validation paradigm employs a two variable scheme: a) criterion (i.e., stimulus) variable, and b) concurrent (i.e., response) variable (Robertson, 2004). The most common criterion variables used for RPE concurrent validation during aerobic exercise have been HR, VO2, and power output (Robertson, 2004).

The first examination into the validity of the Adult OMNI-Walk/Run RPE Scale was conducted in 2004. Utter et al. (2004) investigated both concurrent and construct validity of the scale in 67 healthy men and women ranging in age from 18 to 36 years of age. Subjects performed a single graded exercise test on a treadmill to determine VO2max. They were asked to provide estimates of the undifferentiated feelings of effort associated with the entire body using both the Borg 6 – 20 RPE Scale and Adult OMNI-Walk/Run RPE Scale, in counterbalanced order, during the exercise test. Validity coefficients between OMNI and the criterion measures %VO2max and HR, were significant for men ($r = 0.86$ and $r = 0.75$, respectively; $p < 0.05$) and women ($r = 0.85$ and $r = 0.84$, respectively; $p < 0.05$). The results also showed a high level of construct validity between the two RPE scales in both men and women ($r = 0.96$ and $r = 0.96$, respectively; $p < 0.01$). Therefore, concurrent and construct validity of the OMNI-Walk/Run RPE Scale was established in healthy young adult men and women.

2.14.6 Session RPE

Session RPE is defined as the post-exercise rating of global exertion experienced during an entire exercise session and was introduced and validated by Foster et al. (2001). The session RPE allows for a single rating of perceived exertion for an entire exercise session, rather than reporting a series of RPE measures during an exercise session. The goal for session RPE is to simplify the monitoring of aerobic and resistance exercise intensity for fitness professionals (McGuigan et al., 2008).

Previous studies regarding the influence of caffeine on perceptual responses have been limited to in-task or acute RPE (i.e. responses during exercise). In addition to other applications of RPE, Kilpatrick et al. (2009) suggested that predicted feelings of effort before exercise or post-exercise ratings may be an effective way to improve physical activity adoption and maintenance. While original applications of RPE were limited to intensity estimations during exercise, session RPE is obtained 5–30 min following termination of an exercise bout and is a subjective estimation of the difficulty of the entire exercise bout. Various mediating factors have been identified with respect to session RPE including a hot (vs. cold) environment and also elevated blood lactate in response to interval (vs. constant-load) exercise (Green et al. 2007a). Session RPE also has been more closely linked to exercise intensity than duration (Green et al. 2009, 2010). While the effects of caffeine on acute RPE are well established (Jackman et al. 1996; Birnbaum and Herbst 2004; Doherty and Smith 2005; Green et al. 2007b; Hudson et al. 2008; Warren et al. 2010), very few investigations have examined the potential influence of caffeine on session RPE.

In one such investigation, Killen et al (2013) examined fifteen individuals of varying aerobic fitness levels. Subjects completed a VO_2 max trial and two 30 min cycling bouts (double-blind, counterbalanced) following ingestion of 6 mL/kg of caffeine or matched placebo. RPE overall, legs and breathing were estimated every 5 min and session RPE was estimated 30 min post-exercise using the OMNI pictorial scale. Caffeine ingestion resulted in a significantly lower session RPE and acute perceptual responses ($p < 0.05$) for caffeine (6.1 ± 2.2) versus placebo (6.8 ± 2.1). The authors concluded that caffeine ingestion resulted in a decreased acute RPE during exercise which could partially have accounted for a lower session RPE response. Also, a decreased session RPE could also reveal a latent analgesic effect of caffeine that extends into recovery.

2.14.7 Caffeine and Perceived Exertion

The majority of the literature reveals attenuated RPE in response to caffeine. In a review article, Doherty and Smith (2005) examined 21 studies, and data revealed lower RPE during prolonged constant-load exercise, and this effect explained 29% of the improved performance with caffeine intake. However, they reported that RPE is unaltered during exhaustive exercise when assessed at exercise termination, such as at the end of a VO2max test when maximal HR and cardiac output are attained. The trend for a reduced RPE with caffeine ingestion, suggests that caffeine may elicit a central nervous system effect by reducing the perception of effort and fatigue.

Previous research has shown a reduction in RPE with higher doses of caffeine (5 mg/kg body weight) after treadmill running at 70% VO2max (Birnbaum & Herbst, 2004) and cycling at 80% VO2max (Bell & McLellan, 2002). Also, Ivy et al. (1979) 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 compared with placebo, 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. 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 (Gambert et al., 1981; Laurent et al., 2000). In this regard, Laurent et al. (2000) reported that after 2 hr of cycling to exhaustion, plasma β-endorphin levels were significantly elevated when participants consumed 6 mg caffeine/kg body weight 90 min before exercise.

Another study by Umana-Alvarado and Moncada-Jiménez (2004) indicated the RPEs in male endurance runners were lower when energy drinks were ingested compared to a placebo (Umana-Alvarado & Moncada-Jiménez, 2004). These blunted RPE values may be due to many factors such as the taste of the beverage, carbohydrate and caffeine concentration. Utter et al. (1999) reported a link between a lower RPE and carbohydrate substrate availability as well as selected hormonal regulation during prolonged running and cycling at 75% VO2max. A lower RPE was in relation to a higher level of carbohydrate oxidation, higher plasma glucose and insulin levels, and lower plasma cortisol and growth hormone levels (Utter et al, 1999). Backhouse et al (2005) reported the influence of regular carbohydrate beverage ingestion on increased feelings of pleasure during and decreased RPE following prolonged cycling. Utter et al. (2002) found that marathoners consuming carbohydrate compared to placebo beverages could

run at a higher intensity, so that no significant difference was observed in RPEs during a competitive race (Utter et al, 2002). Doherty and Smith (2005), demonstrated that caffeine reduces RPE during constant load exercise and upon termination of exhausting exercise and this may partly explain the subsequent ergogenic effects of caffeine on performance, so that caffeine improved exercise performance by 11.2% (Doherty & Smith, 2005).

2.15 AFFECT

2.15.1 The Feeling Scale

Rejeski and colleagues (1987) developed the Feeling Scale to measure affective responses during exercise. The scale is not designed to measure various categories of emotion. Rather, the Feeling Scale is used to differentiate between feelings along the continuum of core emotions: pleasure or pleasantness versus displeasure or unpleasantness (Frijda, 1988) related to the exercise experience. The Feeling Scale is an 11-point bipolar metric with numbers ranging from -5 to 5. Verbal descriptors situated at each odd integer range from 'Very bad' (at -5), representing maximal displeasure, to 'Neutral' (at 0), to 'Very good' (at 5) representing maximal pleasure (Hardy & Rejeski, 1989). Since its development, the Feeling Scale has been widely used to measure the affective response of various subject populations during a variety of exercise situations (Ekkekakis et al., 2004; Ekkekakis et al., 2000; Ekkekakis & Petruzzello, 2002; Lind et al., 2008; Parfitt et al., 2006). In addition, previous research has found the Feeling Scale to be

significantly correlated with other self-reported measures of pleasure (Hardy & Rejeski, 1989) (Figure 4).

Figure 4. Feeling Scale

2.15.2 Affect in relation to exercise intensity

Exercise intensity has a profound influence on affect, but the relation between exercise intensity and affect is not completely clear. Kirkcaldy and Shephard (1990) proposed that moderate intensity exercise produces an optimal affective response. High exercise intensities may have detrimental effects on the affective response. This produces an inverted-U relationship, with the affective response beginning, most likely, at a level approximating 0 (neutral) on the Feeling Scale during low-intensity exercise, increasing into the positive zone during moderate-intensity

exercise, and then decreasing past the neutral zone into the negative zone during high-intensity exercise. However, there is also evidence refuting this relation. Tate and Petruzzello (1995) found that high-intensity exercise programs can lead to positive changes in affect, while Ekkekakis and colleagues (2000) found that low-intensity exercise programs can improve affect.

A dose response relationship has been shown between intensity and affect (Ekkekakis et al, 2011), in that workloads below the lactate (ventilatory) threshold do not negatively impact affect, yet at higher intensities, affect is typically reduced. At these supra-threshold intensities, a steady-state does not occur, blood lactate concentration rises, and there is a greater reliance upon oxygen-independent metabolism.

2.15.3 Caffeine and Affect

Traditionally, dimensions of affect have not been assessed in nutritional manipulation studies. Instead, the focus has been on "what" a person feels, as measured by the Rating of Perceived Exertion (RPE) scale (Borg, 1982). Alternatively, those few studies that have adopted a more encompassing subjective assessment (e.g., Welsh, Davis, Burke & Williams, 2002) have focused on the assessment of distinct variables, namely the six mood states (i.e., tension, depression, anger, vigor, fatigue and confusion) tapped by the Profile of Mood States (POMS) (McNair, Lorr & Droppleman, 1981). There is very little research on caffeine's influence on the dimensions of affect during exercise. Backhouse et al. (2011) required male cyclists to exercise for 1.5 h at 70% VO_2max after ingestion of caffeine (6 mg/kg body weight) or placebo. Continuously during exercise, RPE was assessed using the Borg 6–20 scale and affect was measured using the Feeling Scale and Felt Arousal scale. During exercise, pleasure ratings were better maintained in the

caffeine trial compared to the placebo trial with significantly higher ratings at 15, 30 and 75 min. The authors concluded that based on the results from this study a moderate dose of caffeine ingested 1 h prior to exercise maintains a more positive subjective experience during prolonged cycling. This observation may partially explain caffeine's ergogenic effects. In another study, Acevedo et al. (1996) demonstrated that a favorable affective state benefited prolonged running performance. In addition, these scales were previously used in a carbohydrate manipulation study (Backhouse et al, 2007) in which arousal was amplified with CHO intake. Data revealed a caffeine-mediated reduction ($p < 0.05$) in RPE during exercise compared to placebo, as well as a significant elevation in pleasure, yet arousal was unaffected.

2.16 CONCLUSION

Although energy drinks contain a number of nutrients that are purported to affect mental and/or physical performance, the primary ergogenic nutrients in most energy drinks appear to be carbohydrate and/or caffeine. The ergogenic value of caffeine on mental and physical performance has been well-established but the potential additive benefits of other nutrients contained in energy drinks remains to be determined. Consuming energy drinks 10-60 minutes before exercise can improve mental focus, alertness, anaerobic performance, and/or endurance performance. The consumption of energy drinks has increased markedly in recent years. Regulation of energy drinks in the U.S. has been poor up to this point. The absence of regulatory oversight has resulted in aggressive marketing of energy drinks, targeted primarily toward young adults, for psychoactive, performance-enhancing and stimulant drug effects. Many energy drinks

contain numerous ingredients; these products in particular merit further study to demonstrate their safety and potential effects on physical and mental performance. Athletes should consider the impact of ingesting high glycemic load carbohydrates on metabolic health, blood glucose and insulin levels, as well as the effects of caffeine and other stimulants on motor skill performance. Children and adolescents should only consider use of energy drinks with parental approval after consideration of the amount of carbohydrate, caffeine, and other nutrients contained in the energy drink and a thorough understanding of the potential side effects. Indiscriminant use of energy drinks, especially if more than one serving per day is consumed, may lead to adverse events and harmful side effects. Diabetics and individuals with pre-existing cardiovascular, metabolic, and neurologic disease who are taking medications that may be affected by high glycemic load foods, caffeine, and/or other stimulants should avoid use of energy drinks unless approved by their physician.

3.0 METHODS

3.1 EXPERIMENTAL DESIGN

This study followed a randomized double-blind, crossover design where subjects was randomized to supplement with regular Red Bull (500 ml) or placebo 60 minutes before exercise, separated by a 7-day washout period. Exercise testing sessions was separated by 7 days to ensure adequate recovery between subsequent tests and to allow adaptation to caffeine withdrawal before the next testing session. Each subject underwent 3 days of testing: 1) Orientation session and VO_2max test; 2) Experimental Trial I; 3) Experimental Trial II. Exercise testing occurred at the same time each day at room temperature (19-21^{0}C). During the first visit to the laboratory, subjects performed an incremental VO_2max test to exhaustion on a motorized treadmill. Two to three days after the VO_2max trial, subjects were randomly assigned to supplement with regular Red Bull or placebo 60 minutes before performing a running 5-km time trial. One week after the initial supplementation and testing trial, subjects returned to the laboratory and ingested the opposite supplement drink and performed the same test. Variables that was measured are (a) 5-km running time, (b) RPE, (c) heart rate (d) affect, (e) session RPE, (f) session affect and (g) the distance covered at each 5 min interval during the 5-km time trial. Because acute caffeine ingestion has been purported to influence a range of physiological, psychological, and performance variables (Astorino & Roberson, 2010) (Ganio et al, 2009) (Graham, 2001), the

experimental design used was designed to examine the effect of the independent variable (Energy drink vs. Placebo ingestion) on the following dependent variables that prior authors have suggested are influenced by caffeine ingestion (Astorino & Roberson, 2010) (Beck et al, 2008): 5-km time trial, heart rate, affect, RPE, session RPE and session affect. All testing took place within the institutions Human Energy Research Laboratory.

3.2 SUBJECTS

Eighteen recreational distance runners were asked to participate in this study. Subjects were recruited from local running clubs and also by advertising within the local community. Inclusion criteria included the following: 1) active males and females who are capable of completing a 5-km running distance under 30 minutes; 2) currently run a minimum of 20 miles per week; 3) between the ages of 18 and 35 years. Exclusion Criteria included the following: 1) Subjects who are pregnant; 2) smoke; 3) have any known metabolic or cardiovascular disease, 4) presence of any orthopedic, musculoskeletal, neurological, and/or any medical conditions that prohibit exercise; 5) and/or psychiatric disorder. Subjects were also required to be free of any ergogenic aids for one month preceding the study, and were asked to refrain from taking any additional supplement(s) during the course of the study.

Subjects were asked to not change their regular training and dietary habits for the duration of the study, and they were asked to not exercise prior to testing. Subjects were asked to refrain from caffeine and alcohol for 48 hours, physical activity for 24 hours, and food and drink for 3 hours before each exercise test. The participants were instructed to maintain a training and

dietary log for 2 days before the first experimental trial. They were provided with a copy of their log and instructed to have the same dietary intake and activity during the 48 hours before their second trial. In addition, participants were instructed to keep their caffeine consumption stable throughout the period of study participation (Ivy et al, 2009). Subjects were provided with a habitual caffeine consumption questionnaire before the experimental testing began.

Subjects were screened for health problems using the medical history/Physical Activity Readiness Questionnaire (PAR-Q) to determine eligibility. These questionnaires assess an individual's readiness for participation in exercise training programs and included questions related to heart conditions, angina at rest or during physical activity, balance and bone or joint problems that may affect exercise performance. All subjects were informed of the possible participation risks before providing their written informed consent.

3.3 RECRUITMENT

Subjects were recruited from the local running clubs and also by advertising within the local community. Interested individuals were instructed to contact the Center for Exercise and Health-Fitness Research (CEHFR) and were interviewed over the phone by the Principal Investigator to determine initial eligibility. This screening included a brief description of the individual's respective study of interest, and eligibility was determined by responses to questions relevant to inclusion and exclusion criteria. Potential subjects who appeared to be eligible, based on the phone screening, was invited to attend an orientation session where the Principal Investigator provided complete details of the respective study. Individuals were encouraged to ask questions

during this session so they had full knowledge of the study protocols and expectations. If they met preliminary screening and inclusion criteria, and agreed to participate, potential subjects were asked complete a written informed consent to participate in the study, complete a Physical Activity Readiness Questionnaire (PAR-Q) (APPENDIX A) (Thomas et al., 1992), and a medical history form (APPENDIX B). Subjects were informed of their right to withdraw from participation at any time during the investigation.

3.4 EXPERIMENTAL PROCEDURES

This investigation consisted of an orientation/VO_2 max session and two Experimental Trials I and II (See Figure 5).

