THE EFFECTS OF CAFFEINE ON NEUROCOGNITIVE FUNCTION

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The Effects of Caffeine on Neurocognitive Function

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

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ABSTRACT

Objective: The purpose of this study was to determine the effect of caffeine, as introduced by a popular energy drink, on neurocognitive function. **Methods:** Twenty-four male participants, 18-28 yrs old, completed two days of testing: baseline and post-consumption testing. Exactly 48-hours separated the two sessions. During the second day of testing, participants received treatment or control drink and waited 90 minutes before performing the ImPACT for post-consumption data. **Results:** Verbal Memory: ($F[1, 22]=0.69$, $p=.416$, $\eta^2=.03$) Visual Memory:($F[1,22]=1.31$, $p=.264$, $n^2=.056$) Visual Motor Speed:($F[1,22]=.660$, $p=.425$, $n^2=.029$) Reaction Time: ($F[1,22]=.015$, $p=.903$, $n^2=.001$) Impulse Control: ($F[1,22]=.453$, $p=.508$, $n^2=.020$) **Conclusions:** Researchers determined caffeine from an energy drink, consumed 90 minutes prior to ImPACT baseline testing has no statistically significant effect on ImPACT composite scores compared to control group. Therefore, caffeine does not appear to be an obstacle for clinicians when assessing composite scores of ImPACT.

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CHAPTER 1. INTRODUCTION

Overview of Problem

One of the most common substances that is thought to help produce subjectively positive effects, both mentally and physically, is caffeine (Giles, Mahoney, Brunyé, Gardony, Taylor, & Kanarek, 2012; Hartley, Lovallo, & Whitsett, 2004; Hoffman, 2010; Ruxton, 2008). Caffeine can be found in a variety of different sources, however, one of the most common and most consumed by college athletes are energy drinks (Attila & Cakir, 2011; Giles et al., 2012; Hoffman, 2010). Although athletes report personal positive gains from consuming caffeine, such as improved alertness, increased energy, better attention, and increased endurance and performance (Attila & Cakir, 2010; Reissig, Strain, and Griffiths, 2008; Smit, and Rogers, 2002; Wesnes, Barrett & Udani, 2013), research suggests those effects do not last long (Alford, Cox, & Wescott, 2001; Benowitz, 1990; Ruxton, 2008). Individuals will have varying effects from caffeine based on the half-life of the product consumed. This half-life has been found to be two and a half to four and a half hours but can vary from one to ten hours based on the individual (Alford, Cox & Wescott, 2001; Benowitz, 1990; Ruxton, 2008).

In addition, many athletes do not understand the aspects of moderation and how large quantities can produce short-term and long-term effects of insomnia, nervousness, headache, tachycardia, and possibly lead to addiction (Hoffman, 2010; Reissig et al., 2008). Consuming large amounts of caffeine before competition could affect the athlete's cognitive function during competition by inducing fatigue and decreased alertness (Benowitz, 1990; Alford, Cox, and Wescott, 2001; Ruxton, 2008). Due to this, athletes who consume caffeine prior to competition could potentially be harming their athletic potential mentally and physically instead of improving it (Benowitz, 1990; Hoffman, 2010; Kelemen & Creeley, 2001; Reissig, et al., 2008).

Testing neurocognitive function has become an accessible assessment with the modifications in modern technology. Currently, there are a variety of different computer-based neurocognitive testing protocols. One of the most commonly used tests in athletic training is the Immediate Post Concussion Assessment and Cognitive Testing (ImPACT test). This test assesses five different components of the athlete's cognitive function pre- and post-concussion. The five components included are verbal memory, visual memory, reaction time, processing speed, and impulse control (Allen & Geller, 2011; ImPACT Applications, Inc., 2015; Nakayama, Covassin, Schatz, Nogle, & Kovan, 2014). Even though the ImPACT test is utilized for assessing neurocognitive function before and after a concussion, it could be a useful tool to utilize when assessing neurocognitive function in general.

Significance of Study

Caffeine is a substance that has received debate over the past few years due to the increase in levels of caffeine consumption and the amounts of caffeine found in different items (Adan & Serra-Grabulosa, 2010; Alford, Cox, & Wescott, 2001; Benowitz, 1990; Hoffman, 2010; Kelemen & Creeley, 2001; Reissig, et al., 2008). Caffeine has become a popular supplement included in a variety of different products and advertised as having subjectively positive effects, which can potentially improve an individual's neurocognitive function (Attila & Cakir, 2010; Drug Free Sport, 2010; Reissig et al., 2008; Smit & Rogers, 2001; Wesnes et al., 2013). Based on the subjectively positive effects experienced, athletes have been taking supplements that usually contain large amounts of caffeine (Drug Free Sport, 2010).

Reissig et al. (2008) state that having an athlete consume an energy drink in order to enhance athletic performance is no different than an athlete consuming anabolic steroids or pharmaceutical stimulants to improve their athleticism. Due to this statement, amongst other

findings in research on neurocognitive function, it is important to understand how caffeine can affect athletes' neurocognitive function. The results from this study could alter the current practices of athletic trainers who utilize ImPACT to determine return-to-play considerations for athletes following a diagnosis of a concussion.

Statement of Purpose

The purpose of this study was to determine caffeine's effect on neurocognitive function in collegiate males. The method for measuring neurocognitive function was ImPACT. This project utilized a pre-test/post-test design by comparing 12 college males who consumed Rockstar Punched (treatment) to 12 college males who consumed sparkling flavored water (control). Comparing a treatment to a control group, researchers were able to study the effects of neurocognitive function as measured by composite scores of ImPACT.

Research Question

1. Is there an effect on neurocognitive function in collegiate males after the consumption of the Rockstar Punched energy drink?

Limitations

One limitation that occurred in this study was the small sample size. A sample size of 24 participants has limited application to a broader population. Another possible limitation was that subjects were asked to avoid consuming caffeine between the day of the baseline and the day of the treatment versus controlled administration of caffeine. Unfortunately, the researchers did not have first-hand knowledge of whether the participants avoided all caffeine. Another component of the caffeine, which resulted in a limitation, was that some of the participants were familiar with the Rockstar Punched Energy Drink. The researchers did not specifically ask the

participants if they were aware of whether or not they received the placebo or treatment. However, a few made comments post-testing which limits the potential findings.

The ImPACT test was utilized which has been shown to have error associated with it if the test-retest considerations are not followed (Nakayama et al., 2014). Not following test-retest considerations could have caused a limitation because subjects may have been able to easily recall testing modules. This time frame typically suggested for the test-retest of ImPACT is averaged at five days (Nakayama et al., 2014). A five-day time frame was unreasonable when asking college aged males to abstain from caffeine intake for that period of time. Instead, we shortened the time between testing to 48 hours, which could have produced error. The researchers were aware of all of the aforementioned limitations and have made specific study protocols with the possibilities of error in mind.

Delimitations

Due to the use of caffeine within the study, NCAA athletes were not included into the study. Ultimately, the results of this research will be used for clinicians to make evidence-based decisions about the effects of caffeine on neurocognitive function. Because there is no existing research regarding the topic, the research team was hesitant to allow participants that were current NCAA athletes based on the potential for a positive drug screening. The purpose was to find if athletes should avoid using caffeine prior to ImPACT. By not having athletes participate in the study, we avoided allowing the consumption of caffeine prior to knowing the results from this study.

There was also no recording of physical effects from caffeine because this study was focusing on cognition. In addition, another delimitation associated with this study was the use of only male subjects. Females were not chosen for this study because female bodies have a

different chemistry and varying hormones when compared to males. Therefore, the study could only be applied to 18-28-year-old males. Lastly, another delimitation associated with the study was that researchers did not control the activity of the participants during the 90-minute wait period on the second day of testing. All participants were to stay in the researcher laboratory; however, the researchers did not limit their choice of activity. Having some participants performing cognitive activity, such as reading, homework, or playing games, could cause error in the results when they complete ImPACT after consumption.

Definitions

1. **Half-life:** "The time required to change the amount of drug in the body by one-half during elimination (or during constant infusion) (pg41)" (Katzung, Trevor, & Masters, 2009).
2. **ImPACT:** Immediate Post-Concussion Assessment and Cognitive Testing. "ImPACT provides trained clinicians with neurocognitive assessment tools and services that have been medically accepted as state-of-the-art best practices" (ImPACT Applications Inc., 2015).
3. **Neurocognitive function:** "an intellectual process by which one becomes aware of, perceives, or comprehends ideas. It involves all aspects of perception, thinking, reasoning, and remembering " (Mosby's Medical Dictionary, n.d.).
4. **Reaction Time:** Reaction time is a measure of how quickly a subject reacts to a stimulus (Kosinski, 2010).
5. **Memory:** "the store of things learned and retained from an organism's activity or experience as evidenced by modification of structure or behavior or by recall and recognition" (Merriam-Webster Dictionary, n.d.).

6. **Attention:** “in psychology, the concentration of awareness on some phenomenon to the exclusion of other stimuli” (McCallum, 2015).

CHAPTER 2. LITERATURE REVIEW

Introduction

Caffeine is one of the most consumed dietary substances in the United States (Giles et al., 2012; Hartley, Lovallo & Whitsett, 2004; Hoffman, 2010; NCCIH Website, 2016; Ruxton, 2008), making it one of the biggest sources of revenue within the American culture. There are a few common sources for caffeine consumption including coffee, tea, soft drinks and energy drinks (Mandel, 2002). The American adult's daily caffeine intake averages from 170 to 210 mg/day in the United States (Giles, et al., 2012). This vast amount being consumed, especially amongst young people, could be due to the subjective effects caffeine gives a person, including reduced fatigue, increased alertness, increased attention, and improved mood (Attila & Cakir, 2010; Reissig et al., 2008; Smit & Rogers, 2001; Wesnes et al., 2013). In addition to subjective effects, vast consumption could also be caused by the objective effects associated with caffeine such as, improved cognitive function, assistance in weight loss, and potential performance and endurance enhancement Alford, Cox & Wescott, 2001; Reissig et al., 2008).

Ever since the debut of Red Bull Energy Drink in 1997, energy drinks have become a leader in the caffeine drink market (Malinauskas, Aeby, Overton, Carpenter-Aeby, & Barber-Heidal, 2007). Males between the ages of 18 and 34 years old consume the most energy drinks (NCCIH Website, 2016). The market value of energy drinks alone was $5.4 billion in 2006 (Reissig et al., 2008). Due to this information, caffeine has become a frequently researched topic partly because of its effects on neurocognitive function (Adan & Serra-Grabulosa, 2010; Alford, Cox, & Wescott, 2001; Giles et al., 2012; Peacock, Martin, & Carr, 2012; Seidl et al., 2000; Smit & Rogers, 2002; Wesnes et al., 2013).