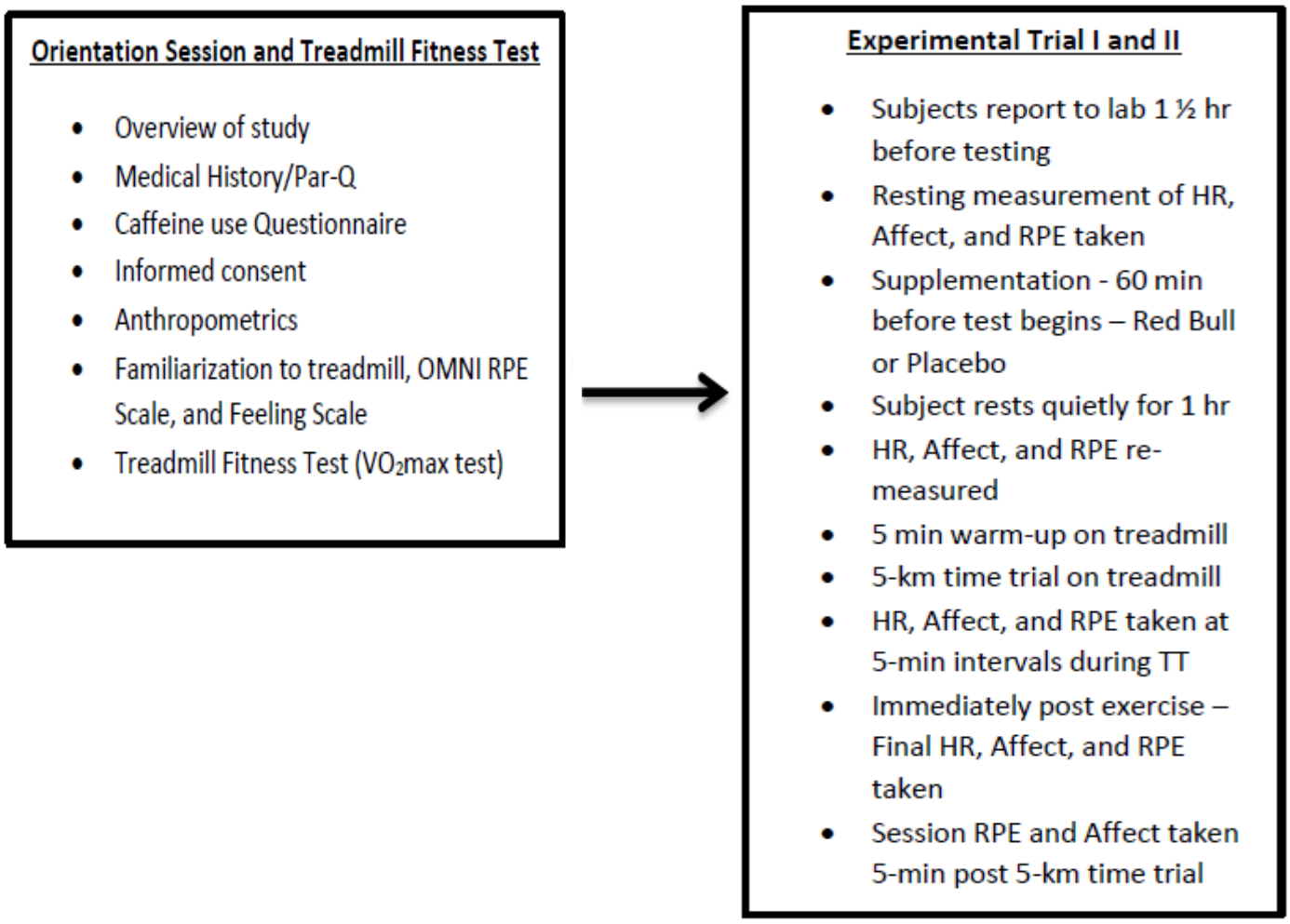

Figure 5. Experimental Design

3.4.1 Orientation Session and Treadmill Fitness Test (VO_2max trial)

During the orientation session, participants were allocated to a treatment regimen by counterbalancing the order of the treatments across the two experimental trials. This was done using a random number generator to ensure randomization. During the orientation session, subjects were provided with an overview of the study. Subjects completed the PAR-Q (Appendix A) as well as a medical history questionnaire (Appendix B) in order to be screened for eligibility to participate. If the medical history questionnaire indicated any contraindications to exercise testing or subjects answered "yes" to any of the PAR-Q questions they were excluded from the study. Subjects were also provided with a habitual caffeine consumption questionnaire before the experimental testing began in order to assess each subject's daily average caffeine intake (Appendix F). Potential risks and benefits, along with the study rationale was explained. Informed Consent was obtained during the orientation session. Subjects were encouraged to ask any questions regarding participation in the study. All subjects were asked to wear standardized athletic clothing (lightweight and comfortable) and running shoes during the subsequent experimental trials.

The subjects undergone an orientation to the treadmill to practice running, as well as to familiarize them with the equipment. Subjects were also familiarized with the OMNI Perceived Exertion Scale and Feeling Scale to be used in all experimental trials. Following the orientation session, anthropometric measures was obtained including height (cm), weight (kg), fat free mass (kg) and fat mass (% and kg). Height (cm) was measured using a physician's scale. Weight (kg) and body composition was measured using a Tanita bioelectrical impedance analyzer (BIA) (TBF-310GS Tanita Corporation of America, Arlington Heights, Illinois). BIA determines

opposition to the flow of an electric current through body tissue, for estimation of total body water, fat-free body mass, and % body fat (Wolff, 1956). Subjects were asked to remove all jewelry in addition to socks. All BIA testing were conducted in "Athletic" mode because of characteristics of the testing sample.

Following the assessment procedures, subjects then performed an incremental test to exhaustion on a motorized treadmill (VO_2max test). The treadmill was calibrated before each exercise test according to the manufacturer's instructions. All measurements of total body oxygen consumption (VO_2) and carbon dioxide production (VCO_2) was performed using a metabolic measurement system (TrueOne 2400, ParvoMedics, Sandy, UT) calibrated prior to each exercise test using standard calibration gases (16% O_2, 4% CO_2, nitrogen balanced). Before getting on the treadmill, the facemask was fitted on the subject to enable measurement of VO_2. In addition, the subject was fitted with a heart rate (HR) monitor (Polar Electro, Kempele, Finland). The heart rate monitor was applied to the subject at the level of the xiphoid process to ensure a quality heart rate signal. Prior to exercise, the subject stood quietly on the treadmill for 2 minutes so that resting measurements of VO_2 and HR could be acquired. Subjects breathed through a respiratory mask for the duration of the exercise test. Expired air was collected and analyzed (O_2 and CO_2) breath-by-breath though a 2-way valve using a calibrated metabolic cart. Concentrations of O_2 and CO_2 was analyzed by open circuit spirometry in 15-second intervals. After obtaining resting values of heart rate (HR), oxygen consumption (VO_2) and carbon dioxide production (VCO_2) the modified Astrand treadmill protocol began (Pollock et al, 1978). After a thorough explanation of the experimental procedures, each subject was instructed to start walking for 3 min as a warm-up at a self-selected speed (0% grade). As soon as the 3-min warm-up session was completed, the speed was increased to 5–8 mph for 3 min (0% grade) according

to the subjects' comfortable running pace. After 3 min at 0% grade running, the grade was increased 2.5% every 2 min throughout the session while speed was kept constant until exhaustion was reached (i.e., subject reached a volitional end point). To ensure that a physiologically valid VO_2max has been obtained the following criteria was used: (a) a plateau in VO_2 with increasing exercise intensity (< 150 ml/min or < 2.1 ml/kg/min), (b) a respiratory exchange ratio (RER) of ≥ 1.1, (c) and attainment of ± 5 beats/min of the subjects' age predicted maximum/peak heart rate, (d) a Omni-RPE of > 9, (e) and volitional termination due to exhaustion. Immediately following termination, the mouthpiece and nose clips was removed from the subject. At the completion of the test, subjects were allowed a cool-down period at 2.0 km/hr^{-1} and 0% grade for three minutes, or until heart rate decreased to < 110 $beat/min^{-1}$. Heart rate and RPE (RPE-O; RPE-C; RPE-L) were recorded during the final 15 seconds of each 3-minute stage during the exercise test. In addition, the final 30-second average VO2 of each completed 3-minute exercise stage was recorded. Staff were instructed to discontinue testing if at any time subjects showed signs of dizziness, pain, nausea, undue fatigue, or any other physical/psychological symptoms of exercise intolerance. If an abnormal response occurred during assessments or exercise, the test was immediately discontinued and the subject given proper medical attention. Emergency equipment was on site for all testing procedures.

3.5 EXPERIMENTAL TRIAL I AND II

Two to three days after the VO_2max trial, subjects underwent the first experimental trial (regular Red Bull or placebo). All experimental trials took place at the same time of day to avoid

circadian variation (Atkinson & Reilly, 1996). Each testing session was separated by one week to ensure adequate recovery between subsequent tests, and to allow adaptation to caffeine withdrawal before the next exercise bout. The participants were instructed to report to the laboratory 1 1/2 hours before experimental testing. During this time, resting measurements of heart rate, affect and RPE was taken. Subjects were fitted with a heart rate (HR) monitor (Polar Electro, Kempele, Finland). The heart rate monitor was applied to the subject at the level of the xiphoid process to ensure a quality heart rate signal.

The subjects then ingested one of the two treatments: Placebo (500 ml of artificially sweetened water) or Red Bull (500 ml drink, 160 mg caffeine). The beverages were served cold (~6 °C) and was administered to the subject 60 minutes before the test will begin. The subjects were instructed to drink the beverage within 2 minutes of receiving it. Treatments were consumed 60 minutes before each exercise trial because plasma caffeine concentration is maximal one hour after ingestion of caffeine (Graham, 2001; Fredholm et al, 1997), and several studies have shown an ergogenic effect from caffeine ingestion 60 minutes before exercise (Forbes et al, 2007; Jenkins et al, 2008). Each treatment was presented to participants in an opaque sports bottle to prevent the researchers who administered the treatments or the participants consuming the treatments from actually seeing the treatments themselves. After consumption of the beverage, the participants were instructed to sit quietly for one hour. One hour post-ingestion, resting heart rate, affect and RPE were re-measured. Heart rate, RPE (RPE-O; RPE-C; RPE-L; using the adult OMNI walk/run scale), and affect (Feeling Scale) was recorded at rest, 1-hr post ingestion, at 5-minute intervals during the 5-km time trial, and immediately post exercise.

Exercise performance was evaluated with a self-paced 5-km treadmill time trial, which has been shown to correspond with comparable, although slightly greater, performance times as those obtained during a competitive outdoor 5-km track run (Hopkins et al, 2001). Furthermore, the 5-km treadmill time trial has been shown to have better reproducibility than time-to-exhaustion tests of performance (Currell & Jeukendrup, 2008; Laursen et al, 2007). The subjects then began a warm-up run of approximately 5 min on the treadmill before the start of the 5-km time trial. Following the completion of the 5 min warm-up run, the treadmill was brought to a standstill (0 mph). At this time stopwatches/timers was reset, the distance covered on the treadmill monitor was reset, a 5-s count down was given and the 5-km time trial began (Bell et al, 2002). The subjects were told to finish the 5-km run as fast as possible. Subjects performed the 5-km time trial on a motorized treadmill at 0.0% gradient. The treadmill was maintained and calibrated in accordance to the manufacturer guidelines. Participants were only provided with feedback on the distance (at regular 500-m intervals) covered during each 5-km time trial and were not informed of the overall performance time until the completion of the final testing session. Heart rate, RPE (RPE-O; RPE-C; RPE-L; using the adult OMNI walk/run scale), and affect (Feeling Scale) were recorded at 5-minute intervals during the 5-km time trial. During the 5-km time trial, participants adjusted their pace via control buttons located on the treadmill. Since the speed indicator was concealed from the participants view the speed was determined by their own perceived exertion of the intensity of the exercise and their subjective feeling of their running capabilities. Participants were familiarized on how to adjust speed during the warm-up for each session and were permitted to adjust their speed how and whenever they saw fit during the time trial. Subjects were instructed to run as fast as possible and were provided with verbal encouragement during the run (at regular 5-min intervals). Immediately upon cessation of

exercise, subjects estimated their perceived exertion according to the OMNI RPE scale; affect measured by the Feeling scale and a final heart rate measurement was taken. Lastly, a rating of perceived exertion and affect for the entire exercise session (session RPE and session affect) was obtained 5 minutes following the 5-km time trial.

Neither the participants nor the investigators were aware of which participants are on the placebo or energy drink treatment. The two treatments were similar in color, taste, and texture and will was randomly distributed by a laboratory technician not involved in the data collection. Consistent verbal encouragement was given to the participants during each trial. The verbal encouragement was kept consistent from trial to trial by using a "script" (APPENDIX G). During each run participants were not aware of how long they have run, because all timing devices will be removed from their sight.

3.6 SUPPLEMENTATION

Participants consumed 500 ml of an commercially available energy drink (Red Bull), the equivalent of two cans of Red Bull energy drink, which contains the minimum average amount of caffeine found to be effective (Graham & Spriet, 1995). The placebo condition consisted of 500 ml of an artificially colored, flavored, and carbonated-water placebo (0 mg caffeine, 0 kcals). The concentration of ingredients in the 500 ml of energy drink consisted of 2.0 g Taurine, 1.2 g Glucuronolactone, 160 mg caffeine (equivalent to about two cups of coffee), 54 g carbohydrates, 40 mg niacin, 10 mg pantothenic acid, 10 mg vitamin B6, and 10 µg vitamin B12. Regular Red Bull and placebo was similar in volume, texture, taste and appearance. Supplements

were ingested cold (~6 °C) 1 hour before exercise in the presence of a researcher. The Red Bull dose (500 ml) was chosen for the present study because this dose has shown to increase exercise performance (Ivy et al, 2009) without resulting in adverse side effects in young adults (Forbes et al, 2007). Regular Red Bull energy drink ingestion occured 60 minutes before exercise because peak plasma caffeine concentrations are maximized at this time (Graham, 2001; Graham & Spriet, 2005), and several studies have shown an ergogenic effect from caffeine ingestion 60 minutes before exercise (Forbes et al, 2007; Malek et al, 2006).

3.7 DATA COLLECTION AND INSTRUMENTATION

The following measures were used to describe the sample and collect performance measures:

1. Height: Height (cm) was measured using a Detect-Medic Balance Scale and attached stadiometer (Detecto Scales, Inc., Brooklyn, NY). Height was recorded to the nearest 0.25cm.
2. Weight: Body weight (kg) was measured using a Tanita bioelectrical impedance analyzer (BIA) (TBF-310GS Tanita Corporation of America, Arlington Heights, Illinois). Subjects were instructed to wear light-weight exercise clothes consisting of shorts and a T-shirt. The subjects did not wear shoes or socks during body weight measurement. Body weight was recorded to the nearest 0.5kg.
3. Body Composition: % lean body mass (kg) and % body fat (kg) was measured using BIA procedures (TBF-310GS the Tanita Corporation of America, Arlington Heights, Illinois). Subjects were instructed to wear light-weight exercise clothes consisting of shorts and a

T-shirt. The BIA is a non-invasive pain-free procedure for assessing body composition in which a low-grade electrical impulse is transmitted through the body. The resistance to current flow through tissues reflects the relative amount of fat percent (Wilmore, 1999). After height and weight have been entered and shoes and socks have been removed, subjects stood on the Tanita scale for approximately 10 seconds to obtain body composition. Body fat was recorded to the nearest 0.1% and 0.5kg using the athletic setting.

4. Treadmill: A Trackmaster TMX425C treadmill (Newton, KS) was utilized to administer the graded exercise test and the 5-km time trials.
5. Indirect Calorimetry: An open circuit respiratory-metabolic system (Parvo Medics TrueMax 2400 metabolic system, Salt Lake City, Utah) was used to measure the following: Oxygen consumption (VO2;L·min-1 and ml·kg-1·min-1), carbon dioxide production (VCO2), pulmonary ventilation (Ve;L·min-1), and RER. Measurements were made every 30 s during the VO_2max test. A standard facemask was used for all respiratory-metabolic measurements. The respiratory-metabolic system was calibrated using gases of known concentrations before each exercise protocol according to the manufacturer specifications.
6. Heart Rate: Heart rate (beats·min-1) was measured during the last 30 s of each minute of exercise during the graded exercise test using a wireless Polar Monitoring System (Woodbury, NJ). A Polar transmitter belt was fitted to the subject's chest, just below the pectoralis major muscles. A Polar monitor was attached to the treadmill to record the HR responses. Heart rate was recorded at rest (pre-ingestion), 1-hr post ingestion, at 5-minute intervals during the 5-km time trial, and immediately post exercise.

7. Ratings of perceived exertion: Subjective ratings of perceived exertion was recorded by using the adult OMNI walk/run RPE scale (Utter, 2004). RPE was obtained at the same time points as heart rate. Each subject was read the definition of RPE, and standard instructions (APPENDIX C) on how to use the Adult OMNI-Walk/Run RPE (Utter et al., 2004; Robertson, 2004) (Figure 3) scale prior to performing the graded exercise test and experimental trials. During the exercise tests, subjects were asked to rate their feelings of exertion corresponding to their entire body (RPE-Overall, RPE-O), legs (RPE-Legs, RPE-L), and chest (RPE-Chest, RPE-C). Defined as "the subjective intensity of effort, strain, discomfort and/or fatigue that is felt during exercise" (Robertson, 2004), ratings of perceived exertion (RPE) have been determined to be both reliable and valid (Robertson, 2004). Measurement of RPE involves using numerically based category scales that allow a subject to select a number that corresponds to the intensity of their perception of physical exertion. Subjects were familiarized to the scale during the orientation session and prior to each experimental trial.
8. Affect: The Feeling scale was used to measure affective response during exercise. The Feeling Scale is an 11-point bipolar metric with numbers ranging from -5 to 5. Verbal descriptors situated at each odd integer range from 'Very bad' (at -5), representing maximal displeasure, to 'Neutral' (at 0), to 'Very good' (at 5) representing maximal pleasure (Hardy & Rejeski, 1989). Affect was obtained at the same time points as heart rate and RPE. Each subject was read the definition of affect, and standard instructions (APPENDIX E) on how to use the Feeling scale (Figure 4) prior to each exercise test.
9. Session RPE and Affect: A session rating is a nominal rating that is given by an individual to describe the perceived exertion or affect associated with an entire training

session. It involves asking the subject to give a rating of the perceived exertion or affect for the entire exercise session after the conclusion of exercise. Session RPE and session Affect were obtained 5 minutes following completion of the 5-km time trial. The session RPE was obtained by using the adult OMNI walk/run RPE scale while the session affect measurement was taken using the feeling scale.

3.8 VARIABLES

The independent variable in this study was type of supplement consumed (Red Bull energy drink or Placebo). Dependent variables in this study included: 1) 5-km running time; 2) Heart rate; 3) Affect measured by the Feeling scale; 4) ratings of perceived exertion for the entire body (RPE-Overall, RPE-O), legs (RPE-Legs, RPE-L), and chest (RPE-Chest, RPE-C) measured with the adult OMNI walk/run scale; 5) Session RPE; 6) Session Affect; and 7) the distance covered at each 5 min interval during the 5-km time trial. Dependent measures of performance and perceived exertion were conducted at rest, 1-hr post supplement ingestion, during, and following the experimental trial. Session RPE and affect were obtained 5 minutes following the completion of the 5-km time trial.

3.9 STATISTICAL ANALYSIS

Statistical analyses were performed using SPSS version 22.0. Statistical significance was set *a priori* at $p < 0.05$. Descriptive statistics were calculated for all variables. Data were tested for normality. If data were not normally distributed, a Wilcoxon signed ranks test was used. The assumption of normality of the residuals was tested using the Shapiro-Wilk test. Performance data (5-km running time), mean exercise heart rate, affect, RPE-Chest, RPE-Legs, RPE-Overall, Session RPE and Session affect were analyzed using a paired samples t-test. A 2 x 5 (condition x time during the 5-km time trial) repeated measures analysis of variance was conducted to assess the effect of time, treatment, and interaction between time and treatment, on heart rate, affect, RPE-Chest, RPE-Legs, RPE-Overall, and distance covered at each five minute interval during the 5-km time trial. *Post hoc* analyses were conducted where appropriate using the Bonferonni adjustment to determine which conditions were significantly different. The assumption of sphericity was confirmed using Mauchly's test. Greenhouse-Geisser epsilon corrections were used when the sphericity assumption was violated. In addition, the relationship between caffeine intake (mg/kg Body Weight) and 5-km performance was evaluated by calculating the Pearson's correlation. The appropriate nonparametric tests were used for all data not meeting the assumption of normality.