ImPACT is a commonly utilized tool for assessing an athlete's cognitive function pre- and post-concussion. Although ImPACT is generally used for assessing if an athlete suffered a concussion, it has other applications because it evaluates the overall cognitive function of an athlete. Therefore, this test can be an effective way to test neurocognitive function not only on athletes, but the general public as well.

ImPACT is given as a baseline prior to an athlete being concussed, which gives information about an athlete's cognitive capabilities prior to injury. With this baseline there is an ability to determine an athlete's cognitive state before being concussed to use as a comparison post-concussion. The validity and reliability of ImPACT is discussed in future sections of this chapter.

Energy Drinks

Within the collegiate athletic population, it has been estimated that up to 73% of athletes consume brand name energy drinks (Drug Free Sport, 2010). Caffeine comes in many different forms as it is contained in tea, soft drinks, energy drinks, and a variety of different medications and supplements (Mandel, 2002). Some college students have a tendency to consume their caffeine in the form of an energy drink. There are over 100 different brands of energy drinks on the United States market that all range in caffeine content from 50mg to 500mg per serving (Attila & Cakir, 2010). It is estimated that more than 30% of the adolescent and young-adult population in America consumes energy drinks and this rate of energy drink consumption has increased in the younger population over the past decade (Attila & Cakir, 2010; Hoffman, 2010; NCCIH Website, 2016).

The United States market value for energy drinks was at $5.4 billion in 2006 and has continued to show an annual growth rate (Reissig et al., 2008). This trend continues partially

because energy drink companies have great advertising schemes, which target the college student and adolescent population (NCCIH Website, 2016). Energy drink companies also have a tendency to be advertised as products that can improve alertness, increase energy, attention, and help a person achieve better endurance and performance (Attila & Cakir, 2010; Reissig et al., 2008; Smit & Rogers, 2001; Wesnes et al., 2013). Although companies advertise these benefits, most students do not understand that there can also be risks associated with consuming energy drinks as well. Reissig et al. (2008) state that having an athlete consume an energy drink, in order to enhance athletic performance, is no different than an athlete consuming anabolic steroids or pharmaceutical stimulants to improve their athleticism.

Energy drinks contain caffeine and often they also include other additives such as glucose, taurine, and B vitamins for example (Alford, Cox, & Wescott, 2001; Attila & Cakir, 2010; Peacock, Martin, & Carr, 2012). Caffeine is a banned dietary supplement by the National Collegiate Athletic Association (NCAA) in specific amounts. Urinary caffeine concentrations exceeding 15 micrograms per milliliter, which is equivalent to about six to eight cups of coffee or 500 milligrams, two to three hours before competition can result in a positive drug test (NCAA Website, 2016). It is important for athletes to know that energy drinks and other sport enhancement substances may contain unlabeled amounts of banned stimulants that can result in serious health consequences (NCAA Website, 2016).

Pharmacology of Caffeine

Half-Life

Caffeine is a complex substance that has varying effects based on individual physiology. The half-life is the amount of time it takes a specific substance's effects to decrease to half. The average half-life of caffeine has been found to be two and a half to four and a half hours but can

vary from one to ten hours based on the individual (Alford, Cox & Wescott, 2001; Benowitz, 1990; Ruxton, 2008).

Physiology of Caffeine

It is believed that caffeine is absorbed from the gastrointestinal tract and reaches a peak in blood plasma approximately 30 to 120 minutes after ingestion (Benowitz, 1990; Giles et al., 2012; Ruxton, 2008). Caffeine is mostly metabolized by the P45 enzyme, which produces a range of different metabolites (Ruxton, 2008). Furthermore, caffeine antagonizes adenosine A-1 and A-2 receptors. Adenosine is a vasodilator that decreases norepinephrine release of sympathetic nerve terminals (Hartley, Lovallo, & Whitsett, 2004, p.1025). In short, adenosine facilitates sleep and dilates the blood vessels. Additionally, by caffeine acting as an antagonist to adenosine, an individual is likely to feel more awake and have increased alertness.

Caffeine also quickly enters the brain after absorption, which is one of the most significant aspects of its physiology. This could also explain why there is a rapid onset of psychological effects after drinking caffeine (Benowitz, 1990). It also causes effects on mood and performance because it inhibits the binding of adenosine and benzodiazepine receptor ligands to brain membranes (Ruxton, 2008). “These neurotransmitters are known to slow down brain activity, a blockade of their receptors lessens this effect” (Ruxton, 2008, p. 16). In addition, “caffeine has demonstrated to be effective in enhancing lipolysis, fat oxidation, and decrease glycogen breakdown” (Hoffman, 2010, p. 15). In summary, caffeine acts as a wall to block adenosine receptors, thereby resulting in individual’s to feel less tired, be more alert, and possibly have better cognitive performance.

Main Effects of Caffeine

An important mechanism of action for caffeine is the antagonism of adenosine receptors (Benowitz, 1990, Echeverri, Montes, Cabrera, Galán & Prieto, 2010). Since caffeine acts as a competitive antagonist of adenosine receptors, this antagonism causes mild dilation of blood vessels, increases blood pressure, catecholamine release, and central nervous system activity amongst other effects (Attila & Cakir, 2010; Smit and Rogers, 2002). Caffeine non-selectively blocks adenosine and inhibits actions of adenosine in people consuming caffeine (Benowitz, 1990; Echeverri et al., 2010). Adenosine reduces firing of neurons in many regions of the brain and produces sedation. Caffeine releases norepinephrine, dopamine, and serotonin into the brain, which can increase arousal, decreases fatigue, and decrease motor reaction time for some tasks (Benowitz, 1990). Additionally, caffeine decreases cerebral blood flow, increases blood pressure by five to ten mmHg dependent upon the individual, and increases heart rate in some individuals (Benowitz, 1990). Caffeine consumed at very high levels, six to nine milligrams of caffeine per kilogram of body weight, can cause adverse effects and can have potential to negatively impact training (NCAA Website, 2016).

Side Effects

There are many adverse effects associated with caffeine consumption. Some of those effects include insomnia, nervousness, headache, and tachycardia (Attila & Cakir, 2010; Hoffman, 2010). In addition, caffeine can decrease total number of sleep hours and increase sleep latency (Attila & Cakir, 2010; Benowitz, 1990; Hoffman, 2010). Although there are many adverse effects associated with caffeine, there has been evidence to show positive effects associated with caffeine consumption as well (Hoffman, 2010; Klepacki, 2010; Smit & Rogers, 2002). Some of those positive effects include improved endurance performance, enhanced

cognitive performance, and improved alertness (Hoffman, 2010; Ruxton, 2008). However, caution is always advised when consuming caffeine as is for all supplements (Attila and Cakir, 2010; Hoffman, 2010; Reissig et al., 2008; Ruxton, 2008).

Addiction

Caffeine is an addictive substance and when consumed regularly in amounts as low as 100 milligrams per day can produce withdrawal symptoms (NCCA Website, 2016; Reissig et al., 2008). Due to this, there has been research done on the addictiveness of caffeine, also known as caffeine toxicity. Caffeine toxicity has been defined by specific symptoms that are produced by the consumption of caffeine (Reissig et al., 2008). Signs of caffeine toxicity include, nervousness, anxiety, restlessness, insomnia, gastrointestinal upset, tremors, tachycardia, and psychomotor agitation (Hoffman, 2010; Reissig et al., 2008). Due to toxicity side effects, there has been an increase in concern with energy drinks due to the dependence, withdrawal, and tolerance associated with regular consumption (Benowitz, 1990; Hoffman, 2010; Reissig et al., 2008).

Caffeine can cause substance dependence syndrome in some people. Reissig et al. (2008) examined and reviewed studies on adults who have shown an inability to quit, despite harm or withdrawal symptoms that could occur. Abstinence from regular caffeine consumption can result in these withdrawal symptoms. This is also known as physical dependence (Benowitz, 1990; Reissig et al., 2008). Withdrawal symptoms can begin 12 to 24 hours after stopping caffeine consumption and can peak at 20 to 48 hours. Regular caffeine consumers have shown characteristics of addiction, such as, psychoactivity, drug reinforced behavior, and compulsive use (Benowitz, 1990; Reissig et al., 2008).

ImPACT

The Immediate Post Concussion Assessment and Cognitive Test (ImPACT) assessment tool was developed and co-founded by Dr. Mark Lovell, Dr. Joseph Maroon, and Dr. Michael Collins in 2002. These researchers collaborated to develop the test because the National Football League (NFL) wanted assistance in finding better ways to perform neurocognitive testing to determine safe return to play (ImPACT Applications, Inc., 2015). The program is used in Major League Baseball (MLB), National Hockey League (NHL), National Football League (NFL), World Wrestling Entertainment (WWE), more than 7,400 high schools, 1,000 plus colleges and universities and other facilities (Allen et al., 2011; ImPACT Applications, Inc., 2015). Due to the wide use of ImPACT from the variety of organizations listed previously, it has become a commonly established tool for assessing neurocognitive function and one of the most validated (ImPACT Applications, Inc., 2015; Nakayama et al., 2014). Neurocognitive assessments have become increasingly popular and useful in concussion management and protocol (Allen et al., 2011). Over the past two decades, neurocognition tools have evolved from paper to computer based testing to assist in the many cited methods of concussion management (Schatz & Sandel, 2012).

There are a variety of advantages that come with the use of computerized neurocognitive testing. Some of those advantages include easy data storage, improved accuracy in measuring reaction time and processing speed, ease of randomized test material, ability to evaluate large groups without excessive amounts of professionals, rapid integration of data into report format for professionals interpretation of results, and baseline assessments for comparisons of results after a concussion is suspected (Allen et al., 2011; Nakayama et al., 2014). In addition to the previously described advantages, computerized neurocognitive testing has become the

cornerstone of concussion management due to the lack of dependence on self-reported symptoms, as well as providing individualized cognitive assessments (Schatz, Pardini, Lovell, Collins, & Podell, 2006).