3.10 POWER ANALYSIS

Based on an article by Ivy and colleagues (2009), the following was used *a priori* to determine statistical power: a repeated measures design with 1 between factor (B1), 1 within factor (W1), 2 groups with 9 subjects each for a total of 18 subjects. Each subject is measured 2 times. This design achieved an 83% power to test the B1*W1 interaction if a Regular F Test is used with a 5% significance level and the actual effect standard deviation is 25.000 (an effect size of 0.7). Therefore, a final sample of 18 participants was recruited to undergo the experimental trials.

4.0 RESULTS

The purpose of this study was to evaluate physiological and perceptual responses to exercise performance of recreational endurance runners after they ingested a commercially available energy drink (Red Bull) containing caffeine, glucose, and Taurine. This study utilized a randomized crossover design and the results from the study are presented in the following sections.

Based on the potential ergogenic properties of caffeine, it was hypothesized that acute energy drink ingestion would improve 5-km time trial running performance and cause perceived exertion (RPE) to be equivalent to the placebo condition. It was also hypothesized that the subjects in the energy drink condition would experience more pleasure when performing the 5-km time trial in comparison to the placebo group as evidenced by their Feeling scale rating. Furthermore, it was hypothesized that energy drink ingestion would result in a greater mean heart rate response during the 5-km time trial in comparison to the placebo group. Finally, it was hypothesized that energy drink supplementation would result in a comparatively greater attenuation of perceived exertion and affect for the entire exercise session (Session RPE and Session Affect) when compared to the placebo condition.

4.1 SUBJECTS

Telephone screening calls were conducted for a total of 31 individuals. Of these participants, 20 were deemed to be eligible based on the criteria reported previously. The primary reason for exclusion were weekly mileage below the criteria (N = 11). A total of 20 healthy recreational male (N = 13) and female (N = 5) distance runners attended a study orientation and consented to participate in this study. However, two participants withdrew from the study resulting in 18 participants (age 20.39 ± 3.27) who consented and completed all the experimental sessions. Participants were recruited from the university and surrounding community. Subject descriptive characteristics (mean ± standard deviation) for the overall sample are included in Table 4.

Before testing, 1 subject was caffeine naïve, 13 subjects reported consuming less than 200 mg caffeine/day, and 4 subjects reported consuming >200 mg caffeine/day. There were no differences in performance variables (5-km time trial performance) between caffeine-consuming subjects and caffeine-naïve subjects or between men and women ($p > 0.05$). There were no side effects reported from the exercise testing or Red Bull energy drink or placebo. Furthermore, this study examined one absolute dosage (500 ml) of the commercially available energy drink Red Bull on performance (2.0 g Taurine, 1.2 g Glucuronolactone, 160 mg caffeine, 54 g carbohydrates, 40 mg niacin, 10 mg pantothenic acid, 10 mg vitamin B6, and 10 µg vitamin B12). This resulted in participants ingesting doses of caffeine in the range of 1.5-3.9 mg/kg body weight in relative terms (average 2.9 mg/kg body weight of CAF).

Table 4. Descriptive characteristics for participants (N = 18)

Variable	Mean ± SD	Range
Age (years)	20.39 ± 3.27	18 – 31
Height (cm)	178.00 ± 7.57	163 – 191
Weight (kg)	71.25 ± 17.17	51.45 – 131.10
BMI (kg/m^2)	22.29 ± 5.01	17.7 – 40.2
Percent Body Fat	10.4 ± 6.56	2.4 – 24.9
Number of 5k Races	10.39 ± 18.81	0 – 75
Weekly Mileage (miles)	24.17 ± 6.06	20 – 45
Daily CAF Intake (mg)	130.94 ± 98.56	0 – 380
VO_2max (mL/kg/min)	55.94 ± 7.66	42.4 – 65.6

Data are Mean ± SD. CAF = Caffeine

4.2 EXPERIMENTAL TRIALS

All participants were able to successfully complete the entire 5-km time trial for each experimental session. Heart rate, RPE, and Affect were obtained at rest (pre-ingestion), 1-hr post ingestion, at 5-minute intervals during the 5-km time trial, and immediately post exercise. Data collected for heart rate, RPE (Chest, legs and overall) and affect at five minute intervals during the time trial (exercise) were averaged and are reported as means. Results for time trial performance, heart rate, RPE (chest, legs, overall), affect, session RPE and session affect are shown in Table 5. Paired sample t-tests showed that performance times in the ED trial were significantly faster compared to the PLA trial for the 5-km run ($p = 0.016$).

Table 5. Differences in Physiological and Perceptual Data for 5-km Time-Trial Performance (N=18)

Variable	ED	PLA	*P-Value*
TT Performance (s)	1413.2 ± 169.7	1443.6 ±179.2	*0.016*
Mean HR (b/min)	178.8 ± 10.2	179.2 ± 10.3	*0.759*
Mean RPE-O	4.9 ± 1.4	4.9 ± 1.3	*0.969*
Mean RPE-C	4.5 ± 1.5	4.4 ± 1.4	*0.886*
Mean RPE-L	4.9 ± 1.3	5.0 ± 1.3	*0.592*
Mean Affect	0.7 ± 1.7	0.8 ± 1.5	*0.545*
IPE HR (b/min)	189.7 ± 9.1	188.2 ± 11.2	*0.534*
IPE Affect	-2.0 ± 2.7	-2.0 ± 2.8	*1.000*
IPE RPE-L	7.3 ± 2.2	7.4 ± 1.7	*0.707*
IPE RPE-C	7.4 ± 2.1	7.1 ± 1.9	*0.454*
IPE RPE-O	7.6 ± 1.9	7.3 ± 1.8	*0.311*
Session RPE	6.4 ± 1.8	6.6 ± 1.5	*0.495*
Session Affect	-0.3 ± 2.5	0.17 ± 2.3	*0.177*

Data are Mean ± SD. ED = Energy Drink; PLA = Placebo; TT = time trial; HR = Heart Rate; RPE = OMNI Rating of Exertion; IPE = Immediately Post Exercise; RPE-O = Overall; RPE-C = Chest; RPE-L = Legs.

4.2.1 Time Trial Performance

Time to complete the 5-km time trial was significantly improved when the participants ingested 500 ml of the ED one hour before exercise ($p = 0.016$) (Figure 6). The mean 5-km performance time for the ED trial was 1413 ± 169.7 sec. The mean 5-km performance time for the PLA condition was 1443 ± 179.2 sec. Relative to the mean time for the PLA trial, ED ingestion resulted in an average improvement of 30.39 sec (95% confidence interval = 6.39 to 54.38 sec), which translated into a 2.12% improvement in performance. The inter-individual range of improvement was 8 to 95 seconds. Fourteen subjects (78%) performed better when supplementing with the ED (average: 1421 ± 176.6 sec), compared to four subjects (22%) who ran faster on the placebo (average 1350 ± 181.4 sec) (Figure 7). In addition, ten male subjects ran longer when supplementing with the ED (average: 49.7 ± 36.15 sec or 3.6% increase), and four female subjects ran longer with the ED (average: 45.25 ± 28.06 sec or 2.95% increase). Lastly, Participants ingested doses of caffeine (through the energy drink Red Bull) in the range of 1.5-3.9 mg/kg body weight in relative terms (average 2.9 mg/kg body weight of CAF). Comparison of the relationship between caffeine intake (mg/kg body weight of CAF) and 5-km running performance showed a weak correlation of 0.22 ($p = 0.38$).

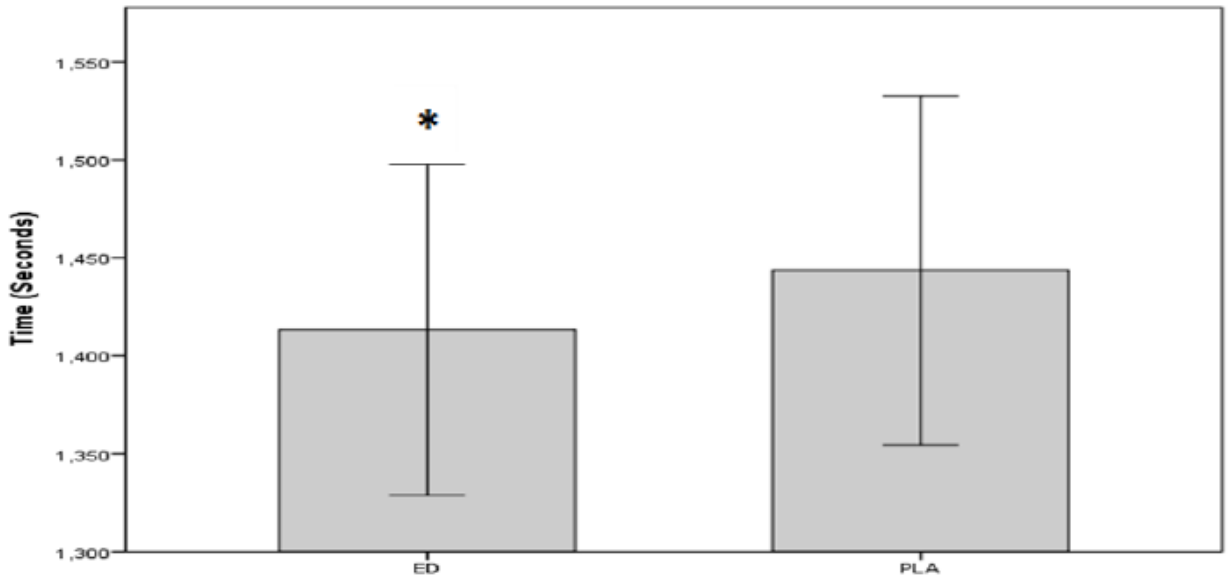

Figure 6. Overall 5-km time trial performance (seconds) for energy drink and placebo (N = 18). Values are means ± SD. *Asterisk* denotes significant difference between conditions. ED = Energy Drink; PLA = Placebo

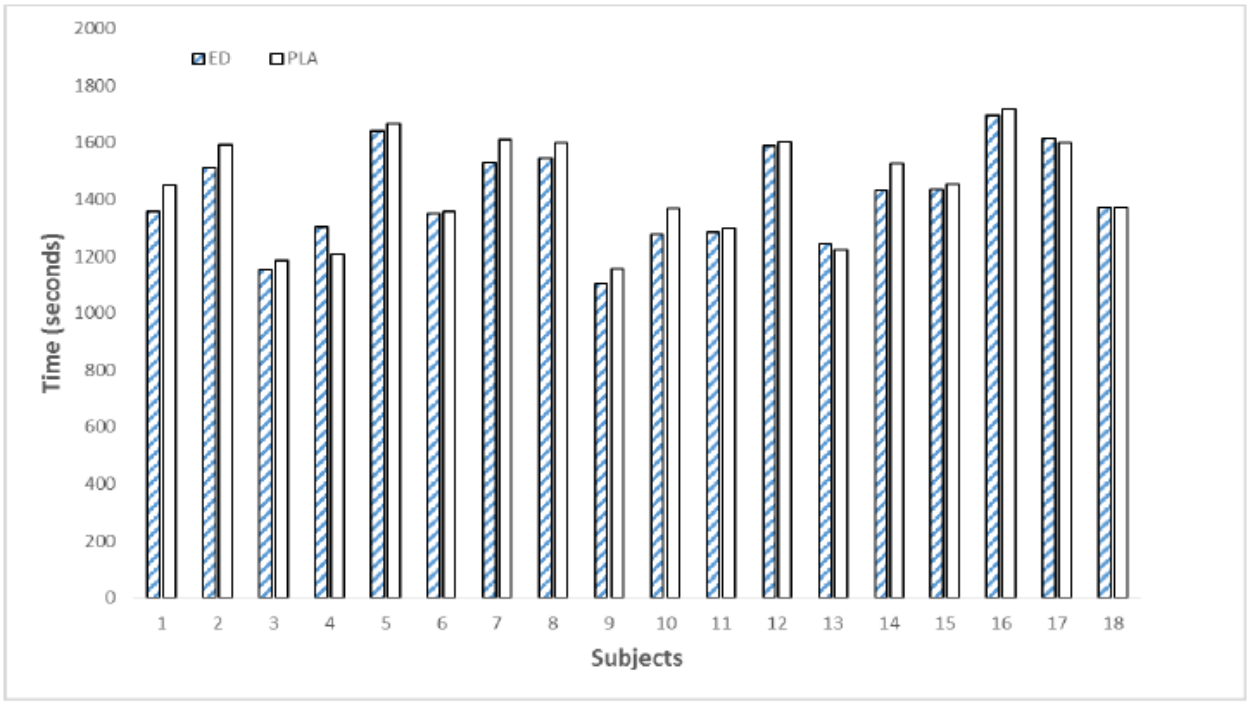

Figure 7. Time-trial times for each participant after ingestion of the energy drink (ED) or placebo (PLA).

4.2.2 Heart Rate

A two-way repeated measures ANOVA was conducted to assess the effects of an ED on heart rate during a 5-km running time-trial. Heart rate was measured at regular five minute intervals during the time-trial. Heart rate increased significantly during exercise ($p < .0001$) but there was no significant effect for treatment ($p = 0.937$) and interaction between time and treatment ($p = 0.568$). Therefore, heart rate increased with exercise but remained similar between treatments (Figure 8). Results from a paired sample t-test showed that there were also no significant differences between treatment groups for mean heart rate (ED: 178.8 ± 10.2 beats/min; PLA: 179.2 ± 10.3 beats/min; $p = 0.759$). At minute five the average heart rate was 171 ± 12.5 beats/min for the ED trial and 171 ± 12.5 beats/min for the PLA trial ($p = 0.983$; $N = 18$). At minute ten the average heart rate was 176 ± 10.8 beats/min for the ED trial and 177 ± 11.3 beats/min for the PLA trial ($p = 0.859$; $N = 18$). At minute fifteen the average heart rate was 181 ± 11.6 beats/min for the ED trial and 182 ± 10.6 beats/min for the PLA trial ($p = 0.642$; $N = 18$). At minute twenty the average heart rate was 182 ± 13.2 beats/min for the ED trial and 184 ± 11.9 beats/min for the PLA trial ($p = 0.355$; $N = 14$). At minute twenty-five the average heart rate was 184 ± 10.8 beats/min for the ED trial and 183 ± 11.4 beats/min for the PLA trial ($p = 0.655$; $N = 6$).

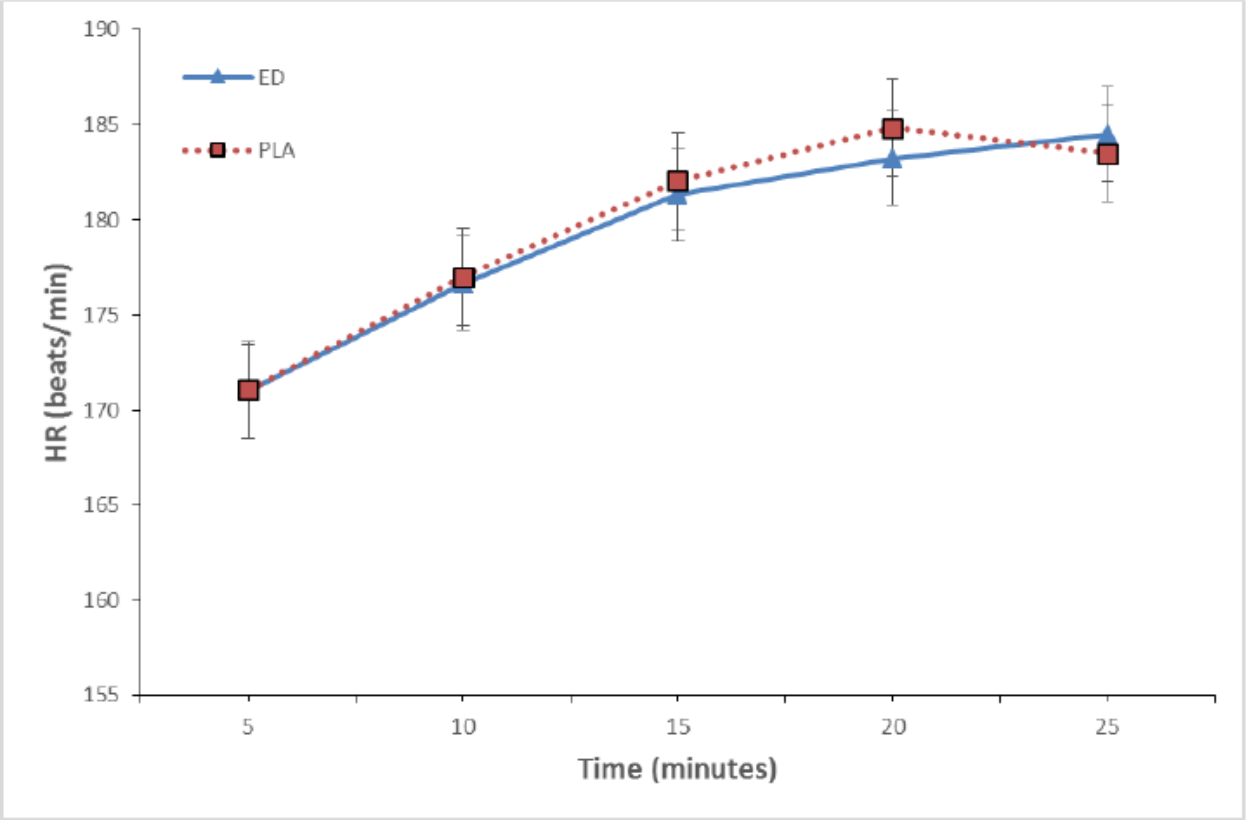

Figure 8. Heart rate at five minute splits during the 5-km time-trial in the Energy Drink (ED) and Placebo (PLA) conditions. Min 5 = 18 subjects; Min 10 = 18 subjects; Min 15 = 18 subjects; Min 20 = 14 Subjects; Min 25 = 6 subjects.

4.2.3 Affect

A two-way analyses of variance (ANOVA) for repeated measures on two factors (experimental condition and sampling time) was used to examine the affective data. Affect was measured at regular five minute intervals during the time-trial. Affect ratings decreased significantly during exercise ($p < .0001$) but there was no significant effect for treatment ($p = 0.643$) and interaction between time and treatment ($p = 0.255$). Therefore, affect ratings decreased with exercise but

remained similar between treatments (Figure 9). Results from a paired sample t-test showed that there were also no significant differences between treatment groups for mean Affect scores in the ED and PLA trials (ED: 0.7 ± 1.7; PLA: 0.8 ± 1.5; p = 0.545) (Figure 4). At minute five the average pleasure rating was 2.83 ± 1.25 for the ED trial and 3.00 ± 1.50 for the PLA trial (p = 0.604; N = 18). At minute ten the average pleasure rating was 1.22 ± 1.98 for the ED trial and 1.78 ± 1.52 for the PLA trial (p = 0.066; N = 18). At minute fifteen the average pleasure rating was -0.17 ± 2.36 for the ED trial and -0.06 ± 1.95 for the PLA trial (p = 0.767; N = 18). At minute twenty the average pleasure rating was -0.50 ± 2.56 for the ED trial and -0.79 ± 2.66 for the PLA trial (p = 0.435; N = 14). At minute twenty-five the average pleasure rating was 1.17 ± 1.83 for the ED trial and 0.33 ± 2.16 for the PLA trial (p = 0.185; N = 6).

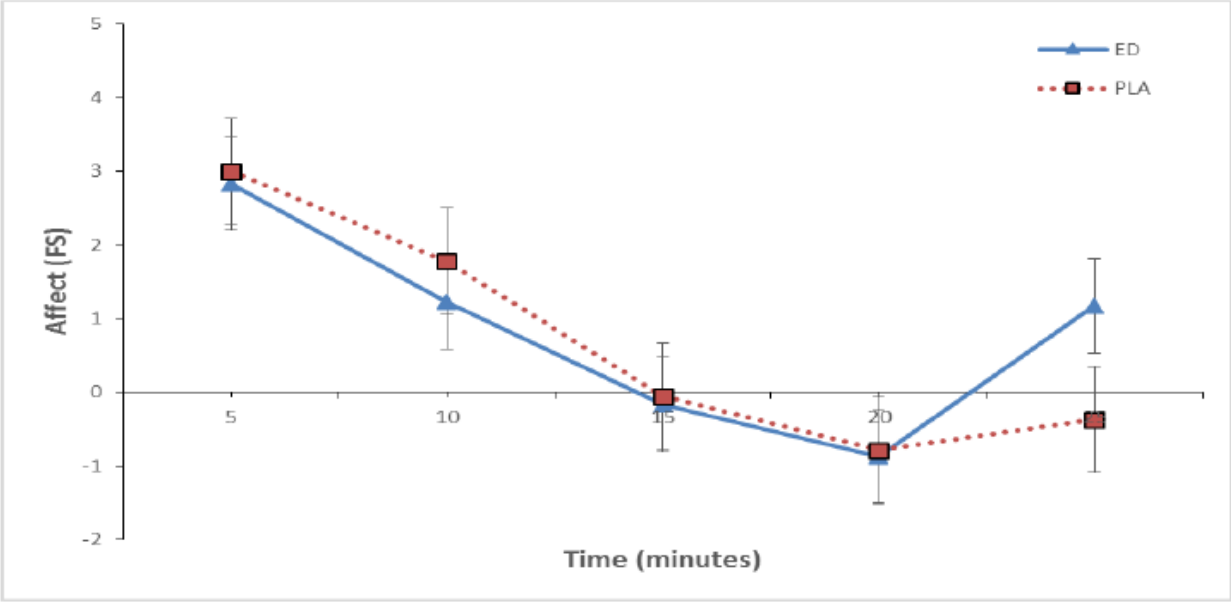

Figure 9. The responses to the feeling scale (FS) at five minute splits during the 5-km time-trial. Min 5 = 18 subjects; Min 10 = 18 subjects; Min 15 = 18 subjects; Min 20 = 14 Subjects; Min 25 = 6 subjects.

A Session Affect was measured five minutes post-exercise. The average Affect ratings were -0.3 ± 2.5 and 0.17 ± 2.3 for the ED and PLA trials, respectively (Figure 10). Results from a paired sample t-test indicated no significant difference in Session Affect occurred between the two treatments ($p = 0.177$).

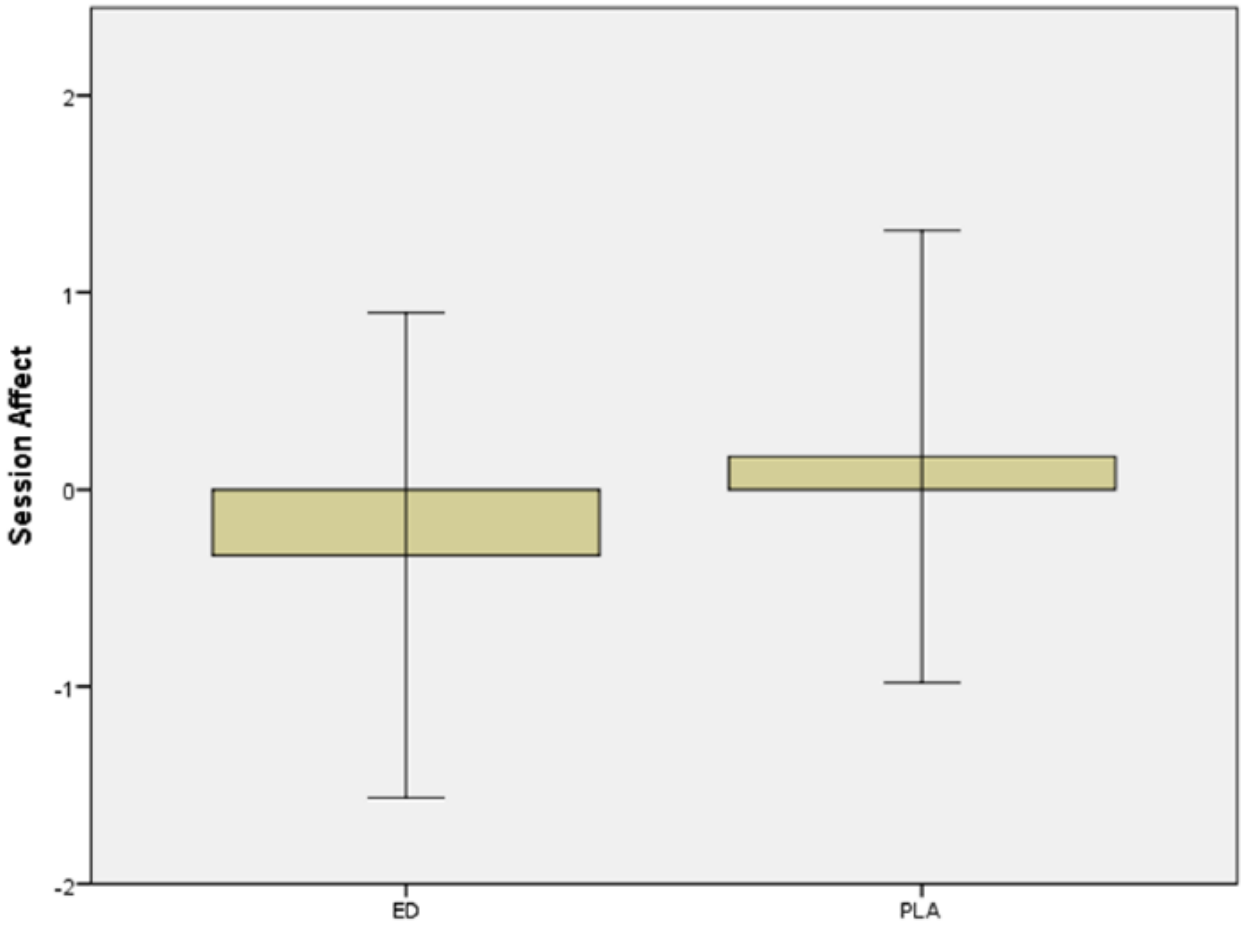

Figure 10. Mean ± SD of session Affect between Energy Drink (ED) and Placebo (PLA) conditions (N = 18)

4.2.4 Perceived Exertion

A two-factor (group x time) repeated measures ANOVA was used to examine the ratings of perceived exertion at each five minute interval throughout the treatment protocol. Perceived exertion was estimated for chest (RPE-Chest), legs (RPE-Legs), and overall body (RPE-O) at regular five minute intervals during the time-trial. A significant time effect was observed for RPE-Chest across time points during both trials ($p < 0.001$). However, RPE-Chest was not significantly different between treatments ($p = 0.642$) and there was not a significant interaction between time and treatment ($p = 0.955$). Results from a paired sample t-test showed that there were also no significant differences between treatment groups for the mean RPE-Chest, between ED and PLA trials (ED: 4.5 ± 1.5; PLA: 4.4 ± 1.4; $p = 0.886$) (Figure 11). At minute five the average RPE-Chest was 2.44 ± 1.50 for the ED trial and 2.55 ± 1.75 for the PLA trial ($p = 0.878$; $N = 18$). At minute ten the average RPE-Chest was 3.67 ± 1.71 for the ED trial and 3.72 ± 1.56 for the PLA trial ($p = 0.848$; $N = 18$). At minute fifteen the average RPE-Chest was 5.22 ± 1.92 for the ED trial and 5.22 ± 1.80 for the PLA trial ($p = 1.000$; $N = 18$). At minute twenty the average RPE-Chest was 6.00 ± 2.29 for the ED trial and 5.79 ± 2.12 for the PLA trial ($p = 0.648$; $N = 14$). At minute twenty-five the average RPE-Chest was 5.00 ± 1.79 for the ED trial and 5.33 ± 1.51 for the PLA trial ($p = 0.363$; $N = 6$).

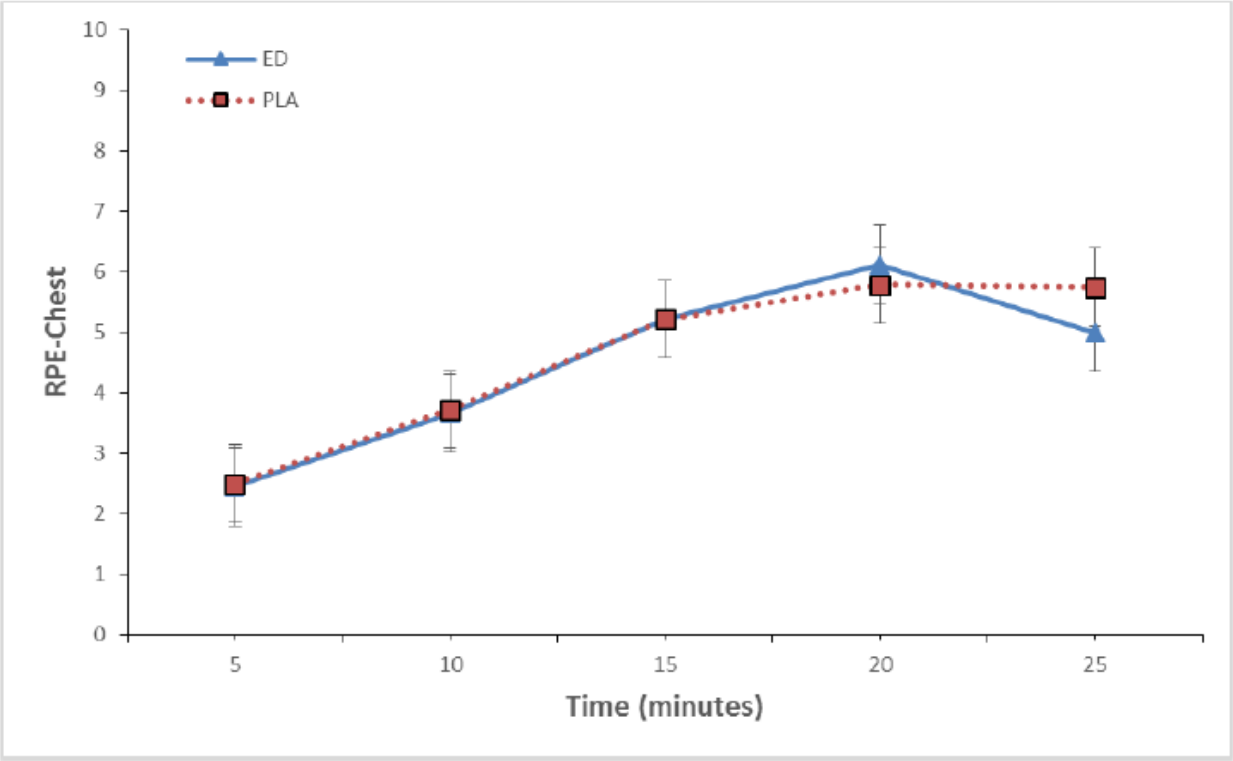

Figure 11. Mean ± SD RPE-Chest at five minute splits during the 5-km time-trial in the Energy Drink (ED) and Placebo (PLA) conditions. Min 5 = 18 subjects; Min 10 = 18 subjects; Min 15 = 18 subjects; Min 20 = 14 Subjects; Min 25 = 6 subjects.

A significant time effect was observed for RPE-Legs across time points during both trials ($p < 0.001$). However, RPE-Legs was not significantly different between treatments ($p = 0.502$) and there was not a significant interaction between time and treatment ($p = 0.915$). Results from a paired sample t-test showed that there were also no significant differences between treatment groups for the mean RPE-Legs, between ED and PLA trials (ED: 4.9 ± 1.3; PLA: 5.0 ± 1.3; $p = 0.592$) (Figure 12). At minute five the average RPE-Legs was 3.17 ± 1.15 for the ED trial and 3.28 ± 1.48 for the PLA trial ($p = 0.682$; N = 18). At minute ten the average RPE-Legs was 4.22 ± 1.59 for the ED trial and 4.33 ± 1.53 for the PLA trial ($p = 0.742$; N = 18). At minute fifteen

the average RPE-Legs was 5.50 ± 1.58 for the ED trial and 5.61 ± 1.85 for the PLA trial (p =0.726; N =18). At minute twenty the average RPE-Legs was 6.43 ± 2.27 for the ED trial and 6.29 ± 1.98 for the PLA trial (p = 0.738; N = 14). At minute twenty-five the average RPE-Legs was 5.00 ± 1.89 for the ED trial and 5.50 ± 1.64 for the PLA trial (p = 0.203; N = 6).

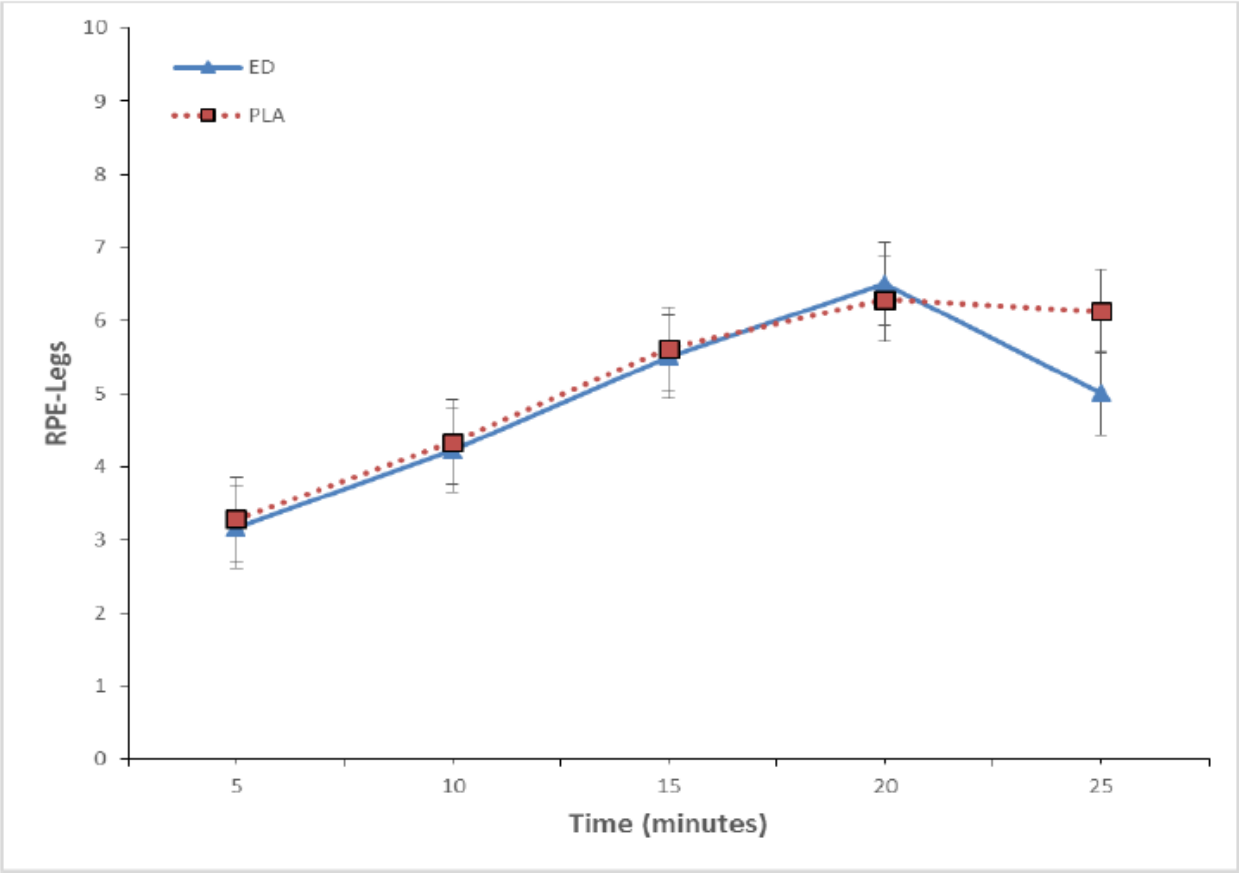

Figure 12. Mean ± SD RPE-Legs at five minute splits during the 5-km time-trial in the Energy Drink (ED) and Placebo (PLA) conditions. Min 5 = 18 subjects; Min 10 = 18 subjects; Min 15 = 18 subjects; Min 20 = 14 Subjects; Min 25 = 6 subjects.