Components of the Test

ImPACT is an objective measure to determine subtle changes in cognition that occur with a concussion (Covassin, Elbin, Stiller-Ostrowski,, & Kontos, 2009). ImPACT consists of three sections, which include demographics, post-concussion symptoms scale, and neurocognitive test modules. Within the third category there are six modules that evaluate attention span, working memory, sustained and selective attention time, response variability, nonverbal problem solving, and reaction time (Allen et al., 2011, ImPACT Applications, Inc., 2015, Nakayama et al., 2014). The six test modules provide five composite scores and include: verbal memory, visual memory, reaction time, visual motor speed, and impulse control (Allen et al., 2011). According to ImPACT Applications, Inc., the six modules are as listed: Module One= Word Memory; Module Two= Design Memory; Module Three= X's and O's; Module Four= Symbol Matching; Module Five= Color Match; Module Six= Three Letter Memory. An accessible reference, to the previously mentioned modules, can be found for readers in Table 2.1.

Table 2.1

ImPACT Modules

Modules	
Module One	Word Memory
Module Two	Design Memory
Module Three	X's and O's
Module Four	Symbol Matching
Module Five	Color Matching
Module Six	Three Letter Memory

From there, these module scores are combined to make up the five composite scores. The verbal memory composite score is determined by percentage correct from the word memory, symbol match, and three letters task. In addition, the visual memory composite score is concluded from design memory and x's and o's. Also, the visual motor speed composite score comes from the weighted averages of x's and o's, and three letters module. Next, scores from the x's and o's, symbol match and color match module combine to compose the reaction time composite score. Finally, the total number of errors from x's and o's and total number of commissions on color match combine to create the impulse control composite score (Allen et al., 2011). A compilation of the previously discussed ImPACT composite scores can be found in Table 2.2. as a reference for readers.

Table 2.2

Organization of ImPACT Composite Scores

Composite Score	Module Combined to Determine Composite Score
Verbal Memory	Word memory total percent correct + symbol match (total correct hidden)/9x100 + three letters percent total letters correct= TOTAL/3
Visual Memory	Design memory total percent correct + x's and o's (total correct memory)/12= TOTAL/2
Visual Motor Speed	Total number correct/4 during interference of x's and o's+ avg counted correctly x 3 from countdown phase of three letters= TOTAL/2
Reaction Time	Avg correct RT of interference stage of x's and o's+ symbol match avg correct RT visible/3 + color match avg correct RT= TOTAL/3= reaction time composite
Impulse Control	Total incorrect on interference phase of x's and o's + color match total commissions

Overall the test takes, on average, 25 minutes to complete. It also contains a Validity Index to identify invalid performance that could be due to insufficient effort the participant gives (Allen et al., 2011). Thirty-eight percent of concussed athletes show impaired testing even

though they deny having concussive symptoms (Allen et al., 2011). Therefore, this test proves to be a vital component of concussion management along with symptom checklist and balance assessments (Nakayama et al., 2014; Schatz et al., 2012).

Accuracy of the Test

It has been determined that neuropsychological testing is the cornerstone of concussion management (Schatz et al., 2012). There has been debate over the reliability of ImPACT (Broglio, Ferrara, Macciocchi, Baugmgartner, & Elliott, 2007; Nakayama et al., 2014; Randolph, McCrea, & Barr, 2005; Schatz et al., 2012). However, Nakayama et al., (2014) determined the ImPACT test to have good reliability. The researchers implemented a repeated-measures design to evaluate the test-retest reliability of the ImPACT. Time of test administration was as follows: baseline, 45 days after baseline, and 50 days after baseline. Participants in this study included 85 physically active college students (male=51 and female=34). Outcomes revealed the ICC values of each composite score either met or exceeded .60 levels to indicate the reliability of the test.

In addition, other researchers have found the test to have a high sensitivity (79.2%, 91.4%, 81.9%) and fairly high specificity (69.1%, 89.4%) (Broglio, Macciocchi, & Ferrara, 2007; Schatz et al., 2012; Schatz et al., 2006). A study conducted by Broglio et al. (2007) included high-risk athletes from 1998-2005. These participants completed baseline testing prior to injury. After a participant had suffered a concussion, post-concussion assessments were administered 24-hours following injury. Outcomes revealed ImPACT to have sensitivity of 79.2%, which determined ImPACT to be a valid tool in neurocognitive assessments.

Another study conducted by Schatz et al. (2012) sought to document the sensitivity of ImPACT in samples of symptomatic concussed high school and collegiate athletes, as well as, asymptomatic concussed high school and collegiate athletes. Participants completed ImpACT

within three days of injury and data was compared with an independent sample of athletes who completed preseason baseline assessments with ImPACT. Data collected yielded sensitivity of 91.4% and 69.1% specificity. Data for asymptomatic athletes yielded sensitivity of 94.6% and specificity of 97.3%.

Finally, Schatz et al. (2006) researched the utility of composite scores of ImPACT. This study utilized 72 high school athletes who sustained a concussion and were tested within 72-hours of injury. Data was compared to non-concussed high school athletes and results determined that 82% of participants in the concussion group and 89% in the control group were correctly classified. This determined ImPACT to have a sensitivity of 81.9% and specificity of 89.4%. With these high sensitivities and specificities, we are able to conclude that ImPACT is a reliable test to rule in and potentially rule out concussions when comparing individual's baseline to post concussion scores in conjunction with other concussion assessment tools.

Literature on the Effects of Caffeine on Neurocognition

An exhaustive literature review reveals a considerable amount of studies and research done on the effects of caffeine on neurocognitive function. Although many researchers have compared similar aspects in their studies, all vary slightly from another in some form. However, the overall research question amongst the studies was to find how caffeine affects reaction time, memory, and attention.

Caffeine Methodology

Researchers have included a variety of substances to test the effects of caffeine. As indicated previously, the pharmacokinetics of the type and amount of caffeine must be considered when researching potential impacts on neurocognitive performance. The following section is divided into the types of caffeine consumption: capsule and liquid form. In addition,

the specifics of the treatment; timing of consumption to testing; and sleep, dietary, or activity restrictions are discussed in detail.

Capsule

Three studies were found to incorporate a capsule form of caffeine. Peacock, Martin, and Carr (2012) included 19 females each of whom participated in a variety of activities with varying amounts of caffeine and other substances throughout four sessions. This was a double-blinded study in order to ensure there were no conclusions drawn by either the participants or researchers during the time of data collection. At the start of every session, each participant received a two capsule combination received in counterbalanced order: placebo/placebo, taurine/placebo, caffeine/placebo, and caffeine/taurine. For those sessions in which caffeine was included, an 80 mg capsule was ingested. Forty-five minutes following ingestion of each combination of ingredients, participants took part in two tasks to evaluate reaction time. In addition, participants abstained from food for four hours and caffeine and other energy drinks for eight hours prior to each testing session.

Similar to Peacock, Martin, and Carr (2012), Seidl et al. (2000), conducted a randomized and double-blinded study comparing caffeine to placebo substances. Ten participants (male= 4, female=6) reported to the laboratory two times separated by at least one week to evaluate the differences between a wheat bran capsule (placebo) and a capsule filled with 80 mg of Caffeine, 1 g of Taurine, and 600 mg of Glucose (CTG). In contrast to Peackock, Martin, and Carr, participants were asked to refrain from ingesting caffeine 24 hours prior to testing rather than eight hours as previously described. The ten participants waited 60 minutes from ingestion to participating in a variety of tasks associated with reaction time. There was no mention of sleep, diet, or other activity restrictions for the ten participants.

An additional double-blinded, repeated measures study compared four different conditions: caffeine and taurine, no caffeine and taurine, caffeine and no taurine, and placebo (Giles et al., 2012). In contrast to the previously reported studies, the capsule contained 200 mg of caffeine and 2,000 mg of taurine. The increase in amount of caffeine was attributed to mimic the amounts of caffeine included in the popular energy drink, Monster. This study utilized 48 undergraduate students (male=18, female= 30). These participants were asked to abstain from caffeine for 24 hours prior to each test session. In addition, participants were to not eat or drink anything except for water after 9:00 AM the day of their test session. Participants waited 30 minutes before completing the three attention tasks, and 60 minutes before completing the memory and reaction time tasks after consuming the capsules. There was also no mention of sleep or activity restrictions.

Liquid

In addition to capsule forms of caffeine in research, four studies incorporated liquid forms of caffeine. Similar to the aforementioned studies, Adan and Serra-Grabulosa (2010) incorporated a double-blinded and randomized design that included 18 female undergraduate students separated into two groups of nine. Participants arrived to the testing center after fasting from caffeine for 18 hours and food for eight hours prior to their session. Four beverages were comprised of a placebo containing water, water plus 75 mg of powder caffeine, water plus 75 g of glucose, and water plus the caffeine and glucose amounts. Thirty minutes following the intake of the assigned beverage, participants began six performance recordings that assessed memory, reaction time and attention.

In contrast to powder caffeine utilized by Adan and Serra-Grabulosa (2010), three studies incorporated popular energy drinks as the caffeine substance. Smit and Rogers (2002) included

23 participants (males=10, females=13) who were tested once a week for five weeks. Contrary to previously discussed studies, participants performed a brief but tiring mental task with the objective of eliciting mental fatigue to assess the effects of the treatment drinks. Each subject received every treatment in a randomized, counterbalanced order during the five-week period. Five experimental "treatments" were included and consisted of undisclosed Energy Drink A (75mg caffeine), water, undisclosed Energy Drink B (75mg of caffeine), water, and nothing (break). Participants were asked to abstain from food or drinks from 9:00 PM the day preceding until the testing was completed the following day. Unlike the previous studies, Smit and Rogers (2002) did not disclose the amount of time participants were to wait between beverage consumption and cognitive performance tasks assessing reaction time and memory.

Alford, Cox, and Wescott (2001) incorporated Red Bull Energy Drink as a method of introducing caffeine. Researchers also integrated a repeated measure, double-blind design with each subject receiving both treatments in random order. However, in contrast to other studies, these researchers performed three separate studies, which were then combined into one manuscript discussing each. The first study assessed heart rate, blood pressure, subjective mood, and choice reaction time pre- and post-treatment (n=10, male=5, female=5). Within this study, researchers utilized the Red Bull Energy Drink (80 mg of caffeine) and a placebo of carbonated water. The second study also assessed heart rate, blood pressure, subjective alertness, and choice reaction time pre- and post-treatment (n=14, male=7, female=7). Researchers again utilized the Red Bull Energy Drink (80 mg of caffeine) but had no control drink. Finally, the third study included cognitive tasks that assessed concentration and memory pre- and post-treatment along with an anaerobic endurance assessment post-treatment (n=12, male=7, female=5). Researchers stated they utilized the physical assessment followed by the American College of Sports

Medicine guidelines for exercise testing and prescription by a cycling procedure. This third study substituted non-carbonated water as the control drink and to contrast the Red Bull Energy Drink, the researchers added a placebo energy drink that was comparable (Alford, Cox, & Wescott, 2001). Within all three studies, participants had no caffeine restrictions. Similar to Adan and Serra-Grabulosa (2010) assessments were completed 30-minutes after consumption of beverages in all three studies.