A significant time effect was observed for RPE-Overall across time points during both trials ($p < 0.001$). However, RPE-Overall was not significantly different between treatments ($p = 0.494$) and there was not a significant interaction between time and treatment ($p = 0.932$). Results from a paired sample t-test showed that there were also no significant differences between treatment groups for the mean RPE-Overall, between ED and PLA trials (ED: 4.9 ± 1.4; PLA: 4.9 ± 1.3; $p = 0.969$) (Figure 13). At minute five the average RPE-Overall was 2.94 ± 1.21 for the ED trial and 3.06 ± 1.59 for the PLA trial ($p = 0.756$; $N = 18$). At minute ten the average RPE-Overall was 4.22 ± 1.66 for the ED trial and 4.22 ± 1.52 for the PLA trial ($p = 1.000$; $N = 18$). At minute fifteen the average RPE-Overall was 5.67 ± 1.72 for the ED trial and 5.72 ± 1.84 for the PLA trial ($p = 0.871$; $N =18$). At minute twenty the average RPE-Overall was 6.50 ± 2.24 for the ED trial and 6.21 ± 2.05 for the PLA trial ($p = 0.435$; $N = 14$). At minute twenty-five the average RPE-Overall was 5.00 ± 1.78 for the ED trial and 5.367 ± 1.63 for the PLA trial ($p = 0.394$; $N = 6$).

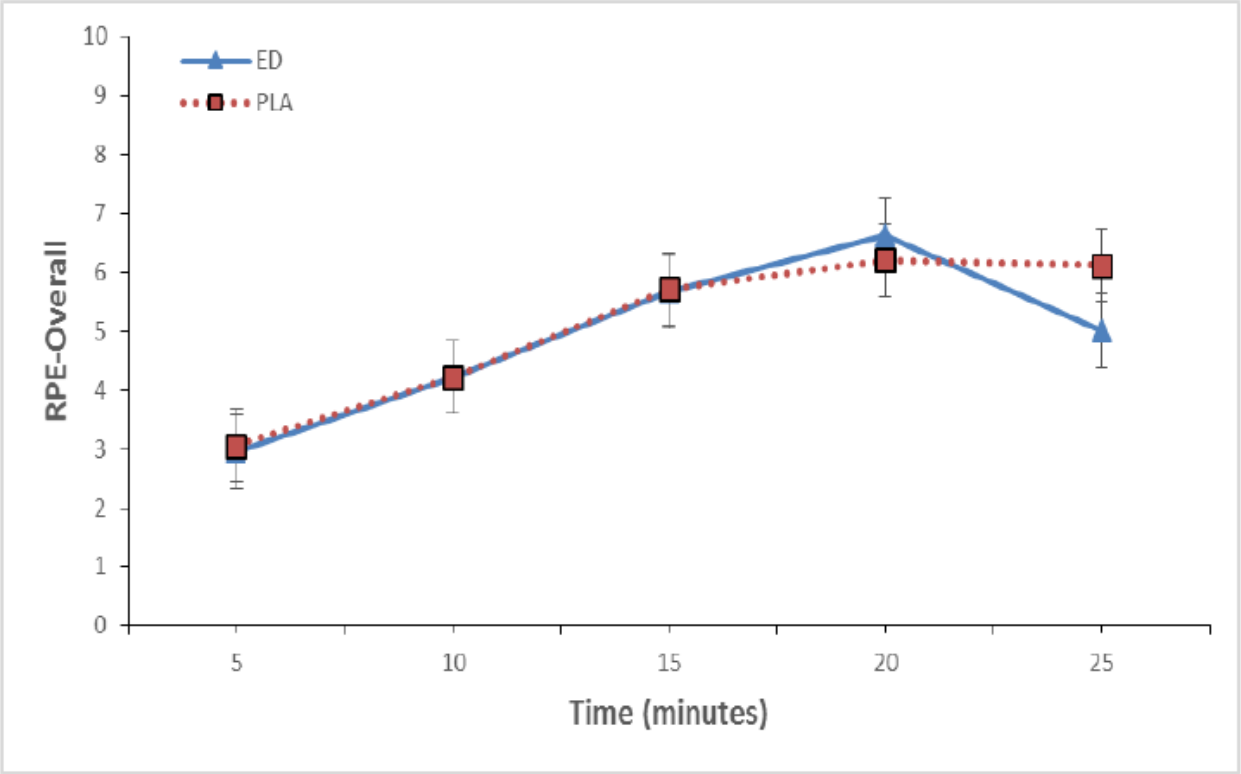

Figure 13. Mean ± SD RPE-Overall at five minute splits during the 5-km time-trial in the Energy Drink (ED) and Placebo (PLA) conditions. Min 5 = 18 subjects; Min 10 = 18 subjects; Min 15 = 18 subjects; Min 20 = 14 Subjects; Min 25 = 6 subjects.

A session RPE for overall body was measured five minutes post-exercise. The average Session ratings of perceived exertion were 6.4 ± 1.8 and 6.6 ± 1.5 for the ED and PLA trials, respectively (Figure 14). Results from a paired sample t-test indicated no significant difference in Session RPE between the two treatments ($p = 0.495$).

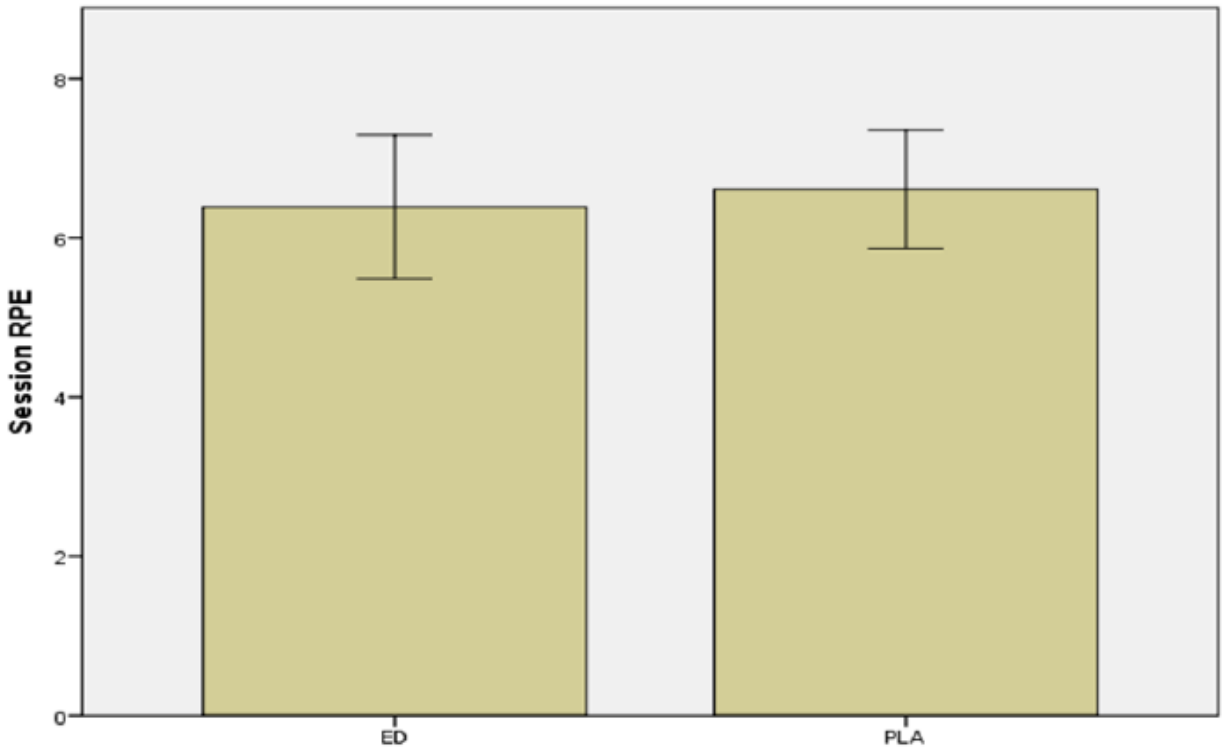

Figure 14. Mean ± SD of the Session RPE between Energy Drink (ED) and Placebo (PLA) conditions (N = 18).

4.2.5 Distance

A 2 x 5 (condition x 5-minute interval during the time-trial) repeated measures ANOVA was used to analyze the distance covered at each five minute interval. Differences between conditions for five minute splits throughout the 5-km time-trial did not reach statistical significance ($p = 0.159$). There was a significant interaction between time and condition ($p = 0.048$). The interaction indicated that the distance covered between the conditions tended to be very similar from minute five to minute fifteen. However, between minute fifteen and twenty the ED condition resulted in a greater distance covered in comparison to the PLA condition. Overall,

the difference in distance covered between conditions was greatest for subjects from minute fifteen to twenty. And this effect was more pronounced for the ED than PLA condition. Figure 15 depicts the distance covered at five minute intervals during the 5-km time trial. At minute five the average distance covered was 1.01 ± .15 km for the ED trial and 1.02 ± .13 km for the PLA trial ($p = 0.843$; mean difference: -0.005 ± 0.11; $N = 18$). At minute ten the average distance covered was 2.06 ± .26 km for the ED trial and 2.05 ± .26 km for the PLA trial ($p = 0.814$; mean difference: 0.009 ± 0.16; $N = 18$). At minute fifteen the average distance covered was 3.16 ± .39 km for the ED trial and 3.11 ± .39 km for the PLA trial ($p = 0.234$; mean difference: 0.051 ± 0.18; $N = 18$). At minute twenty the average distance covered was 4.05 ± .39 km for the ED trial and 3.97 ± .33 km for the PLA trial ($p = 0.70$; mean difference: 0.083 ± 0.16; $N = 14$). At minute twenty-five the average distance covered was 4.66 ± .19 km for the ED trial and 4.58 ± .14 km for the PLA trial ($p = 0.179$; mean difference: 0.072 ± 0.11; $N = 6$).

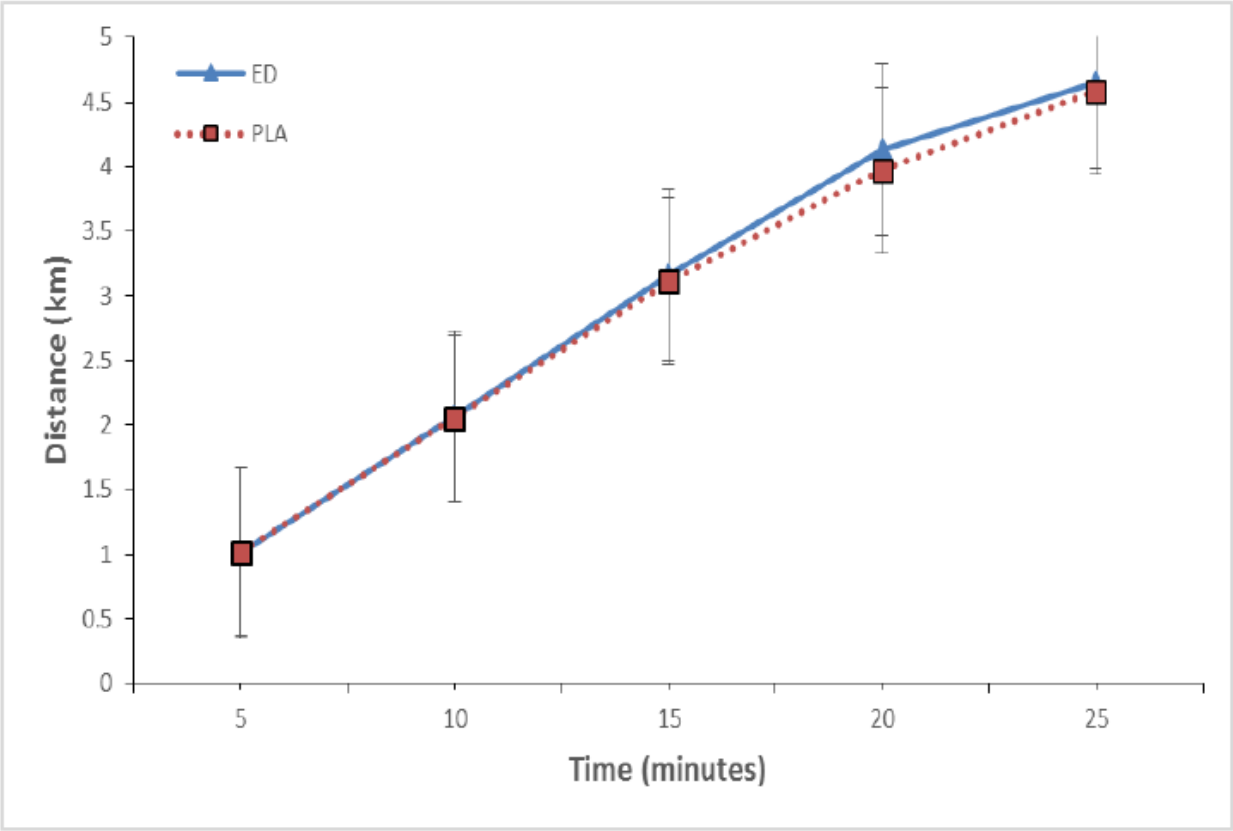

Figure 15. Mean ± SD distance covered at five minute splits during the 5-km time-trial in the Energy Drink (ED) and Placebo (PLA) conditions. Min 5 = 18 subjects; Min 10 = 18 subjects; Min 15 = 18 subjects; Min 20 = 14 Subjects; Min 25 = 6 subjects.

5.0 DISCUSSION

5.1 SUMMARY OF THE MAIN FINDINGS

The purpose of this study was to evaluate physiological and perceptual responses to exercise performance of recreational endurance runners after they ingested a commercially available energy drink (Red Bull) containing caffeine, glucose, and Taurine. It was hypothesized that acute energy drink ingestion would improve 5-km time trial running performance. Results indicated gdifferences in time-trial performance between the two treatment groups. Red Bull energy drink ingestion significantly improved 5-km time-trial performance compared with the placebo condition. Mean 5km performance time for the energy drink trial was 2.12% faster than the placebo trial.

It was also hypothesized that acute energy drink ingestion would cause perceived exertion (RPE) to be equivalent to the placebo condition. Results revealed no significant differences for ratings of perceived exertion for chest (RPE-Chest), legs (RPE-Legs), and overall body (RPE-Overall) between the energy drink and placebo condition.

Additionally, it was also hypothesized that the subjects in the energy drink condition would experience more pleasure when performing the 5-km time trial in comparison to the placebo group as evidenced by their Feeling scale rating. Furthermore, it was hypothesized that energy drink ingestion will result in a greater mean heart rate response during the 5-km time trial

in comparison to the placebo group. On the contrary, there were no differences in Affect ratings and exercise heart rate during the 5-km time trial between the energy drink and placebo conditions.

Finally, it was hypothesized that energy drink supplementation will result in a comparatively greater attenuation of perceived exertion and affect for the entire exercise session (Session RPE and Session Affect) when compared to the placebo condition. Results however, indicated that there were no significant differences between trials for Session Affect or Session RPE.

Therefore the results of the present study indicate that the ingestion of 500 ml of a commercially available energy drink improves treadmill five kilometer time trial performance in male and female recreational endurance runners. However, the results indicated no change in perceptual (RPE and Affect) or physiological variables (Heart Rate) between the energy drink and placebo trials.

5.2 TIME TRIAL PERFORMANCE

This is the first study to examine the effect of a commercially available energy drink on 5-km running performance in recreation male and female distance runners. The major finding of this study was that ingesting 500 ml of an energy drink containing caffeine, carbohydrates, taurine, glucuronolactone, and several B-vitamins 60 minutes before exercise improved performance during a 5-km running time trial. The improvement averaged 2.12% (~30 sec), with 78% of the participants demonstrating a positive effect. Additionally, the results indicated that there was a significant interaction between time and condition for distance covered during the 5-km time

trial. The interaction showed the difference in distance covered between conditions was greatest for subjects from minute fifteen to minute twenty. And this effect was more pronounced for the energy drink than placebo condition. The energy drink condition resulted in participants completing 0.051 km more than the placebo condition at minute fifteen, and 0.083 km more at minute twenty. Consequently, time to complete the time trial was significantly improved when participants ingested the energy drink before exercise. This occurred as a result of a high work rate from fifteen to twenty minutes of exercise during the energy drink treatment.

The results of this investigation are consistent with several other studies that also have investigated the effects of energy drink ingestion prior to aerobic exercise (Ivy et al, 2009; Candow et al, 2009; Cox & Wescott, 2001; Walsh et al, 2010). The performance improvements after the energy drink ingestion are consistent with those found by Alford, Cox, and Wescott (2001), in whose study performance was indirectly measured as the length of time participants exercised and maintained HR within 65–75% of HR_{max}, and Geiß, et al. (1994), in whose study performance was directly measured as time to exhaustion. Similarly, a study by Walsh and colleagues (2010) reported significant improvements in treadmill run time to exhaustion following ingestion of a carbohydrate-free energy drink. It was reported that the energy drink resulted in 12.5% improvement in running performance in comparison to the placebo treatment. In another study by Geib et al (1994) Endurance time was significantly longer when subjects ingested 500 ml of the taurine-enriched drink Red Bull. The only other research group to utilize a time-trial component in conjunction with energy drink consummation was Ivy and colleagues (2009), who found that 500 ml of a commercially available energy drink (Red Bull) resulted in ~4.7% improvement during a cycling time trial. However, performance during the exercise bout was measured as the time to complete a standardized amount of work equal to 1 hour of cycling

at 70% of maximal power output. Therefore, this study did not measure the effects of energy drink ingestion on high intensity endurance exercise performance.

The mechanism by which the energy drink improved performance is not immediately clear. The main active ingredient in most energy drinks is caffeine. Caffeine has been shown to be an effective ergogenic agent by delaying fatigue and increasing time to exhaustion during endurance exercise (Bruce et al, 2000; Graham et al, 1998) (Graham & Spriet, 1995; Hoffman et al, 2007). Plausible theories for the beneficial effects of caffeine include an increase in central nervous system activity (stimulates the cardiovascular system) (Birnbaum & Herbst, 2004; Graham, 2001), acting as an adenosine receptor antagonist (caffeine prevents adenosine from binding in the brain and thus reduces drowsiness) (Crowe et al, 2006; Davis et al, 2002), increasing calcium release and uptake to the sarcoplasmic reticulum (Lopes et al, 1983), and enhancing plasma epinephrine concentrations (Norager et al, 2006).

The dose of caffeine administered in this study (range: 1.5-3.9 mg/kg body weight; mean: 2.9 mg/kg body weight) was very similar to the threshold dose (>3 mg/kg body weight) for caffeine to elicit an ergogenic response (Costill, Dalsky, & Fink, 1978; Essig, Costill, & Vanhandel, 1980; Graham & Spriet, 1991, 1995; Greer, Friars, & Graham, 2000; Pasman, Van Baak, Jeukendrup, & De Haan, 1995; Ryu et al., 2001; Van Soeren & Graham, 1998; Doherty & Smith, 2004). The results from this study corroborate findings from O'Rouke et al (2008) who demonstrated that consuming 5 mg/kg body weight of caffeine significantly improved 5-km performance in well-trained (-10 seconds, 1.0%) and recreational runners (-11 seconds, 1.1%). In another study Bridge and Jones (2006) also reported improved performance with 5 mg/kg body weight of caffeine (-24 seconds; 1.2%) vs. placebo during an 8-km track race, whereas Bell et al. (2002) found a non-significant 1.7% improvement in 10-km treadmill performance in subjects

wearing 11 kg of military gear with 4 mg/kg of caffeine. However, the results from the current investigation indicated that caffeine intake (mg/kg body weight of CAF) showed a positive, weak relationship with 5-km running performance (r = 0.22). Therefore, in the current investigation the relationships between relative caffeine intake (through the energy drink Red Bull) and running performance indicate no association between these variables.

Research has consistently demonstrated that caffeine ingestion of 3-9 mg/kg body mass produces significant improvements in endurance capacity as measured by time to exhaustion at a sub-maximal workload of 75-85% of maximal oxygen uptake (VO2max) (Costill, Dalsky, & Fink, 1978; Essig, Costill, & Vanhandel, 1980; Graham & Spriet, 1991, 1995; Greer, Friars, & Graham, 2000; Pasman, Van Baak, Jeukendrup, & De Haan, 1995; Ryu et al., 2001; Van Soeren & Graham, 1998; Doherty & Smith, 2004). The results from the present investigation suggest caffeine ingestion also enhances performance shorter duration (10—30 min) high-intensity endurance exercise. It would appear that caffeine-containing energy drinks have an ergogenic effect on running performance over shorter distances, such as 5-km running event.

Although caffeine is the main purported ergogenic ingredient in the energy drink Red Bull, this commercially available energy drink also contains other potential ergogenic ingredients. For example, taurine has been shown to enhance exercise performance (Zhang et al. 2004), augment mood, alertness, and concentration (Ivy et al. 2009), and therefore could independently or synergistically with caffeine, enhance short-term performance by altering perception of effort and/or reducing reaction time. Research suggests that taurine doses of 2-6 g are required to be beneficial (Baum & Weis, 2001; Zhang et al, 2004). For the present study, the absolute amount of taurine ingested was 2 g, which may have been sufficient to elicit an improvement in 5-km performance. Other ingredients such as B vitamins have not been shown to

have an ergogenic effect on acute, high intensity endurance exercise performance (Woolf and Manore, 2006).

Another common ingredient in the energy drink Red Bull is carbohydrate. A number of studies have shown an ergogenic effect when combining caffeine with carbohydrates (Cox et al, 2002; Kovacs et al, 1998; Reissig et al, 2009). In examining the effects of caffeine (0, 150, 225, 320mg/L) and carbohydrate (68.8 g/L) containing solutions on exercise performance, Kovacs et al. (1998) found that the combination of caffeine and carbohydrates significantly improved cycling exercise performance in young male athletes. However, there is a lack of consensus on the ergogenic benefits of carbohydrate supplementation before exercise. A few studies have demonstrated a positive effect (Kirwan, O'Gorman, & Evans, 1998; Sherman et al., 1989) but most studies have indicated a reduced (Foster, Costill, & Fink, 1979) or no performance-enhancing effect (Hargreaves, Costill, Fink, King, & Fielding, 1987; Kuipers, Fransen, & Keizer, 1999; Sherman et al., 1989). For this investigation, 500 ml of the energy drink was provided 60 minutes before exercise. Research indicates, that providing carbohydrate 30–60 min before exercise will increase the plasma insulin concentration before exercise and that this causes a rapid decline in blood glucose because of the suppression of liver glucose output and increase in muscle glucose uptake (Foster et al, 1979; Kuipers et al, 1999). Elevated plasma insulin also inhibits lipolysis and therefore increases reliance on muscle glycogen as a fuel source (Horowitz et al, 1997). Not surprisingly, providing carbohydrate 30–60 min before exercise generally has not been found to enhance endurance performance (Foster et al., 1979; Hargreaves et al., 1987; Kuipers et al., 1999; Sherman et al., 1989). Therefore, it is unlikely that the energy drink consumed before the 5-km time trial increased performance by simply providing additional calories or maintaining blood glucose availability.

In addition, the American College of Sports Medicine (Rodriguez et al, 2009) and the International Society of Sports Nutrition (ISSN) (Kreider et al, 2010) recommends ingesting carbohydrate in a 6-8% solution (6-8 grams per 100 ml of fluid) during endurance exercise. Optimal concentrations of 6–8% can provide an exogenous source of carbohydrate oxidation at rates approximating 60 g/hr. for each liter of fluid consumed (Coyle, 2004). Sport drinks, such as Gatorade, are designed to provide these optimal concentrations of carbohydrate, whereas the sugar content of most energy drinks (including Red Bull) are closer to 11–12% by volume. Ingesting higher percentages (>10%) of carbohydrate in fluids has been reported to delay gastric emptying and increase gastrointestinal distress (Maughan & Leiper, 1999; Coyle, 2004). The energy drink provided in the present investigation contained approximately 54 grams of carbohydrate per 500 mL (16 fluid ounces). This amount falls short of the upper range of 60 g/hr. recommended during endurance exercise (Coyle, 2004). So while the total carbohydrate content of the energy drink provided was quite high, a shortcoming exists in regards to the concentration of carbohydrate contained in the energy drink.

In conclusion, because of the array of different ingredients contained in the energy drink Red Bull, it is possible that caffeine was working in combination with the other functional ingredients contained in the energy drink and that this combination is required to obtain the improvement in exercise performance that was observed presently.

5.3 AFFECT

This is the first study to determine the effects of energy drink ingestion on dimensions of affect during a 5-km running time trial. The results show that 500 ml of a caffeine containing energy drink consumed one hour prior to exercise does not induce any changes in the pleasantness dimensions of affect, as measured by the feeling scale (Hardy & Rejeski, 1889), during exercise. Even though pleasure ratings consistently decreased during the 5-km time trail there were no differences between the energy drink and placebo trials. Current results also indicate that energy drink ingestion had no effect on session affect.

There is currently no research on the influence of energy drink ingestion on the dimensions of affect during exercise, and research pertaining to caffeine and affective responses during exercise is also scarce. However, research by Backhouse et al. (2011) showed that the ingestion of 6 mg/kg of body weight of caffeine resulted in the maintenance of a more positive subjective experience during prolonged cycling. Even though the findings of this present investigation seem to oppose those of Backhouse and colleagues (2011), it is likely that the difference in exercise intensity is a plausible explanation. In the study by Backhouse et al (2011) participants were required to cycle for 90 minutes at 70% of their VO2max. In the present investigation subjects were required to complete a 5-km distance as fast as possible (subjects achieved ~90% MaxHR during exercise). Exercise intensity has been shown to have a profound influence on measures of affect. Research by Kirkcaldy and Shephard (1990) proposes that moderate intensity exercise produces an optimal affective response as opposed to high exercise intensities that may have detrimental effects on the affective response. This produces an inverted-U relationship, with the affective response beginning, most likely, at a level

approximating 0 (neutral) on the Feeling Scale during low-intensity exercise, increasing into the positive zone during moderate-intensity exercise, and then decreasing past the neutral zone into the negative zone during high-intensity exercise. In the present study, affect ratings at the start of the time trail were significantly higher (2.83 ± 1.25 for the ED trial and 3.00 ± 1.50 for the PLA trial) in comparison to affect ratings measured at the completion of exercise (-2.0 ± 2.7 for the ED trial and -2.0 ± 2.8 for the placebo trial), indicating that the high exercise intensity had a detrimental effect on the subjects affective response. The results show that energy drink ingestion is not a useful supplementation practice for manipulating feelings of pleasure during a high intensity endurance event, such as a 5-km distance.

5.4 PERCEIVED EXERTION

There were no significant differences between RPE's (RPE-Chest, RPE-Legs, RPE-Overall, and session RPE) when supplementing with the energy drink Red Bull or placebo. This finding is in disagreement with the majority of the literature that consistency demonstrates attenuated RPE in response to caffeine ingestion. It is also in opposition to research by Umana-Alvarado and Moncada-Jiménez (2004) that indicated the RPEs in male endurance runners were lower when energy drinks were ingested 30 minutes before a 10 km cross country race. This is one of only a few studies in which RPE was measured in combination with energy drink ingestion. Meta-analysis conducted by Doherty and Smith (2005), revealed lower RPE during prolonged constant-load exercise with caffeine intake. However, they reported little variability in RPE during exhaustive exercise when assessed at exercise termination, such as at the end of a

VO_2max test when maximal heart rate and cardiac output are attained. Subjects in the present investigation were encouraged to provide a maximum effort during each time trial. Participants exercised at a high percentage of their maximal heart rate (~90% MaxHR) during the energy drink and placebo trial (mean HR: 178.8 ± 10.2 beats/min for the ED trial; mean HR: 179.2 ± 10.3 beats/min for the placebo trial). This finding provides evidence that RPE is unchanged during exhaustive exercise.

Previous research has shown a reduction in RPE with higher doses of caffeine (5 mg/kg body weight) after treadmill running at 70% VO_2max (Birnbaum & Herbst, 2004) and cycling at 80% VO_2max (Bell & McLellan, 2002), suggesting that the amount of caffeine contained in the energy drink (Absolute dosage: 160 mg; relative dosage: 2.9 mg/kg body weight) may have been too low to produce a meaningful effect.

Furthermore, research by Ivy et al. (1979) reported that with caffeine ingestion participants are able to exercise more intensely than with placebo but with the same perception of effort. Similarly, Cole et al. (1996) observed that compared with placebo, a greater amount of work was performed at predetermined levels of perceived exertion after participants consumed 6 mg caffeine/kg body weight one hour before exercise. These findings corroborate the results of the present investigation in which performance was significantly increased with energy drink ingestion and a comparatively greater distance was completed in a shorter amount of time compared to placebo, but RPE was equivalent between conditions. This ability to influence the psychological state and alter pain perception can significantly affect exercise performance.

No significant differences occurred in Session RPE between the energy drink and placebo trials (mean Session RPE: 6.4 ± 1.8 for the ED trial; mean Session RPE: 6.6 ± 1.5 for the PLA trials). While the effects of caffeine on acute RPE are well established (Jackman et al. 1996;

Birnbaum and Herbst 2004; Doherty and Smith 2005; Green et al. 2007b; Hudson et al. 2008; Warren et al. 2010), very few investigations have examined the potential influence of caffeine on session RPE. However, no study to date has examined the potential influence of pre-exercise energy drink ingestion on session RPE. Previous evidence by Killen et al (2013) showed that caffeine ingestion of 6 ml/kg of body weight significantly lowered session RPE and acute perceptual responses. In the investigation by Killen et al (2013), session RPE was estimated 30 minutes post-exercise. This differed from the current investigation during which session RPE was estimated 5 minutes post exercise. The results from the present investigation suggest that energy drink ingestion does not attenuate Session RPE. Research suggests that caffeine ingestion results in a decreased acute RPE during exercise which could lower the RPE response post-exercise (Session RPE) (Killen et al, 2013). In the current study, acute RPE was not reduced when an energy drink was consumed prior to exercise. Therefore, because acute RPE was not attenuated by energy drink ingestion this could explain equivalency in session RPE between the conditions. It is also possible that the amount of caffeine ingested in the energy drink was not enough to provide a significant effect. Furthermore, as previously mentioned subjects achieved a high exercise heart rate during the time trial, indicating that the participants performed the time trial at a high intensity. Research suggests that Session RPE is more closely linked to exercise intensity than duration (Green et al. 2009, 2010). Therefore suggesting that exercise intensity during the 5-km time trials possibly contributed to the current findings.

5.5 STRENGTHS OF THE PRESENT STUDY

The present study is the first to examine the effect of acute energy drink ingestion on physiological and perceptional measures in a sample of recreational men and women distance runners. The study was designed to address gaps in the literature and add to the current body of literature regarding energy drink ingestion and endurance performance. Firstly, the present study was one of the first studies to examine the effects of a caffeine-containing energy drink on shorter duration (10—30 min) high-intensity endurance exercise. Previous research has focused on the ingestion of caffeine containing energy drinks in low intensity endurance events lasting several hours. Secondly, the present investigation is the only study known by the investigator to examine the ecological validity of a caffeine-containing ED (Red Bull) during a running-based time trial protocol. Previous literature has focused on caffeine ingestion (3-9 mg/kg body mass from natural sources or pills) using primarily time to exhaustion protocols utilizing submaximal exercise workloads (75-85% VO_2max). Thirdly, this investigation is also the first study to examine the effect of energy drink ingestion on affective state. Traditionally, dimensions of affect have not been assessed in nutritional manipulation studies. Instead, the focus has been on "what" a person feels, as measured by a Rating of Perceived Exertion metric. Lastly, the present investigation is also one of the few to examine the effect of energy drink ingestion and perceived exertion, and whether or not energy drink intake will attenuate perceived exertion. The majority of the literature has focused on the impact of caffeine intake and RPE. With these strengths in mind, the findings of this study are an important addition to the existing body of scientific literature.

5.6 LIMITATIONS

There are several limitations to this investigation that may have contributed to the interpretation of the observed outcomes. Therefore, these findings must be considered within the context of these limitations and future investigations should address the following:

1. The energy drink employed in this investigation contained several active ingredients including: caffeine, carbohydrates, taurine, glucoronolactone and B-group vitamins, while the placebo drink did not include these substances. Therefore, it is not feasible to identify the specific influence of each of these active ingredients on performance. Also, because the energy drink used consisted of a multitude of other ingredients and the results are specific to the complete energy drink (Red Bull) used in the present study.
2. The experimental protocols (5-km run) were separated by a week to ensure adequate recovery between trials and to allow adaptation to caffeine withdrawal before the next testing session. However, the day to day variation that exists in running performances cannot be accounted for.
3. This study was limited to healthy male and female recreational runners between the ages of 18 and 35, who were able to complete a 5-km running distance in less than 30 minutes, and who ran on average 20 miles of greater per week. Therefore, caution should be used when generalizing these findings to other populations.
4. The present study examined the effect of acute energy drink ingestion on 5-km running performance. Therefore, the results are specific to the endurance run employed (5-km) and cannot be generalized to other distances (for ex. 10-km) or outdoor running performance.

5. The experimental protocols were performed indoors under strict laboratory conditions utilizing a motorized treadmill. While steady state running can be adequate simulated on a treadmill, the demands of a 5-km time trial are more difficult to meet. Therefore, caution should be made when attempting to generalize the findings of the study to outdoor running performance and conditions.
6. This investigation included both male and female participants; therefore acute energy drink ingestion may have influenced physiological or perceptual responses differently according to gender. In addition, the final sample included a total of 5 women and 13 men. This sample size was not large enough to provide adequate power to examine the influence of gender on differences in 5-km running performance.
7. Another potential limitation was individual subject adherence to dietary and exercise guidelines. Subjects were encouraged to maintain the same dietary and exercise habits before both 5-km runs. Subjects were also instructed to avoid taking any additional nutritional supplements of any kind during the course of the investigation. In addition, subjects were asked to refrain from caffeine and alcohol intake for 48 hours, physical activity for 24 hours, and food and drink for 3 hours before each exercise test. If subjects did not specifically follow any of these instructions, the results of the study may have been compromised.
8. While the placebo was designed to taste similar to the energy drink, some subjects may have assumed they had a particular supplement based on the taste of the beverage. This may have influenced subject performance and perception during the experimental trials.

5.7 RECOMMENDATIONS FOR FUTURE RESEARCH

Based on the limitations and results of this study, the following should be examined in future research regarding the use of caffeine containing energy drinks supplementation on exercise performance.

1. The results of this study leave a number of questions regarding the underlying physiological mechanisms responsible for the increase in exercise performance, such as: 1) the effect of caffeine contained in the energy drink on physiological and perceptual responses; 2) the effect of carbohydrate contained in the energy drink on physiological and perceptual responses; and 3) the effect of taurine contained in the energy drink on physiological and perceptual responses. Therefore future research should focus on measuring the effect of the individual functional ingredients contained the energy drink Red Bull in conjunction with the complete beverage. These measurements should help to identify the underlying mechanisms responsible for improvement in exercise performance.
2. The majority of previous investigations have made the assumption that caffeine is likely the most important ingredient contained in the energy drink affecting performance because this appears to be the most likely explanation and is in line with other studies that have examined the ergogenic effects of similar products. However, many commercially available energy drinks contain taurine and glucuronolactone as a form of energy matrix and have shown to be ergogenic in aerobic endurance exercise. Future investigations should therefore measure the effects of caffeine in combination with energy drink

ingestion on exercise performance. This may provide additional insight into the potential ingredient and mechanism responsible for increases in performance.