Similar to Alford, Cox and Wescott (2001), Wesnes et al. (2013) incorporated a double-blind and randomized design to their study. However, Wesnes et al. (2013) also included a two-way crossover concept comparing the 5hr Energy Shot to a placebo. Ninety-four participants were included (male=54, female=40). The 5hr Energy Shot contains 157 mg of caffeine amongst other substances. The placebo utilized in this study was created by a consultant hired by the sponsor of the study to be similar in packaging and flavor without the caffeine. Participants received the two test products over two study sessions that were separated by at least one day and no more than 16-days. Participants were also asked to avoid consuming energy drinks 24-hours prior to each test session and any food for at least 8 hours prior.

In contrast to previously mentioned studies, Wesnes et al. (2013) required participants to restrict sleep between 3 and 6 hours the night before each test session. By limiting participants' sleep, researchers were able to examine the effects caffeine has on partially sleep-deprived individuals to mimic fatigue. Upon arrival to the testing center, baseline measurements were taken utilizing the Cognitive Drug Research (CDR) Computerized Assessment System. Following that, participants were given the study product they were scheduled to receive and then performed the 10 CDR System tasks hourly for six hours. Similarly to Smit and Rogers (2002), researchers did not specify time between product consumption and testing. Participants

were not allowed to sleep between testing tasks. In addition, there was no other mention of diet or activity restrictions.

Conclusion: Methodology of Caffeine

The aforementioned studies all had similar aspects within their methodologies. Most researchers took into consideration caffeine's half-life when deciding on time between consumption and testing. However, most decided on the use of conservative times of 30 to 60 minutes. This time frame could conclude why researchers discovered an improvement with cognitive function. More similarities included the use of a double-blind design and similar amounts of caffeine utilized. Once more, these factors could have helped researchers in concluding that caffeine positively affects cognitive function. These improvements in cognitive function were found in three specific domains: reaction time, memory, and attention. The findings of these domains are discussed later in this chapter. In addition, a compilation of the previously discussed studies can be found in Table 2-3 as a reference for readers.

Table 2.3

Caffeine Research Methodologies

Researchers	Type of Caffeine	Timing Between Consumption and Testing	Diet/Activity/Sleep Restrictions
Adan and Serra-Grabulosa (2010)	**Liquid:** 75mg of caffeine powder mixed with water (75mg glucose)	30 minutes	**Diet:** No caffeine 18-hrs prior to testing, no food 8-hrs prior to testing **Activity:** not stated **Sleep:** not stated
Alford, Cox and Wescott (2001)	**Liquid:** Red Bull Energy Drink (80mg)	30 minutes	**Diet:** No caffeine restrictions prior to sessions **Activity:** Not stated **Sleep:** Not stated
Giles et al., (2012)	**Capsule:** caffeine amounts similar to that found in Monster Energy Drink amounts used (200mg caffeine) (2000mg taurine)	30 minutes before attention tasks 60 minutes before memory and reaction time tasks	**Diet:** No caffeine 24-hours prior to sessions. No eating or drinking except water after 9am day of testing. Fed lunch by researchers. **Activity:** not stated **Sleep:** not stated
Peacock, Martin and Carr (2012)	**Capsule:** placebo/placebo, taurine/placebo, caffeine/placebo and caffeine/taurine (80mg caffeine) (1,000mg taurine)	45 minutes	**Diet:** No food for 4-hrs and caffeine for 8-hrs prior to testing **Activity:** not stated **Sleep:** not stated
Seidl et al., (2000)	**Capsule:** 1g taurine, 80mg caffeine, and 600mg glucuronolactone	60 minutes	**Diet:** No caffeine consumption 24-hrs prior to testing **Activity:** Not stated **Sleep:** Not stated
Smit and Rogers (2002)	**Liquid:** Energy Drink A and B (75mg caffeine)	Not stated	**Diet:** No food or drinks from 9pm the day before testing until the following day after testing was complete **Activity:** not stated **Sleep:** not stated
Wesnes et al., (2013)	**Liquid:** 5hr Energy Shot (157mg caffeine)	Not stated	**Diet:** No energy drinks 24-hrs prior and no food 8-hrs prior **Activity:** not stated **Sleep:** Restrict sleep between 3-6-hrs the night preceding testing and no sleeping during the 6-hr testing session

Instrumentation Utilized in Research

A variety of instruments exist that test reaction time, memory, and attention. Because so many options exist, literature did not yield researchers utilizing the same testing methods in different clinical trials. Therefore, Seidl et al. (2000) researched reaction time specifically and utilized event related potential recordings along with P300 latencies. Event related potential recordings measure brain response from a cognitive event and evaluate brain function. Event related potentials recorded in this study were on a simple active oddball procedure (auditory oddball paradigm) and motor reaction time. Peacock, Martin, and Carr (2012) also researched visual oddball and stimulation degradation tasks but used the Neuroscan Stim^2 for visual oddball and stimulation degradation tasks. Stim^2 rather than P300 latencies, which shares similarities with ImPACT.

In addition to the aforementioned instruments, Wesnes et al. (2013) utilized computerized cognitive tests for clinical trials known as the Cognitive Drug Research (CDR) for testing reaction time, word recall, digital vigilance, memory and other factors. Furthermore, Adan and Serra-Grabulosa (2010) used the California Computer Assessment, Digit Span of WAIS, Purdue Pegboard, and many other well-known tests for assessing cognitive function. Smit and Rogers (2002) also used computerized tasks using Micro Experimental Laboratory (MEL) for testing simple reaction time, visual processing, and memory. After consumption of the received treatment in the study by Giles et al. 2012, subjects waited 30 minutes before completing the Attention Network Task for visual attention networks. Sixty minutes after treatment consumption, subjects also completed the N-Back test for memory and the Reaction Time Task. These aforementioned tests all share similar components because they assess components of reaction time, memory, and attention. Due to this, these studies were valuable when determining

methodology for the current study because of the similarities these instruments have with the ImPACT.

In conclusion, most studies utilized computerized testing procedures to determine the effects of caffeine on neurocognitive function. Computerized testing has become the front-runner in testing protocols due to the reliability of computerized tests, such as ImPACT. Reaction time, memory, and attention are important components of an athlete's cognitive function. By understanding how caffeine effects these aspects is vital for athletic trainers due to the possible implications caffeine could have on an individual's ImPACT test.

Reaction Time

Introduction

Reaction time is a measure of how quickly a subject reacts to a stimulus (Kosinski, 2010). There are two commonly assessed forms of reaction time, simple and choice reaction time (Kosinski, 2010). Simple reaction time involves only one stimulus and one response. An example of this would be catching a dropping ball (Kosinski, 2010). In contrast, choice reaction time has multiple stimuli and multiple responses but the reaction time must correspond to the correct stimulus (Kosinski, 2010). An example of choice reaction time is when a participant is asked to select a certain button when a red light appears and another button when a blue light appears.

Amounts of Caffeine Utilized to Measure Reaction Time

It has been discovered that reaction time can be faster after an individual consumes caffeine (Adan & Serra-Grabulosa, 2010; Alford, Cox, & Wescott, 2001; Giles et al., 2012; Peacock, Martin, & Carr, 2012; Seidl et al., 2000; Smit & Rogers, 2002; Wesnes et al., 2013). Three of these researchers found an improvement with reaction time and utilized similar amounts

of caffeine (80 mg) (Alford, Cox, & Wescott, 2001; Peacock, Martin, & Carr (2012); Seidl et al., 2000). The researchers utilized 80 mg of caffeine because it was an amount that is found in the Red Bull Energy Drink. Alford, Cox, and Wescott (2001) performed three separate studies, which were then combined into one manuscript discussing each. The first study assessed heart rate, blood pressure, subjective mood, and choice reaction time pre- and post-treatment (n=10, male=5, female=5). Within this study, researchers utilized the Red Bull Energy Drink (80 mg of caffeine) and a placebo of carbonated water. The second study also assessed heart rate, blood pressure, subjective alertness, and choice reaction time pre- and post-treatment (n=14, male=7, female=7). Researchers again utilized the Red Bull Energy Drink (80 mg of caffeine) but had no control drink. Finally, the third study included cognitive tasks that assessed concentration and memory pre- and post-treatment along with an anaerobic endurance assessment post-treatment (n=12, male=7, female=5). This third study substituted non-carbonated water as the control drink and to contrast the Red Bull Energy Drink, the researchers added a placebo energy drink that was comparable (Alford, Cox, & Wescott, 2001). Researchers determined choice reaction time to significantly improve [F(1,8) 18.02; Mse 0.00; $p< 0.005$ and F(2,25) 3.93; Mse 956.0; $p<0.05$] by the Red Bull Energy Drink when compared to placebo.

In addition, Peacock, Martin, and Carr (2012) included 19 females each of whom participated in a variety of activities with varying amounts of caffeine and other substances throughout four sessions. At the start of every session, each participant received a two-capsule combination received in counterbalanced order: placebo/placebo, taurine/placebo, caffeine/placebo, and caffeine/taurine. For those sessions in which caffeine was included, an 80 mg capsule was ingested. Forty-five minutes following ingestion of each combination of ingredients, participants took part in two tasks to evaluate reaction time. Analyses revealed no

significant effect of caffeine/taurine interaction (p=.454) for mean reaction time. However, researchers established that mean reaction time was significantly faster in caffeine/placebo condition relative to placebo/placebo condition in follow-up tests (M= 622, SD= 64, p<.001).

Lastly, Seidl et al. (2000) conducted a randomized and double-blinded study comparing caffeine to placebo substances. Ten participants (male= 4, female=6) reported to the laboratory two times separated by at least one week to evaluate the differences between a wheat bran capsule (placebo) and a capsule filled with 80 mg of Caffeine, 1 g of Taurine, and 600 mg of Glucose (CTG). The ten participants waited 60 minutes from ingestion to participating in a variety of tasks associated with reaction time. Outcomes revealed reaction time to improve after the CTG treatment compared to placebo (M=277.9, SD= 49.7, p<0.001).