3. The effects of energy drink ingestion on different running distances should also be explored. Caffeine-containing energy drinks have become the most popular supplement in the sports population, with many runners using energy drinks as a pre-exercise supplement with little scientific rationale for its ergogenic benefits. In addition, most of the existing body of literature has focused on studying the effects of energy drink ingestion during time to exhaustion protocols. Therefore, more ecologically valid approaches are necessary to study the effect of energy drink ingestion on different running distances. This would help both researchers and recreational runners understand the impact of these supplements on sport performance. Consequently, the current results from this investigation should be considered preliminary due to the relatively small sample size, and future studies should examine the effects of energy drink ingestion on performance in a variety of sport and field settings.
4. Future research should consider the effects of different brands of energy drink supplementation found on the market today. Energy drinks are available in different forms and vary based on factors such as nutrient concentration (i.e. % concentration of caffeine, taurine, vitamins, minerals, etc.) and ingredients (caffeine, taurine, carbohydrates, vitamins, minerals, guarana, etc.). The differences in the formulation of a supplement may positively or negatively affect the supplements ability to provide benefits for a given exercise situation.

5. Additional studies are needed to examine the long term effects of energy drink consumption on health, body composition, in addition to athletic performance, before recommendations about their usage can be provided to coaches and athletes.
6. Future research should be designed to test the efficacy of different dosages of energy drinks on performance. Previous studies have provided energy drinks in either relative or absolute dosage. An absolute dose of an energy drink provides a more ecologically valid examination of how the product would be used by athletes and recreational exercisers. Currently, the correct dosage for energy drink supplementation has not been established. Energy drinks consumed in the correct dosage might be an effective ergogenic aid to improve physical performance in endurance events such as running or team sports with similar physical demands.

5.9 CONCLUSIONS

The use of pre-exercise energy drinks has become a popular supplementation habit among recreational and competitive athletic populations. It is common for athletes to consume energy drinks prior to athletic competition, yet it is unresolved whether this is an effective strategy to increase performance, especially in short duration high intensity events. The present investigation was the first to study the ergogenic benefits of a commercially available energy drink on 5-km running performance. The current investigation demonstrated that consuming 500 ml of the energy drink Red Bull 60 minutes before exercise improves 5-km time trial performance in male and female recreational distance runners. Energy drink ingestion resulted in a total mean reduction in performance time of 30.39 seconds for 5-km performance time, which

translates into a 2.12% improvement. Energy drink ingestion however, did not alter ratings of perceived exertion or affect during exercise.

Results of this study suggest that young, physically active, healthy adults do experience performance benefits from Red Bull supplementation when consumed pre-exercise before performing high intensity short term exercise. These results may have application for altering pre-exercise nutritional strategies in athletes and recreational runners. Based on the results of this investigation, runners (recreational and well-trained), athletes, trainers, and coaches should consider recommending the use of the commercially available energy drink Red Bull as a pre-exercise supplement. Red Bull energy drinks are commonly ingested in the hope that it will increase exercise performance. These findings suggest that it might be effective for individuals who engage in short duration high intensity endurance exercise, such as a 5-km running event. Future research interventions should focus on the various potential performance enhancing ingredients (caffeine, taurine, and glucose) contained in the energy drink Red Bull, as well as comparing the effects of Red Bull at various caffeine dosages on exercise performance. In addition, further exploration of the nature and mechanisms surrounding energy drink supplementation may help to identify the adaptations necessary for training and improved sport performance.

APPENDIX A

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE (PAR-Q)

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE (PAR-Q)

Subject ID: _____ Date: _____

Please read the questions carefully and answer each one honestly: check YES or NO

1. Has your doctor ever said you have a heart condition and that you should only do physical activity recommended by a doctor?

□ Yes □ No

2. Do you feel pain in your chest when you do physical activity?

□ Yes □ No

3. In the past month, have you had chest pain when you were not doing physical activity?

□ Yes □ No

4. Do you lose your balance because of dizziness or do you ever lose consciousness?

□ Yes □ No

5. Do you have a bone or joint problem that could be made worse by a change in your physical activity?

□ Yes □ No

6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?

□ Yes □ No

7. Do you know of any other reason why you should not do physical activity?

□ Yes □ No

Reference: American Medical Association: Guides to the Evaluation of Permanent Impairment. AMA, Chicago, 1990.

APPENDIX B

GENERAL HEALTH HISTORY

GENERAL HEALTH HISTORY

Subject ID:_____DATE:____/____/____

1. Do you have or have you ever had any of the following medical conditions?

		Approximate Date of Diagnosis	Describe the Problem
a. Heart Attack	□yes □no	_____	_____
b. Angina (chest pain on exertion)	□yes □no	_____	_____
c. Irregular Heart Problems	□yes □no	_____	_____
d. Other Heart Problems	□yes □no	_____	_____
e. Stroke	□yes □no	_____	_____
f. Fainting Spells	□yes □no	_____	_____
g. High Blood Pressure	□yes □no	_____	_____
h. High Cholesterol	□yes □no	_____	_____
i. Thyroid Problems	□yes □no	_____	_____
j. Cancer	□yes □no	_____	_____
k. Kidney Problems	□yes □no	_____	_____
l. Liver Problems	□yes □no	_____	_____
m. Gout	□yes □no	_____	_____
n. Diabetes	□yes □no	_____	_____
o. Emotional/Psychiatric Problems	□yes □no	_____	_____
p. Drug/Alcohol Problems	□yes □no	_____	_____
q. Breathing or lung problems	□yes □no	_____	_____
r. Asthma	□yes □no	_____	_____
s. Muscle, joint, back disorder, or any previous injury still affecting you	□yes □no	_____	_____

2. Do you have any medical problems that would prevent you from participating in a regular physical activity program? □yes □no

If yes, please describe the problem:_____

_____

3. Have you participated in a regular exercise program over the past 6 months which consists of at least 20 minutes of activity, 3 days per week? □yes □no

Please describe:_____

_____

4. Please list all medications that you are currently taking on a regular basis (make sure to indicate if you are taking medication for high blood pressure or cholesterol):

MEDICATION	REASON FOR TAKING
_____	_____
_____	_____
_____	_____

5. Over the last 6 months, on how many weekdays (Monday through Friday) do you usually drink wine, beer, or liquor on average?

(0) □ Never (4) □ 2 days/week

(1) □ Less than once/month (5) □ 3 days/week

(2) □ 1-2 times/month (6) □ 4 days/week

(3) □ 1 day/week (7) □ 5 days/week

6. On those weekdays that you drink wine, beer, or liquor how many drinks do you have?

_____

7. Over the last 6 months, on how many weekend days (Saturday and Sunday) do you usually drink wine, beer, or liquor?

(0) □ Never (4) □ 1 weekend day/week

(1) □ Less than once/month (5) □ 2 weekend days/week

(2) □ 1-2 times/month

8. On those weekend days that you drink wine, beer, or liquor how many drinks do you have?

_____

9. In the past year, have you regularly smoked cigarettes, pipes, cigars, or used chewing tobacco?

		Please describe daily habit
Cigarettes	□yes □no	_____
Pipe	□yes □no	_____
Cigars	□yes □no	_____
Chewing Tobacco	□yes □no	_____

WOMEN ONLY ANSWER THE FOLLOWING QUESTIONS

10. Are you currently pregnant? □yes □no

11. Were you pregnant within the past 6 months? □yes □no

12. Do you plan to become pregnant in the next 18 months? □yes □no

13. When was your last menstrual period? DATE:____/____/____

14. Do you take:

Birth Control Pills?	□yes □no
Estrogens (ie. Premarin)?	□yes □no
Progesterone (ie. Provera)?	□yes □no

APPENDIX C

OMNI-WALK/RUN RPE SCALE INSTRUCTIONS

OMNI-WALK/RUN RPE SCALE INSTRUCTIONS

You are about to undergo a treadmill exercise test. This scale contains numbers 0 to 10, and will be used to assess your perceptions of exertion while exercising. Perceived exertion is defined as the subjective intensity of effort, strain, discomfort, and/or fatigue that is felt during exercise. We use these scales so you may translate into numbers your feelings of exertion while exercising.

OMNI RPE Instructions

The numbers on this scale represent a range of feelings from EXTREMELY EASY to EXTREMELY HARD. Look at the person at the bottom of the hill who is just starting to walk. If you feel like this person when you are walking, the exertion will be EXTREMELY EASY. In this case, your rating should be the number zero. Now look at the person who is barely able to walk at the top of the hill. If you feel like this person when walking, the exertion will be EXTREMELY HARD. In this case, your rating should be the number 10. If you feel somewhere between Extremely Easy (0) and Extremely Hard (10) then give a number between 0 and 10. Use both the pictures and words to help you select a number.

We will ask you to point to a number that tells how your whole body feels. Do not underestimate or overestimate the exertion; simply rate your feeling caused by the exercise at the moment. There is no right or wrong numbers. Use any of the numbers to tell how you feel when walking.

Using the scale:

Ask the following questions after reading both sets of instructions, and prior to performing the exercise test:

Please rate your feelings of exertion right now:

Please rate your feelings of exertion while walking at a moderate intensity:

Please rate your feelings of exertion when you exercised as hard as you can remember:

Do you have any questions?

APPENDIX D

FEELING SCALE

[FEELING SCALE]

+ 5 Very Good

+ 4

+ 3 Good

+ 2

+ 1 Fairly Good

0 Neutral

- 1 Fairly Bad

- 2

- 3 Bad

- 4

- 5 Very Bad

APPENDIX E

FEELING SCALE INSTRUCTIONS

FEELING SCALE INSTRUCTIONS

Read to subject:

Throughout the exercise session, I will ask you to rate how you feel using the Feeling Scale (point to scale). While participating in exercise, it is quite common to experience changes in how you feel. You may find that exercise can be pleasant (and make you feel good), or you may find it to be unpleasant (and make you feel bad). Additionally, your feelings may change over time. You might feel good and bad a number of times during exercise. The Feeling Scale is used to measure these responses. The scale ranges from negative 5, "very bad", to positive 5, "very good". "0" represents neutral feeling, neither good nor bad. Your answer may stay the same or may change, and there are no incorrect answers. Please point to the number that best describes how you are feeling when you are asked.

APPENDIX F

CAFFEINE CONSUMPTION QUESTIONNAIRE

CAFFEINE CONSUMPTION QUESTIONNAIRE

Subject ID: _____ Date: _____

Please address the following items about your caffeine usage. Respond to items that you consume at least once a week. In the *left-hand column* under "Days," indicate how many days per week you normally consume the item (answer from 0 to 7 days per week). In the *right-hand column* under "Servings," indicate how many servings of each item you consume on a typical day (e.g., if you have two 12-ounce cans of a soft drink, enter a 2 in the "Servings" box for soft drinks).

Items			**Days**	**Servings**
Beverages				
Coffee	125mg	X	_____	_____(6 oz.)
Decaf Coffee	5 mg	X	_____	_____(6 oz.)
Espresso	35 mg	X	_____	_____(1 oz.)
Tea	50 mg	X	_____	_____(6 oz.)
Green tea	20 mg	X	_____	_____(6 oz.)
Energy drinks	160 mg			
Red Bull		X	_____	_____(16 oz.)
Rockstar		X	_____	_____(16 oz.)
Monster		X	_____	_____(16 oz.)
Other		X	_____	_____
Hot cocoa	15 mg	X	_____	_____(6 oz.)
Caffeinated Soft Drinks	40-60 mg	X	_____	_____(12 oz.)
Chocolate candy bar	20 mg	X	_____	_____(1 bar)
Over-the-Counter Medications				
Anacin	32 mg	X	_____	_____
Appetite-control pills	100-200 mg	X	_____	_____
Dristan	16 mg	X	_____	_____
Excedrine	65 mg	X	_____	_____

Items			**Days**	**Servings**
Extra Strength Excedrine	100 mg	X	_____	_____
Midol	132mg	X	_____	_____
NoDoz	100mg	X	_____	_____
Triaminicin	30 mg	X	_____	_____
Vanquish	33 mg	X	_____	_____
Vivarin	200 mg	X	_____	_____

Prescription Medications

Cafergot	100 mg	X	_____	_____
Fiorinal	40 mg	X	_____	_____
Darvon compound	32 mg	X	_____	_____

TOTAL MG. CAFFEINE PER DAY _____

APPENDIX G

VERBAL ENCOURAGEMENT SCRIPT

VERBAL ENCOURAGEMENT SCRIPT

Consistent verbal encouragement will be given to the participants during each 5-km time trial. Verbal encouragement will be provided to the subjects at regular 5 minute intervals during the run. The verbal encouragement will be kept consistent from trial to trial by using a "script". The research team will be using words from this script when they are providing feedback to each individual participant.

The words from the script will contain the following:

1. You're doing great
2. Nice job
3. Looking good
4. Good pace
5. Finish strong
6. Halfway there…keep it up

APPENDIX H

INFORMED CONSENT

CONSENT TO ACT AS A SUBJECT IN A RESEARCH STUDY

TITLE: The Effect of Energy Drink Ingestion on 5-km Running Performance in Recreational Endurance Runners

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SOURCE OF SUPPORT: University of Pittsburgh School of Education Research Grant

DESCRIPTION:

Why is this research being done?

Running is one of the most popular forms of sport and recreation in the United States. With such a large population of runners, identifying nutritional factors that can cause improvements in performance is merited. It is common for athletes to consume energy drinks prior to athletic competition, yet it is unsure whether this is an effective strategy to increase performance, especially in short duration high intensity events. Therefore, it is important to determine the most appropriate type of pre-exercise supplement to extend endurance and improve exercise performance. Many studies have documented the effectiveness of energy drinks. However, many of these studies have used protocols that are not an indication of actual performance. This would be the first study that would compare the effects of the commercially available caffeine-containing energy drink Red Bull, to an un-caffeinated beverage utilizing a short duration high intensity exercise (5-km) running time trial on both physical and emotional indicators in a sample of recreational endurance runners.

Who is being asked to take part in this research study?

Eighteen healthy recreational male and female distance runners 18-35 years old who are capable of completing a 5-km running distance in under 30 minutes and currently run a minimum of 20 miles per week. If you have a cardiovascular (heart), musculoskeletal (muscle or bone), metabolic disease (i.e. diabetes), currently being treated for psychological disorder, are knowingly pregnant, or if you are a current smoker, and/or knowingly taking any performance enhancing substances including anabolic steroids you will not be eligible to participate in this research study.

What procedures will be performed for research purposes?

If you qualify to take part in this research study, you will undergo the following procedures:

<u>Screening Procedures:</u>
Procedures to determine if you are eligible to take part in the research study are called "screening procedures." For this research study the screening procedures will be completed in the Grove City College Exercise Science Laboratory.

The screening procedures will include the following and this will take approximately 10 minutes to complete:

1) A medical history to examine your current and past record of serious or unstable medical illness, surgeries and hospitalizations, orthopedic limitations, metabolic, respiratory, or cardiovascular conditions, and medication usage.
2) The PAR-Q & YOU will assess your readiness for physical activity and identifies if physical activity may be unsafe for you, and includes seven questions inquiring about your current health status as it relates to physical activity/exercise (i.e. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?; Do you feel pain in your chest when you do physical activity?; Do you lose your balance because of dizziness or do you ever lose consciousness?). If you answer "yes" to

any of the seven questions, you will be excluded from the present study.

Orientation Session and treadmill fitness test (VO_2max trial)

If you qualify to take part in this research study based on the screening procedures, you will undergo the following experimental procedures which will take an additional 50 minutes:

A. Body Height, Weight, and Composition (10 minutes): Your height will be measured with a ruler that is attached to a flat wall. After height has been entered, you will remove your shoes and socks and stand on the scale for approximately 10 seconds to obtain weight and body composition, which is the ratio of fat to muscle, using a technique known as Bioelectrical Impedance Analysis (BIA). The BIA is a non-invasive pain-free procedure for assessing body composition in which a low-grade electrical impulse is transmitted through the body that is not harmful to you and that you will not feel.
B. Habitual caffeine consumption questionnaire (5 minutes): This questionnaire will assess your daily average caffeine intake.
C. Practice Session (10 minutes): The next portion of the orientation session will allow you to familiarize yourself with the treadmill by allowing you to practice running and adjusting the speed on a treadmill. This familiarization period will also include a written explanation of the specific termination procedures for the treadmill running fitness tests, and will be read to you prior to each session. You will also receive standard instructions on Ratings of Perceived Exertion (RPE) and affect. The investigator will first read to you the following definition of RPE: *"The rating of perceived exertion (RPE) is defined as a measure of your feelings of effort, strain, discomfort, and or/fatigue that are experienced during exercise."* The investigator will then also read to you the following text regarding affect: *"During exercise, it is common to experience changes in mood. Some individuals find exercise pleasurable; whereas, others find it to be unpleasant. Additionally, feeling may fluctuate across time. That is, one might feel good and bad a number of times during exercise".* A set of instructions on how to use the RPE and affect scales will be read to you prior to each test.
D. Treadmill Fitness Test - VO_2max Test (20 minutes): Following the orientation and assessment procedures, you will perform an incremental test to exhaustion on a motorized treadmill. You will be fitted with a Polar Heart Rate monitor around your chest to measure heart rate and a facemask covering your nose and mouth to determine the amount of oxygen you use during exercise.
    a. You will be instructed to start walk/jog for 3 minutes as a warm-up at a self-selected speed. As soon as the 3-minute warm-up session is completed, the speed will be increased to 5–8 mph for 3 minutes (0% grade) according to your comfortable running pace. After 3 minutes at 0% grade running, the grade will be increased 2.5% every 2 minutes throughout the session while speed will be kept constant until exhaustion is reached.
    b. The test duration will be approximately 12 minutes, and you will be encouraged to continue the test until exhaustion.
    c. The rating of perceived exertion (RPE) and affect will be assessed during the last 15 seconds of minute 3 and then again at regular 2 minute intervals by presenting you with a poster-size version of the scales. You will be asked to indicate your response either verbally or by pointing to the appropriate number.

d. The entire experimental test including preparation shall last no longer than 20 minutes. At the completion of the test, you will be given a cool-down at a slow walking speed for three minutes allowing your heart rate to decline.

The screening and initial experimental procedures included in the Orientation and Assessment visit will take approximately 1 hour to complete.

5-km Running Time Trial I and II (120 minutes per session)

Two to three days after the VO_2max trial, you will undergo the first experimental trial (5-km running time trial). Experimental procedures will be completed in the Grove City College Exercise Science Laboratory. Each testing session will be separated by one week to ensure adequate recovery between subsequent tests. You will be asked to wear standardized athletic clothing (lightweight and comfortable) and running shoes during the subsequent experimental trials. For each testing session you will be asked to refrain from caffeine and alcohol for 48 hours, physical activity for 24 hours, and food and drink for 3 hours before each exercise test. You will also be instructed to maintain a training and dietary log for 2 days before the first experimental trial. You will then be provided with a copy of your log and instructed to have the same dietary intake and activity during the 48 hours before your second trial.

You will be instructed to report to the laboratory 1 1/2 hours before experimental testing. During this time, resting measurements of heart rate, affect and RPE will be taken. You will then ingest one of the two beverages: Un-caffeinated beverage (16 ounces or 2 cups of artificially sweetened carbonated water) or Red Bull (16 ounces or 2 cups). The beverages will be administered to you 60 minutes before the test will begin. You will be instructed to drink the beverage within 2 minutes of receiving it. Each beverage will be presented to you in an opaque sports bottle to prevent both you and the researchers from actually seeing the beverage. After consumption of the beverage, you will be instructed to sit quietly for one hour. One hour post-ingestion, resting heart rate, affect and RPE will be re-measured.

Exercise performance will then be evaluated with a self-paced 5-km treadmill time trial. A brief description of the 5-km time trial follows:

1) You will begin a warm-up run of approximately 5 minutes on the treadmill before the start of the 5-km time trial.
2) Following the completion of the 5 minute warm-up run, the treadmill will be brought to a standstill.
3) You will be given a 5-second countdown after which the 5-km time trial will begin.
4) You will be allowed to increase the speed on the treadmill to your desired running speed.
5) You will be told to finish the 5-km run as fast as possible.
6) You will perform the 5-km time trial on a motorized treadmill at 0.0% gradient.
7) You will only be provided with feedback on the distance (at regular 500-m intervals) covered during each 5-km time trial and will not be informed of the overall performance time until the completion of the final testing session.
8) At regular 5-minute intervals during the 5-km time trial heart rate, RPE, and affect will be recorded.
9) During the 5-km time trial, you will adjust your pace at any time via control buttons located on the treadmill.

10) The speed indicator will be concealed from your view. Therefore, you running speed will be determined by your own perceived exertion of the intensity of the exercise. You will be familiarized on how to adjust speed during the orientation and warm-up for each session and will be permitted to adjust your speed how and whenever you see fit during the time trial.
11) You will be instructed to run as fast as possible and will be provided with verbal encouragement during the run (at regular 5-minute intervals).
12) Immediately upon cessation of exercise, you will be asked to give an estimate of your final perceived exertion (RPE) and affect. Also, a final heart rate measurement will be taken.
13) Five minutes following the completion of the 5-km time trial, you will be asked to give a rating of perceived exertion and affect for the entire exercise session.

One week after the initial experimental trial, you will return to the laboratory and ingest the opposite supplement drink and perform the same test.

What are the risks of participating in this study?

As with any experimental procedure, there may be adverse events or side effects that are currently unknown and certain of these unknown risks could be permanent, severe or life-threatening.

Risks of the BIA Test

According to the U.S. Department of Health and Human Services, there have been no reported adverse events induced by BIA. During the BIA measurement there may be a potential for the hair on your arms and legs to stand up.

Risks of the Heart Rate Monitors

Risks associated with heart rate monitors include redness, irritation, and chafing, although infrequent. Similar to a sports-bra or other exercise wear which provides secure support and contact with the ribcage, subjects who wear a Polar monitor may encounter some chafing that will dissipate upon removal.

Risks of the Exercise Sessions (5-km time trial and VO_2max test)

Abnormal responses, such as shortness of breath, chest pain, heart rhythm irregularity, collapse, or death due to cardiac arrest as a result of maximal exercise in young healthy females and males are infrequent or rare occurring in less than 1% of people. However, some common risks occurring in up to 25% of people during maximal exercise include heavy breathing, dizziness, and nose-clip discomfort, anxiousness due to the mouthpiece, muscle fatigue and overall fatigue. In order to minimize these risks associated with exercise, you will be asked to complete the PAR-Q screening questionnaire (recall the pre-participation screening procedure). It is very important that you answered the PAR-Q accurately and honestly, because it provides the investigators critical information on your ability to exercise without any risks to your overall health.

As mentioned previously, some individuals may become anxious when fitted with a facemask. If this occurs to you, please inform the investigator, and the test will be stopped and facemask removed. To minimize the risk, you may stop a test at any time by signaling to the investigator either verbally or with a hand signal. If an abnormal response occurs during exercise, such as chest pain, dizziness, or shortness of breath, the test will be stopped immediately and you will be given proper medical attention. Emergency equipment will be on site for all testing procedures and at least one staff personnel present during the test is certified in CPR/AED and First Aid by the American Red Cross. If you have any other abnormal responses during the exercise sessions that do not require immediate medical attention, you will be encouraged to contact your primary care physician.

Risk of Energy Drink Ingestion

Adverse effects of caffeine ingestion typically manifest with ingestion higher than 200 mg of caffeine. The adverse effects seen with caffeine in these doses include insomnia, arrhythmia, nausea, nervousness, headache, and tachycardia. Subjects in this study will however be ingesting and energy drink containing 160 mg of caffeine, a dosage not typically associated with the above mentioned side effects. In comparison, an 8-oz cup of coffee contains 110 to 150 mg. There is the potential for some of the ingredients contained in the energy drink (caffeine) to interact with prescription medications especially medication taken for depression. Caffeine can also cross the placenta and current guidelines recommend that pregnant women should limit their caffeine intake from all sources to less than 200 mg per day. The Red Bull dose (500 ml) was chosen for the present study because this dose has shown in previous studies to increase exercise performance without resulting in adverse side effects in adults.

Risk of Breach of Confidentiality

There is a potential risk for breach of confidentiality of your questionnaire data. However, personal information will not be shared and any information about you obtained from this research will be kept as confidential (private) as possible. Your identity on these records will be indicated by a case number rather than by your name, and the information linking these case numbers with your identity will be kept separate from the research records.

Risks Associated with Completion of Questionnaires

You may be subject to answer questions which may appear to be sensitive in nature and/or experience non-physical risks such as boredom, frustration, stress, and time constraints when completing the questionnaires.

What are possible benefits from taking part in this study?

You will likely receive no direct benefit from taking part in this research study. However, you will receive information regarding your fitness level, height, weight, and body composition.

If I agree to take part in this research study, will I be told of any new risks that may be found during the course of the study?

You will be promptly notified if, during the conduct of this research study, any new information develops which may cause you to change your mind about continuing to participate.

Will my insurance provider or I be charged for the costs of any procedures performed as part of this research study?

You and your insurance provider will not be charged for the costs of any of the procedures performed for the purpose of this research study (i.e., Screening Procedures, Experimental Procedures described above).

Will I be paid if I take part in this research study?

You will be paid $50 for participating upon completion of all experimental sessions. There will be no partial compensation for completion of less than the three visits.

Who will know about my participation in this research study?

Any information about you obtained from this research will be kept as confidential (private) as possible. All records pertaining to your involvement in this research study will be stored in a locked file cabinet. Your identity on these records will be indicated by a case number rather than by your name, and the information linking these case numbers with your identity will be kept separate from the research records. This information will only be accessible to the investigators and their research study co-investigators listed on the first page of this document. All research data will be kept on a Grove City College protected database protected by firewalls, maintained by the computing services and system development. Grove City College policy requires that research records be kept for a minimum of seven years. You will not be identified by name in any publication of research results unless you sign a separate form giving your permission (release).

Will this research study involve the use of disclosure of my identifiable medical information?

This research study will involve the use of your identifiable medical information, but will only be disclosed to the investigators involved in this research.

Who will have access to identifiable information related to my participation in this research study?

Only the investigators listed on this first page of this authorization (consent) form and their research staff will have access to identifiable information related to your participation in this research study.

For how long will the investigators be permitted to use and disclose identifiable information related to my participation in this research study?

Identifiable information related to your participation in this research study will be kept for a minimum of seven years after final reporting or publication of a project.

Is my participation in this research study voluntary?

Your participation in this research study, to include the use and disclosure of your identifiable information for the purposes described above, is completely voluntary. (Note, however, that if you do not provide your consent for the use and disclosure of your identifiable information for the purposes described above, you will not be allowed, in general, to participate in the research study). Participation in the study would be strictly voluntary, and will have no effect on your current or future relationship with Grove City College. If you are a student, the decision to participate or not participate in this study will have no influence on class standing or grades.

May I withdraw, at a future date, my consent for participation in this research study?

You may withdraw, at any time, your consent for participation in this research study, including the use and disclosure of your identifiable information for the purposes described above. Any identifiable research information recorded for, or resulting from, your participation in this research study prior to the date that you formally withdrew your consent will not be continued to be used and disclosed by the investigators.

Your decision to withdraw your consent for participation in this research study will have no effect on your current or future relationship with Grove City College.

If I agree to take part in this research study, can I be removed from the study without my consent?

It is possible that you may be removed from the research study by the researchers to protect your safety or you are unable or unwilling to complete the research protocol.

VOLUNTARY CONSENT

You will be given a copy of this consent form to keep for your records.

All of the above has been explained to me and all of my questions have been answered. I understand that any future questions I have about this research study during the course of this study, and that such future questions will be answered by the investigators listed on the first page of this consent document at the telephone numbers given. By signing this form, I agree to participate in this research study.

_____
Participant's Name (Print)

_____ _____
Participant's Signature Date

CERTIFICATION OF INFORMED CONSENT

I certify that I have explained the nature and purpose of this research study to the above-named individual, and I have discussed the potential benefits, and possible risks associated with participation. Any questions the individual has about this study have been answered, and we will always be available to address future questions as they arise. I further certify that no research component of this protocol was begun until after this consent form was signed.

_____ _____
Printed Name of Person Obtaining Consent Role in Research Study

_____ _____
Signature of Person Obtaining Consent Date

APPENDIX I

PHONE SCREEN SCRIPT

Energy Drink Ingestion on 5-km Running Performance
Recruitment Form

1. Thank you for your interest in our program. My name is _____ and I would briefly like to tell you about this research study.
2. **Procedure for Describing the Study and Obtaining Verbal Consent to Conduct the Phone Screen:** A description of the study will be read to the participants, and this description includes important component of the informed consent process (see attached script). Individuals who express an interest in participating in this study will be told the following to obtain verbal consent:
    - **Investigators Component of Informed Consent:** *This study is being conducted by Philip J. Prins at the University of Pittsburgh.*
    - **Description Component of Informed Consent:** *The purpose of this study is to evaluate physical and emotional responses to exercise performance of recreational endurance runners after they ingested a commercially available energy drink (Red Bull) containing caffeine, sugar, and Taurine (which is an amino acid and amino acids form the main constituents of all proteins*). *We are interested in recruiting 18 healthy recreational male and female distance runners between the ages of 18-35 years. If you are found to be initially eligible for the study after this phone screening, we will invite you to the laboratory in Trees Hall on the University of Pittsburgh Oakland Campus for an orientation session. During the orientation session the full details of the study will be described to you, you will have a chance to ask questions, and if you are interested in participating, you will be asked to sign a consent document. Next, you will complete an assessment of your height, weight, body fatness, and complete a treadmill fitness test. You will also complete two separate 5-km (3.1 miles) running time trials after the ingestion of either a 500 ml (16 ounces or 2 cups) commercially available energy drink (Red Bull) or a placebo beverage. The 5-km time trails will take approximately two hours each to complete.*

      If you are interested in participating in this study, I will need to ask you a few questions about your demographic background and questions about your physical health and medical history to determine you eligibility. It will take approximately 5 minutes to ask you all of the questions. After we complete the interview, I will ask you for some specific information (i.e. complete name, phone number) to contact you regarding your further participation. If you are eligible, you will be scheduled to attend an orientation session where all of your questions will be answered in greater detail. For your first visit you will need to wear running/athletic shoes and exercise clothing such as running shorts, yoga pants or a t-shirt.

      Your responses to these questions are confidential, and all information related to your health history and current behaviors that you are about to give me will all be destroyed after this interview if you are found to be ineligible. If an answer to a particular questions makes it clear that you are not eligible, I will stop the interview and not ask you any more questions.

Do you have any questions regarding the information I have provided you? Staff member will answer any questions prior to proceeding, if the individual would like to think about their participation prior to proceeding with the phone screen, they will be provided with the telephone number that they can call if they decide to participate in the future.

- **Voluntary Consent Component of Informed Consent:** *Do I have your permission to ask these questions?*
    - If "YES" indicate the participant's agreement with this statement on the top of the next page, sign your name and date the form, and then complete the phone screen. If "NO", thank the individual for calling and <u>do not</u> complete the phone screen.

Phone Screen Interview

The caller give verbal permission to conduct the Phone Screen:

_____YES _____NO

Verbal Assent was given to:

_____
Staff Member Signature

_____
Date Verbal Assent was given:

Eligible based on telephone screening: ☐ **Yes** ☐ **No**

If "No", list reason for ineligibility: _____
_____

1. **What is your gender?** Male Female

2. **How old are you?** _____ **[18-35]**

3. **Are you able to complete a 5-km running distance under 30 minutes?** **YES** NO

4. **How many miles on average do you run per week?** _____**[≥20]**

5. **Have you used any performance enhancing aids in the past month?** YES **NO**

6. **Has a doctor or other medical persons ever told you that you have any of the following conditions?**
   a. Heart Disease YES **NO**
   b. Angina YES **NO**
   c. Hypertension YES **NO**
   d. Stroke YES **NO**
   e. Heart attack YES **NO**
   f. Diabetes YES **NO**
   g. Cancer YES **NO**

7. **Are you currently pregnant?** YES **NO**

Contact Tracking Form

****THIS PAGE IS COMPLETE ONLY IF THE RESPONDANT APPEARS TO QUALIFY FOR PARTICIPATION IN THIS STUDY****

Contact Information:

First Name: _____ Last Name: _____

Phone Number: _____ Home Work Cell

_____ Home Work Cell

_____ Home Work Cell

OFFICE USE ONLY:

Eligible: YES NO
Invited to Orientation: YES NO
Orientation Date: ___/___/___

APPENDIX J

ORIENTATION TRIAL AND LAND FITNESS TEST

DATA RECORDING SHEET

ORIENTATION TRIAL AND LAND FITNESS TEST
DATA RECORDING SHEET

Demographic Information

Participant ID#_____ **Date_____**

Age_____ **Gender_____**

Height (cm) _____ **Weight (kg) _____**

% Body Fat_____ **FFM (kg) _____**

Fat Mass (kg)_____

Running History

Number of 5-km races completed _____ **Best time in 5-km race_____**

Average running miles per week _____

Resting Data

Age predicted Max HR_____

Resting HR_____

Selected treadmill speed_____(mph)

Exercise Data

Workload	Grade %	Speed (mph)	HR	VE (L/min)	VO_2 (L/min)	VCO_2 (L/min)	RER	VO_2 ml $kg^{-1}min^{-1}$	RPE	Affect
1 (3 min)	0									
2 (2 min)	2.5									
3	5.0									
4	7.5									
5	10.0									
6	12.5									
7	15.0									

VO_2 max (determined by printout)_____ml kg^{-1} min^{-1}

APPENDIX K

5-KM TIME TRIAL PROTOCOL DATA COLLECTION SHEET

5-KM TIME TRIAL PROTOCOL DATA COLLECTION SHEET

Description of last meal	Time of last meal

Pre-ingestion Measures

Heart Rate	Affect	RPE-C	RPE-L	RPE-O

Post-ingestion Measures

Heart Rate	Affect	RPE-C	RPE-L	RPE-O

5-km time trial

Time (min)	Heart Rate	Affect	RPE-C	RPE-L	RPE-O	Distance
5						
10						
15						
20						
25						
30						
Immediately Post Exercise						

5-minutes post 5-km time trial:

Session RPE	Session Affect

Time to complete 5-km run: _____ (min:sec)

Participant ID#:_____ Date: _____

Comments_____

APPENDIX L

INDIVIDUAL PARTICIPANT RESULTS

Table 6. Individual Participant Results

		TT (s) Performance		Exercise HR		Exercise RPE-O		Exercise Affect		Session Affect		Session RPE	
Subject ID	**VO_2 max**	**ED**	**PLA**	**ED**	**PLA**	**ED**	**PLA**	**ED**	**PLA**	**ED**	**PLA**	**ED**	**PLA**
001	61.9	1358	1449	171.5	168.8	4.50	2.25	0.25	2.00	0	2	7	6
002	53.3	1512	1593	183.5	181.4	5.75	4.80	0.00	-0.40	0	2	8	8
003	65	1154	1187	183.3	180.0	5.67	5.67	-0.67	0.67	-2	2	7	7
004	65.5	1301	1209	177.0	186.3	3.75	6.67	-1.50	-1.67	-5	-4	9	8
005	42.5	1639	1665	183.0	189.0	1.80	2.80	3.20	1.80	3	1	3	5
006	57.0	1351	1359	198.5	200.8	5.50	6.25	-0.25	-1.25	-2	-1	8	6
007	59.8	1529	1609	192.4	184.6	4.80	4.00	3.40	4.00	3	4	5	5
008	49.1	1546	1600	168.4	158.2	5.00	4.80	0.60	1.80	1	2	5	5
009	65.6	1106	1156	176.3	174.0	6.00	6.00	0.00	0.33	0	-1	7	7
010	63.6	1278	1369	178.0	175	6.25	5.75	-1.00	-0.75	-4	-3	9	9
011	58.6	1284	1298	193.3	183.3	7.00	6.25	-1.75	-1.00	-3	-2	7	7
012	56.0	1588	1602	184.6	191.8	2.80	3.00	1.60	2.00	2	3	4	3
013	61.4	1244	1222	176.3	179.7	5.75	4.33	0.00	1.33	-3	-3	7	8
014	50.1	1431	1526	174.0	175.2	6.50	6.00	-1.00	0.20	-1	0	7	6
015	48.7	1434	1454	173.5	175.8	5.50	6.75	2.50	1.00	2	0	7	8
016	42.4	1696	1717	160.4	164.0	3.60	4.60	3.20	2.40	3	2	3	6
017	47.5	1614	1599	161.2	171.0	3.60	4.80	2.20	1.00	1	1	5	8
018	59.0	1373	1371	182.5	187.0	5.50	4.75	1.25	1.25	-1	-2	7	7

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