Time Between Caffeine Consumption and Neurocognitive Testing

Another factor that these researches had in common was the amount of time between caffeine consumption and cognitive testing, which averaged to be between 30 and 60 minutes (Adan & Serra-Grabulosa, 2010; Alford, Cox, & Wescott, 2001; Giles et al., 2012; Peacock, Martin, & Carr, 2012; Seidl et al., 2000). Giles et al. (2012) compared four different conditions: caffeine and taurine, no caffeine and taurine, caffeine and no taurine, and placebo. This study utilized 48 undergraduate students (male=18, female= 30). Also, participants waited 60-minutes before completing reaction time tasks after consuming the capsules. Giles et al. (2012) determined caffeine decreased reaction time on simple reaction time [F (4,184)= 3.161, p < 0.05 (caffeine < no caffeine)] and choice reaction time [F (1,46)= 5.144, p< 0.05 (caffeine < no caffeine)]. Results revealed that caffeine improved reaction time on simple and choice reaction time tasks best compared to the other conditions. However, researchers stated no definitive

results could be determined because it is unknown if caffeine enhanced cognitive function or reversed withdrawal-induced cognitive impairment (Giles et al., 2012).

Similarly, Adan and Serra-Grabulosa (2010) incorporated four beverages that were comprised of a placebo containing water, water plus 75 mg of powder caffeine, water plus 75 g of glucose, and water plus the caffeine and glucose amounts. Thirty minutes following the intake of the assigned beverage, participants began six performance recordings that assessed reaction time. Researchers found the groups that received the caffeine only treatment had positive effects on performance although they were very minimal compared to placebo. During the sequential reaction time one task, the placebo group had a higher mean response time than the glucose group (M=487.72, SD= 17.75, p= 0.042). In the sequential reaction time two task, performance was poorer in the placebo group than in the caffeine + glucose group, with a greater mean response time (M=498.22, SD=20.17, p=0.016). Researchers determined caffeine only provided beneficial effects in simple reaction time when compared to placebo. However, they did determine caffeine with glucose to produce more benefits than caffeine alone.

Although Wesnes et al. (2013) and Smit and Rogers (2002) had no common interactions between amount of caffeine and time of testing to consumption, they both utilized a double-blinded design. Wesnes et al. (2013) required participants to restrict sleep between 3 and 6 hours the night before each test session. By limiting participants' sleep, researchers were able to examine the effects caffeine has on partially sleep-deprived individuals to mimic fatigue. Upon arrival to the testing center, baseline measurements were taken utilizing the Cognitive Drug Research (CDR) Computerized Assessment System. Following that, participants were given the study product they were scheduled to receive and then performed the 10 CDR System tasks hourly for six hours. Results concluded the 5-hour Energy Shot effect size was in the small to

medium range with reaction time. However, reaction time did improve with the treatment compared to placebo ($F(1,92) = 21.86$, $p < 0.0001$).

Lastly, Smit and Rogers (2002) subject's received every treatment in a randomized, counterbalanced order during the five-week period. Five experimental "treatments" were included and consisted of undisclosed Energy Drink A (75mg caffeine), water, undisclosed Energy Drink B (75mg of caffeine), water, and nothing (break). Smit and Rogers (2002) did not disclose the amount of time participants were to wait between beverage consumption and cognitive performance tasks assessing reaction time. However, researchers found better results with the two test drinks compared to placebo but only on simple reaction time ($F(4, 67)=43$; $p<0.001$).

Memory

In humans, memory is the process in which information is stored and recalled (Merriam-Webster Dictionary, n.d.). Memory is information remembered and gives the capability to learn and adapt from previous experiences in life (McLeod, 2007). There are many subcategories associated with memory, however the most well-known are long term (episodic) and short term (working) memory. Four of the previously mentioned researchers sought to measure caffeine's effects on memory and found positive results, which will be discussed.

Three of these studies that determined caffeine to improve memory used amounts of common energy drinks on the market, Monster and 5hr Energy Shot. Giles et al. (2012) utilized 200 mg of caffeine, which mimicked amounts typically found in the Monster Energy Drink. The study compared four different conditions: caffeine and taurine, no caffeine and taurine, caffeine and no taurine, and placebo. Participants waited 60 minutes before completing the memory tasks after consuming the capsules. Researchers determined caffeine increased memory (verbal N-

Back test (F (1,46)= 7.714, p< 0.01), spatial (F (1,46)= 7.641, p< 0.01)). However, Giles et al. (2012) stated they could not confirm if caffeine actually enhances cognitive function or rather if it reverses withdrawal-induced cognitive impairments.

In addition, Alford, Cox and Wescott (2001), who utilized the Red Bull Energy Drink, also determined the Red Bull Energy Drink to improve memory performance when contrasted with the "dummy energy drink." In contrast to other studies, these researchers performed three separate studies, which were then combined into one manuscript discussing each. The third study discussed included cognitive tasks that assessed concentration and memory pre- and post-treatment along with an anaerobic endurance assessment post-treatment (n=12, male=7, female=5). Assessments were completed 30 minutes after consumption of beverages. Researchers determined a significant increase in immediate recall memory (F(3,32)=4,02, p<0.05, Mse=3.14). In addition, researchers stated during paired comparisons there was a significant improvement with memory (HSD: p<0.05) in contrast to the "dummy energy drink".

Wesnes et al. (2013) utilized the 5hr Energy Drink on partially sleep-deprived individuals. Participants were required to restrict sleep between 3 and 6 hours the night before each test session. By limiting participants' sleep, researchers were able to examine the effects caffeine has on fatigue. Upon arrival to the testing center, baseline measurements were taken. Following that, participants were given the study product they were scheduled to receive and then performed the 10 CDR System tasks hourly for six hours. It was determined that the energy shot had favorable effects to hold information in working memory (F(1,92)= 22.04, p<0.0001) and to store and retain verbal and non-verbal information in episodic memory (F(1,92)=15.48, p=0.0002). This information indicated that the 5hr Energy Shot could help facilitate performance on memory and other cognitive tasks in partially sleep-deprived individuals.

Lastly, Adan and Serra-Grabulosa (2010) also studied caffeine's effects on memory. In contrast to previous studies, researchers utilized a liquid form of caffeine that was not based off brand name energy drinks. Adan and Serra-Grabulosa (2010) instead incorporated 75 mg of caffeine powder with water. Four beverages were comprised of a placebo containing water, water plus 75 mg of powder caffeine, water plus 75 g of glucose, and water plus the caffeine and glucose amounts. Thirty minutes following the intake of the assigned beverage, participants began six performance recordings that assessed memory. Researchers determined caffeine and placebo to have no differences when assessing working memory (placebo: 18.50 $\pm$ 0.81; caffeine: 18.11 $\pm$ 0.82; caffeine+glucose 17.00 $\pm$ 0.79). However, during post-hoc testing, differences in memory were found only in consolidation memory which was greater in the caffeine+glucose group ($F(3,68)=3.321$, $p= 0.0001$, $n^2= 0.320$). Thus, no concrete conclusions can be made about caffeine's effect on memory because caffeine was not isolated from glucose.

In conclusion, due to the complexity of memory, it is difficult to fully determine if caffeine has positive effects on the aspects of memory. However, some of these researchers have determined caffeine to be an effective way for an individual to enhance memory in both episodic and working memory. In conclusion, it can be determined that more research should be done on whether or not caffeine truly has effects in both working and episodic memory.

Attention/Concentration

In psychology, attention is how an individual processes information (McCallum, 2016). It is the concentration of awareness on a certain aspect while blocking out other stimuli. Attention is also defined as the state of current awareness. According to McCallum (2016), attention may be understood as a condition of selective awareness, which governs the extent and quality of

one's interactions with one's environment. Due to this, attention is another commonly researched topics when assessing effects of caffeine on neurocognitive function.

Many of the previously stated studies assessed caffeine's effect on attention and concentration. However, only three had found significant results when assessing effects of caffeine on attention and concentration (Alford, Cox & Wescott, 2001; Giles et al., 2012; Wesnes et al., 2013). Two of these studies utilized market energy drinks and one utilized amounts of caffeine similar to a market energy drink. Alford, Cox and Wescott (2001) performed three separate studies, which were then combined into one manuscript discussing each. The second study discussed assessed heart rate, blood pressure, subjective alertness, and choice reaction time pre- and post-treatment (n=14, male=7, female=7). Researchers again utilized the Red Bull Energy Drink (80 mg of caffeine) but had no control drink. Outcomes revealed significant improvements for subjective alertness ($F(2,25)=28.84$, $p<0.001$, MSE=0.97) with the Red Bull Energy Drink. In addition, concentration task performance provided a minor significance ($F(3,32)=2.64$, $p<0.07$, MSE=5.39) with the Red Bull Energy Drink. Overall, this means there was improved performance for both subjective alertness and concentration tasks after the consumption of the Red Bull Energy Drink.

Similar to that, Wesnes et al. (2013) utilized the 5hr Energy Shot (157 mg), which is another popular market energy drink. Wesnes et al. (2013) required participants to restrict sleep between three and six hours the night before each test session. By limiting participants' sleep, researchers were able to examine the effects caffeine has on partially sleep-deprived individuals to mimic fatigue. Researchers determined the energy shot was superior over placebo during the six-hour time frame (power of attention: $F(1,92)=37.22$, $p<0.0001$; continuity of attention:

$F(1,92)=70.74$, $p<0.0001$). These findings determine caffeine can produce an enhancement in alertness. However, it can only be applicable to partially sleep-deprived individuals.

Lastly, Giles et al. (2012) utilized amounts of caffeine commonly found in the Monster Energy Drink (200 mg) in capsule form. The study compared four different conditions: caffeine and taurine, no caffeine and taurine, caffeine and no taurine, and placebo. Participants waited 30 minutes before completing the three attention tasks. Similar to the aforementioned studies, researchers also found an increase in attention from caffeine when compared to placebo ($F(1,46)= 7.184$, $p<0.05$).Therefore, it can be determined that caffeine can assist in enhancing alertness.

Although attention is stated to be one of the main effects associated with caffeine consumption, only three researchers were able to find significant effects. However, based on these results, there is ability to determine caffeine can have a positive effect on alertness and/or concentration within amounts of caffeine ranging from 80mg to 200mg.

Conclusion

In conclusion, it is well know that caffeine is one of the most consumed substances in the United States (Giles et al., 2012; Hartley et al., 2004; Hoffman, 2010; Ruxton, 2008). Ever since the debut of Red Bull Energy Drink in 1997, energy drinks have become a leader in the caffeine drink market (Malinauskas et al., 2007). Caffeine has become a frequently researched topic partly because of its effects on neurocognitive function (Adan & Serra-Grabulosa, 2010; Alford, Cox, & Wescott, 2001; Giles et al., 2012; Peacock, Martin, & Carr, 2012; Seidl et al., 2000; Smit & Rogers, 2002; Wesnes et al., 2013). In addition, studies have shown caffeine can produce some effects for athletes and students who need to gain focus, decrease fatigue, and improve cognitive function (Adan & Serra-Grabulosa, 2010; Alford, Cox, & Wescott, 2001; Giles et al.,

2012; Peackock, Martin, & Carr, 2012; Seidl et al., 2000; Smit & Rogers, 2002; Wesnes et al., 2013).

ImPACT is a commonly utilized tool for assessing an athlete's cognitive function pre- and post-concussion. Although ImPACT is generally used for assessing if an athlete suffered a concussion, it has other applications because it evaluates the overall cognitive function of an athlete. This test can be an effective way to test neurocognitive function not only on athletes, but the general public as well. Determining the effects caffeine has by using this test can lead us to understanding how caffeine could be beneficial or a problem for our athletes, as well as determining if caffeine affects ImPACT results.

Lastly, studying caffeine's effects makes a difference for clinicians because caffeine can have positive effects as well as negative side effects on student athletes. Knowing those side effects can help determine if an individual should be consuming caffeine, especially in large quantities. In addition, determining if ImPACT results are affected by an athlete who has consumed caffeine prior to testing will help clinicians determine safe return-to-play protocols. To the researchers' knowledge, no previous research has been conducted on caffeine and neurocognitive performance, utilizing ImPACT. This has led to the initiated drive to perform this study due to the importance associated with accurate concussion baseline tests.

CHAPTER 3. METHODS

Purpose

The purpose of this study was to determine caffeine's effect on neurocognitive function in collegiate males. The method for measuring neurocognitive function was ImPACT. This project utilized a pre-test/post-test design by comparing 12 college males who consumed Rockstar Punched (treatment) to 12 college males who consumed sparkling flavored water (control). Comparing a treatment to a control group, researchers were able to study the effects of neurocognitive function as measured by composite scores of ImPACT.

The research question addressed through this study was the following:

1. Is there an effect on neurocognitive function in collegiate males after the consumption of the Rockstar Punched energy drink compared to control drink?

A randomized, within and between subject design was used for this study. The independent variable in the study was the type of drinks consumed: Rockstar Punched (treatment) and sparkling flavored water (control). The dependent variables in the study were the results of the multiple components of ImPACT.

Subjects

The study consisted of 24 male participants from the ages of 18 to 28 years old who were non-NCAA athletes. The subjects were recruited from email, word-of-mouth, and recruitment of students in the Health, Nutrition, and Exercise Sciences Department (HNES) at North Dakota State University (NDSU). Each of the participants signed an informed consent form approved by the Institutional Review Board (IRB) at NDSU (Appendix A).

Participants were selected if they met the inclusion criteria: male, age 18 to 28 years old and recreationally active (30 minutes of moderate intensity aerobic physical activity at least five

days per week) (Thompson, 2010, p. 8). Participants filled out a Health History Questionnaire (Appendix B) prior to being accepted in the study to determine their qualification status. Exclusion criteria included sustaining a concussion or traumatic brain injury within six months prior to the study, history of heart conditions, diabetes, seizures, or epilepsy. Little to no risk was associated with this study. However, if an event did occur during testing, certified athletic trainers were on site at all times to assist in an emergency.

Instrumentation

Participants completed the ImPACT online assessment (ImPACT Applications Inc., 2015). ImPACT is an objective measure to determine subtle changes in cognition that occur with a concussion (Covassin et al., 2009). ImPACT consists of three sections that include demographics, post-concussion symptoms scale, and neurocognitive test modules. Within the third category there are six modules that evaluate attention span, working memory, sustained and selective attention time, response variability, nonverbal problem solving, and reaction time (Allen et al., 2011; ImPACT Applications, Inc., 2015; Nakayama et al., 2014). The six test modules provide five composite scores and include verbal memory, visual memory, reaction time, visual motor speed, and impulse control (Allen et al., 2011). According to ImPACT Applications, Inc., (2015) the six modules are as listed: module one word discrimination, module two design memory, module three x's and o's, module four symbol matching, module five color match, and module six three letter memory.

From there, these module scores are combined to make up the five composite scores. The scores and percentage correct from the word memory, symbol match, and three letters task figure the verbal memory composite. In addition, scores from design memory and x's and o's, figure the visual memory composite. Also, the visual motor speed composite comes from the weighted

averages of x's and o's, and three letters module. Next, scores from the x's and o's, symbol match and color match module average to make the reaction time composite score. Finally, the total number of errors from x's and o's and total number of commissions on color match combine to make the impulse control composite score (Allen et al., 2011). Overall the test takes on average 25-30 minutes to complete.

ImPACT also contains a Validity Index to identify invalid performance that could be due to insufficient effort the examinee gives (Allen et al., 2011). The validity index includes six formulae to determine if insufficient effort is being put forth. These formulae include: 1) impulse control composite score of 30 or higher, 2) x's and o's total incorrect score of 30 or higher, 3) processing speed composite score of 25 or below, 4) reaction time composite score of > 0.79, 5) verbal memory composite score below 70%, and or 6) visual memory composite score below 60% (Allen et al., 2011). If any of the stated conditions were met after the testing process, this individual's test would be considered questionable due to potentially insufficient effort given by the examinee. During this study, subjects were verbally encouraged to perform to the best of their ability. However, if any of these subjects fell into a questionable test based on the Validity Score, those results were not included in the statistics.

Procedure

Testing days were selected based on the researchers' availability. Participants were allowed to sign up for any time that worked in their schedule to complete the initial ImPACT baseline test. Initial baseline and follow-up testing was held at NDSU in an on-campus computer lab or conference room with laptop availability to access ImPACT. On the first day of a subject's testing, each participant read and signed an informed consent with the health history questionnaire.

ImPACT was used as a baseline and comparison for the second testing day. The initial and second visit must have been separated by exactly 48 hours. Participants were asked to refrain from consuming caffeine outside of the study during that 48-hour period. Participants were randomized and blinded into two different groups, placebo and energy drink.

After the 48-hour separation period, participants returned to the computer lab. Based on the group the participants were placed into, they received either the placebo, which consisted of Clear American Strawberry Sparkling Water (0 mg caffeine) and red color additive to make it similar to the energy drink group, which consisted of the popular energy drink Rockstar Punched. One 16-ounce can of Rockstar Punched was measured into a fluid ounce measuring cup and poured into a red cup. One can of Rockstar Punched consisted of 120 mg of caffeine. For the control drink, the Clear American Strawberry Sparkling Water also was poured into a fluid ounce measuring cup to equal the same amount as the Rockstar Punched and poured into a red cup as well, then red color additive was added to the drink. Participants needed to consume the entire drink and try to do so in less than 30 minutes. Ninety minutes following consumption of either drink, subjects took the ImPACT test again. During the 90-minute break between consumption and retesting, subjects remained in the testing center and were allowed to partake in any activity they preferred to pass the time. After participants completed the test for a second time, they then had completed the testing procedure and were entered into a drawing for a chance to win ten dollars in cash.

Statistical Analysis

ImPACT scores were analyzed in a two-factor mixed ANOVA. The between-subjects factor was the group (control or treatment), and the within-subjects factor was the repeated measure for each participant, resulting in a 2x2 mixed ANOVA. The analysis was conducted on

the total score and repeated for each subcomponent. Post hoc statistical significance was determined by Tukey's honestly significant difference (HSD) test. The primary comparison of interest was the interaction effect of treatment and time. The *p*-value was set at $\leq .05$. Given the low number of planned follow-up contrasts, a Bonferroni correction was not necessary.

CHAPTER 4. RESULTS

Introduction

One of the most common substances that is thought to help produce subjectively positive effects, both mentally and physically, is caffeine (Giles et al., 2012; Hartley et al., 2004; Hoffman, 2010; Ruxton, 2008). Caffeine can be found in a variety of different sources, however, one of the most common and most consumed by college athletes are energy drinks (Attila & Cakir, 2011; Giles et al., 2012; Hoffman, 2010). Athletes report positive gains from consuming caffeine, such as improved alertness, increased energy, better attention, and increased endurance and performance (Attila & Cakir, 2010; Reissig et al., 2008; Smit & Rogers, 2002; Wesnes et al., 2013). Based on the subjectively positive effects experienced, athletes have been taking supplements that usually contain large amounts of caffeine (Drug Free Sport, 2010). Reissig et al. (2008) state that having an athlete consume an energy drink in order to enhance athletic performance is no different than an athlete consuming anabolic steroids or pharmaceutical stimulants to improve their athleticism. Due to this statement, amongst other findings in research on cognitive function, it is important to understand how caffeine can affect athletes' cognitive function.

Testing neurocognitive function has become an accessible assessment with the modifications in modern technology. Currently, there are a variety of different computer-based neurocognitive testing protocols. One of the most commonly used tests in athletic training is the Immediate Post Concussion Assessment and Cognitive Testing (ImPACT). This test assesses five different components of the athlete's cognitive function pre- and post-concussion. The five components included are verbal memory, visual memory, reaction time, processing speed, and impulse control (Allen et al., 2011; ImPACT Applications, Inc., 2015; Nakayama et al., 2014).

Even though ImPACT is utilized for assessing cognitive function before and after a concussion, it is a useful tool to utilize when assessing cognitive function in general.

The purpose of this study was to determine caffeine's effect on neurocognitive function in collegiate males. The method for measuring neurocognitive function was ImPACT. This project utilized a pre-test/post-test design by comparing 12 college males who consumed Rockstar Punched (treatment) to an additional 12 college males who consumed sparkling flavored water (control). Comparing a treatment to a control group, researchers were able to study the effects of neurocognitive function as measured by composite scores of ImPACT. The research question that was addressed through this study was the following:

1. Is there an effect on neurocognitive function in collegiate males after the consumption of the Rockstar Punched energy drink compared to the control drink?

Methodology

Participants were required to report for two days of testing sessions. The first and second visit was separated by exactly 48 hours. Participants completed ImPACT both days and asked to refrain from consuming caffeine outside of the study during that 48-hour period. After completing the baseline ImPACT, subjects returned after the 48-hour separation period. Based on the group the participants were randomly placed into either the control, which consisted of Clear American Strawberry Sparkling Water (0 mg caffeine) and red color additive to make it similar to the energy drink group, which consisted of the popular energy drink Rockstar Punched. One 16-ounce can of Rockstar Punched was measured into a fluid ounce measuring cup and poured into a red cup. One can of Rockstar Punched consisted of 120 mg of caffeine. For the placebo drink, the Clear American Strawberry Sparkling Water also was poured into a fluid ounce measuring cup to equal the same amount as the Rockstar Punched and poured into a

red cup as well, then red color additive was added to the drink. Participants needed to consume the entire energy drink or placebo in no more than 30 minutes. Following consumption of either drink, subjects took the ImPACT test after a 90-minute break. During 90-minute break between consumption and retesting, subjects remained in the testing center and were allowed to partake in any activity they preferred to pass the time.

Descriptive Statistics

A total of 24-males from local universities volunteered to participate in this study (see Table 4.1.). The participants subjectively provided the following information in the table presented. All participants completed the study in its entirety with no attrition by any of the subjects.

Table 4.1

Subjects' Demographic Information

	Age (years)	**Height (in)**	**Weight (lbs)**	**Years of Completed Education**
Mean	22.38	70.34	185.60	15
SD	$\pm$ 2.53	$\pm$ 2.91	$\pm$ 27.60	$\pm$ 1.50

Statistical Analysis

ImPACT scores were analyzed in a two-factor mixed ANOVA. The between-subjects factor was the group (control or treatment), and the within-subjects factor was the repeated measure for each participant, resulting in a 2x2 mixed ANOVA. The analysis was conducted on the total score and repeated for each subcomponent. The *p*-value was set at $\leq .05$. Post hoc statistical significance was determined by Tukey's honestly significant difference (HSD) test.

The primary comparison of interest was the interaction effect of treatment and time. Given the low number of planned follow-up contrasts, a Bonferroni correction was not necessary.

Neurocognitive Test Results

Verbal Memory

For the verbal memory composite score, the treatment group exhibited a very slight increase from the first measurement (M=91.5, SD=9.09) to the second measurement (M=92.3, SD=11.32). The placebo group displayed a similarly small increase from the first measurement (M=89.2, SD=7.79) to the second measurement (M=92.4, SD=6.16). Neither the effect of time ($F[_{1, 22}]$=1.96, p=.175, η^2=.082) nor the interaction effect ($F[_{1, 22}]$=0.69, p=.416, η^2=.03) were statistically significant. There was also no statistically significant difference between the groups ($F[_{1, 22}]$=0.12, p=.735, η^2=.005). All of the effect sizes were small.

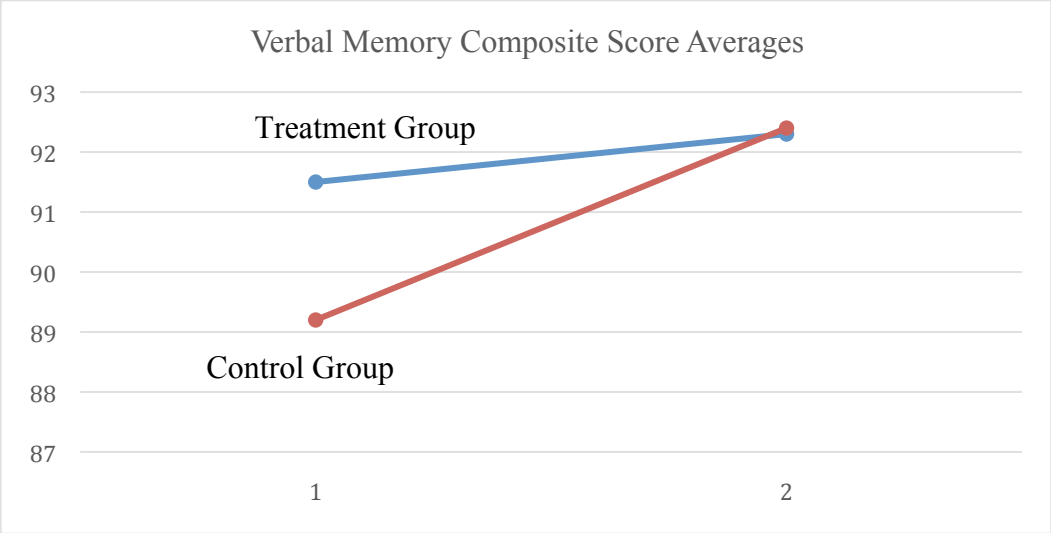

Figure 4.1. Verbal Memory Composite between Treatment and Control Baseline and Post-Treatment

Visual Memory

The visual memory composite treatment group displayed a minimal increase from first measurement (M= 83.2, SD= 9.8) to the second measurement (M= 83.7, SD=13.3). While on the other hand, the placebo group displayed a larger increase from first measurement (M=80.7, SD=

16.0) compared to the second measurement (M= 87.4, SD= 12.6). Neither the effect of time ($F[_{1,22}]$= 1.78, p= .197, n^2=.075) nor the interaction effect ($F[_{1,22}]$=1.31, p=.264, n^2=.056) were statistically significant. There was no statistically significant difference between groups ($F[_{1,22}]$= .016, p=.901, n^2=.001).

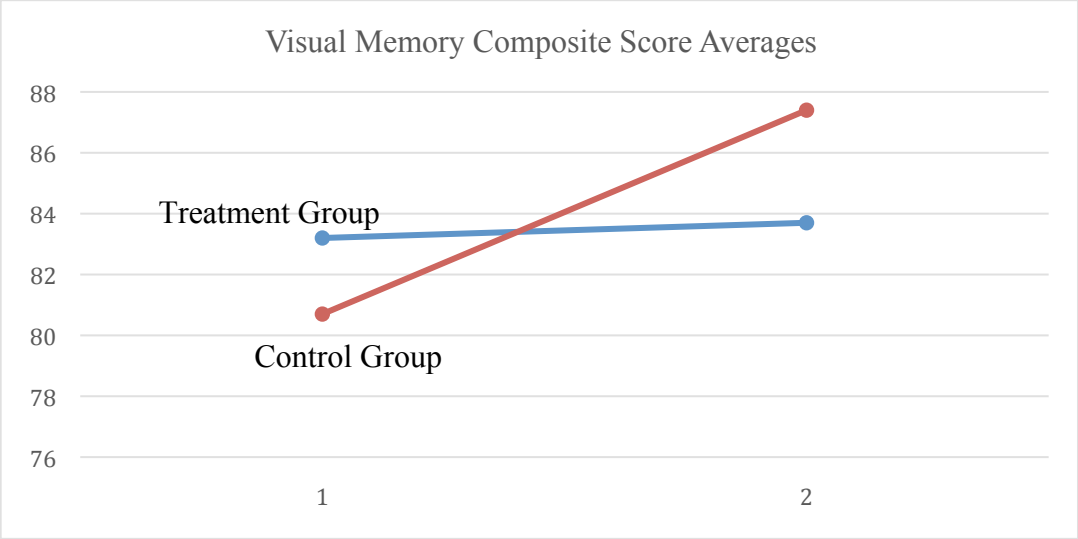

Figure 4.2. Visual Memory Composite between Treatment and Control Baseline and Post-Treatment

Visual Motor Speed `

Within the visual motor speed composite score, there was a minor increase from first measurement (M=43.8, SD=6.0) compared to the second measurement (M=44.6, SD=6.3) with the treatment group. However, with the placebo group, there was a minimal decrease in the first treatment (M=44.0, SD=8.2) compared to the second measurement (M=43.2, SD=7.5). Again, neither the effect time ($F[_{1,22}]$= .005, p=.944, n^2=.000) nor the interaction effect ($F[_{1,22}]$=.660, p=.425, n^2=.029) were statistically significant. There was no statistically significant difference between groups ($F[_{1,22}]$=.056, p=.815, n^2=.003).

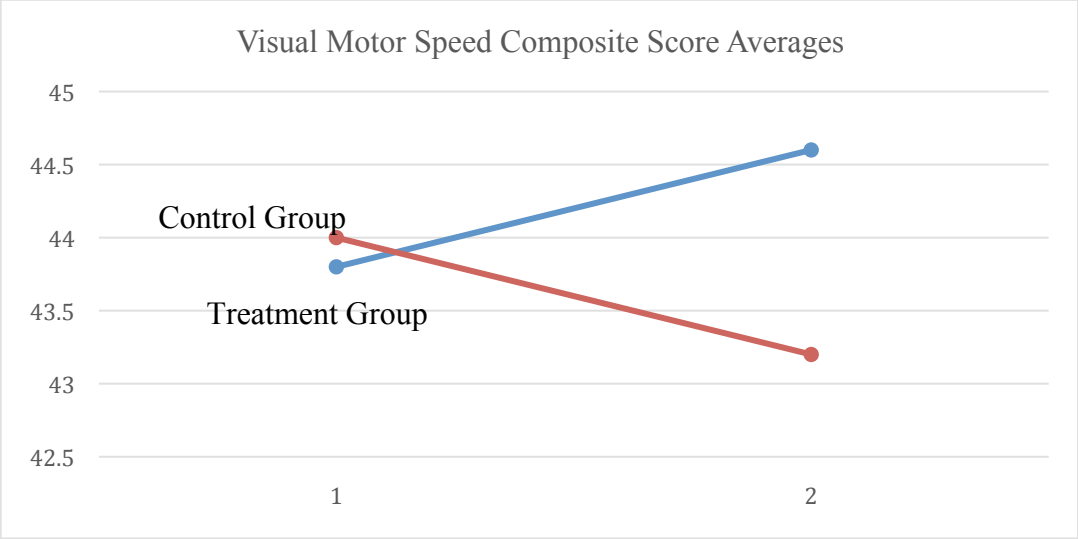

Figure 4.3. Visual Motor Composite between Treatment and Control Baseline and Post-Treatment

Reaction Time

For the reaction time composite score, the treatment group presented the baseline measurement at (M=.55, SD=.11) compared to second measurement (M=.54, SD=.14). Based on these results, there was a minimal decrease between the two groups suggesting that caffeine does not have a statistically significant effect on reaction times. The placebo group also displayed a minimal decrease between the baseline measurement (M=.58, SD=.09) and the second measurement (M=.58, SD=.08). Neither the effect time ($F[_{1,22}]$=.381, p=.543, n^2=.017) nor the interaction effect ($F[_{1,22}]$=.015, p=.903, n^2=.001) was statistically significant. Again, there was no statistically significant difference between groups ($F[_{1,22}]$=.533, p=.473, n^2=.024). All effect sizes were minimal.

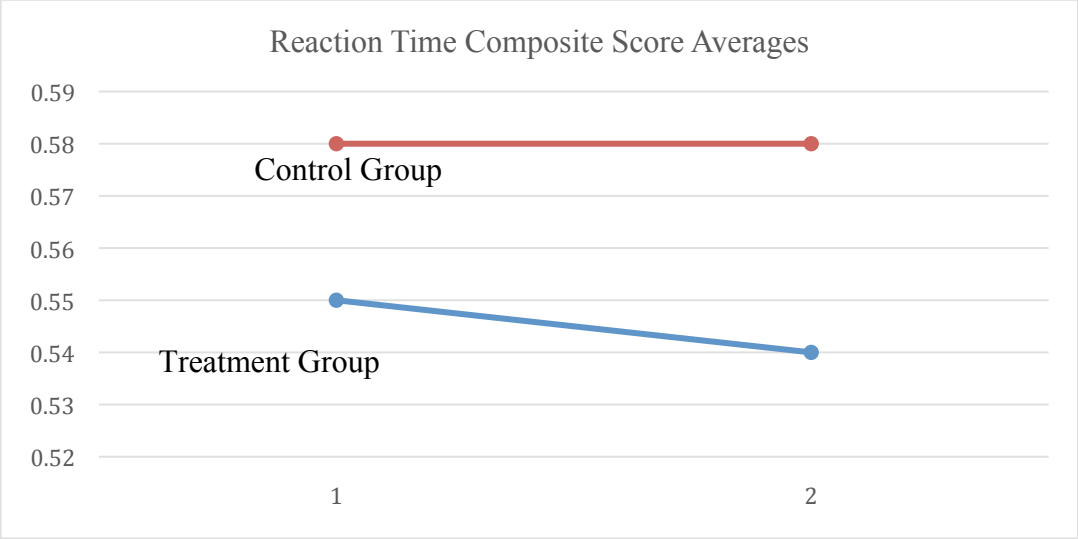

Figure 4.4. Reaction Time Composite between Treatment and Control Baseline and Post-Treatment

Impulse Control

Lastly, the impulse control composite score produced a minimal decrease from the first measurement (M=5.7, SD=3.3) compared to the second measurement (M=5.5, SD=4.2) for the treatment group. Conversely, the placebo group produced an increase between the first measurement (M=5.1, SD=4.7) and the second measurement (M=5.9, SD=3.7). Similar to results of other composite scores, neither the effect time ($F[_{1,22}]$=.201, p=.658, n^2=.009) nor the interaction effect ($F[_{1,22}]$=.453, p=.508, n^2=.020) was statistically significant. In addition, there was no statistically significant differences between groups ($F[_{1,22}]$=.003, p=.955, n^2=.000).

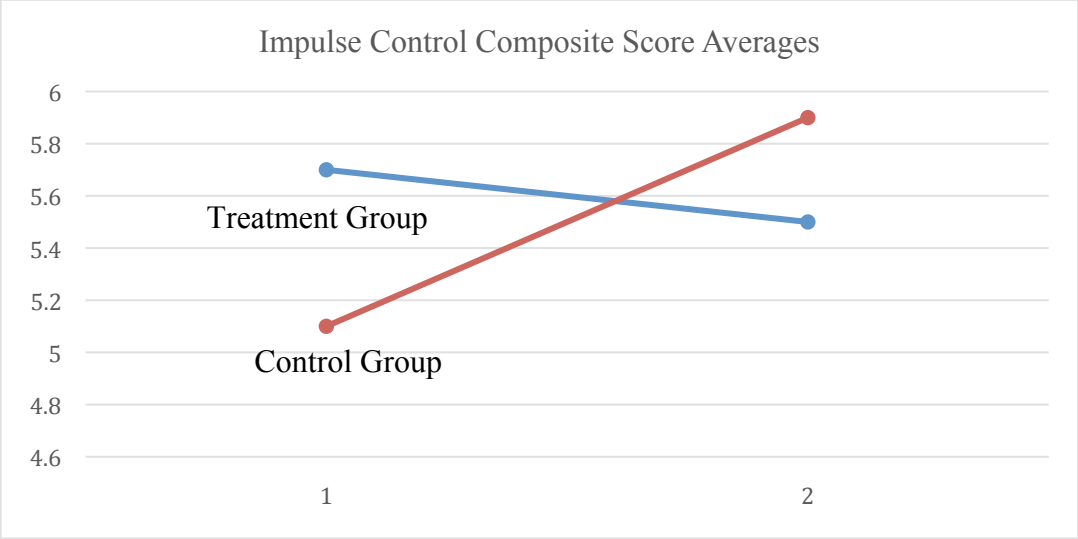

Figure 4.5. Impulse Control Composite between Treatment and Control Baseline and Post-Treatment

Normative Data of ImPACT Composite Scores

Current researchers analyzed the mean and standard deviation of the raw data collected from both the treatment and control groups after caffeine consumption. Normative data associated with ImPACT composite scores includes information for verbal memory, visual memory, visual motor speed and reaction time. These classifications range from impaired to very superior. "Classification ranges and their corresponding percentile rank ranges are commonly used, although not universally accepted: Impaired <2nd percentile; Borderline 3rd-9th percentile; Low Average 10th-24th percentile; Average 25th-75th percentile; High Average 76th-90th percentile; Superior 91st-98th percentile; Very Superior 99th percentile. Thus if an individual obtained a score at the 42nd percentile, this would mean that his performance would be greater than or equal to 42% of his same-aged peers in the general population, and that his score would fall in the Average classification range" (Iverson, Lovell, & Collins, 2003 p. 4).

Control Group

Based on the information from Iverson, Lovell, and Collins (2003) current researchers were able to compare results to the published classifications of ImPACT composite scores. The

control group during post-consumption testing on verbal memory composite score (M=92.4, SD= 6.16) and visual memory composite score (M=87.4, SD=12.6) fell within the average category, (83-94) and (69-94) respectively. The visual motor speed composite score for the control group during post-consumption testing (M=43.2, SD=7.5) fell into the high average classification (42.1-46.0). Finally, the reaction time composite score for the control group during post-consumption testing (M=0.58, SD=.08) also fell into the average classification (0.60-0.52)

Treatment Group

For the treatment group during post-consumption testing in the verbal memory composite score, the mean was 92.3 with a standard deviation of 11.3. According to Iverson, Lovell, and Collins (2003), this group fell within the average classification for composite scores in verbal memory (83-94). Similarly, the visual memory composite score average for the treatment group during post-consumption testing (M=83.7, SD=13.3) also fell into the average category (69-94). In contrast, the visual motor speed composite score for the treatment group during post-consumption testing (M= 44.6, SD=6.3) fell into the high average classification (42.1-46.0). Lastly, the treatment group during post-consumption testing for reaction time composite score (M=0.54, SD=0.14) also fell into the average classification (0.60-0.52). See Table 4.2. for clarity purposes on the overview of comparing treatment and control groups composite score averages and standard deviations during post-consumption testing.

Table 4.2

Comparison of Control and Treatment in Post-Consumption Testing

	Verbal Memory	Visual Memory	Visual Motor Speed	Reaction Time
Control	M= 92.4 SD= 6.16	M=87.4 SD=12.6	M=43.2 SD=7.5	M=0.58 SD= 0.08
Treatment	M= 92.3 SD= 11.32	M=83.7 SD=13.3	M=44.6 SD=6.3	M=0.54 SD=0.14

Conclusion

Based on the results, it was determined that caffeine has no statistical significance on the composite scores of ImPACT. All composite scores had a minimal effect from baseline to post-consumption testing with both treatment and placebo groups. ImPACT composite scores represent summary scores that provide basic information regarding an individual's performance in cognitive domains (ImPACT Applications Inc., 2016). The verbal memory composite score evaluates attentional processes, learning, and memory within the verbal-domain (ImPACT Applications Inc., 2016). Within this study, the verbal memory composite scores, for both treatment and placebo groups, experienced small increases between baseline and post-consumption testing. This determines that caffeine has no real effect on ImPACT verbal memory composite score.

Next, the visual memory composite score evaluates visual attention and scanning, learning, and memory (ImPACT Applications Inc., 2016). Similar to the verbal memory score within the present study, visual memory composite scores also had small increases but no statistical significance between baseline and post-consumption testing. Again, this is important because it is determined caffeine has no effect on visual memory composite scores of ImPACT.

The visual motor speed composite score evaluates visual processing, learning, memory, and visual-motor response speed (ImPACT Applications Inc., 2016). However, within this study, visual motor speed composite scores within the placebo group had a decrease in results from baseline to post-consumption as opposed to the treatment group who experienced a small increase between the baseline and post-consumption tests. However, a lack of statistical significance indicates no generalized conclusions can be made on the effect of caffeine on visual motor speed.

Reaction time composite scores evaluate average response speed of an individual (ImPACT Applications Inc., 2016). Reaction times did improve with both placebo and treatment groups within this study, although it was not statistically significant. The improvements in reaction time with both groups led researchers to determine that caffeine consumption after 90 minutes has no effect on reaction time in comparison to placebo.

Lastly, impulse composite scores provide a measure of errors on testing. This is useful in determining test validity and this score indicates the sum of errors committed during different phases of the test (ImPACT Applications Inc., 2016). There was a minimal decrease in impulse control composites with the treatment group and a minimal increase with the placebo group between baseline and post-consumption tests. Again, all results were not statistically significant determining caffeine does not have effects on neurocognitive performance.

CHAPTER 5. DISCUSSION

Introduction

One of the most common substances that is thought to help produce subjectively positive effects, both mentally and physically, is caffeine (Giles et al., 2012; Hartley et al., 2004; Hoffman, 2010; Ruxton, 2008). Caffeine can be found in a variety of different sources, however, one of the most common and most consumed by college athletes are energy drinks (Attila and Cakir, 2011; Giles et al., 2012; Hoffman, 2010). Athletes report positive gains from consuming caffeine, such as improved alertness, increased energy, better attention, and increased endurance and performance (Attila & Cakir, 2010; Reissig et al., 2008; Smit, & Rogers, 2002; Wesnes et al., 2013). Based on the subjectively positive effects experienced, athletes have been taking supplements that usually contain large amounts of caffeine (Drug Free Sport, 2010). Reissig et al. (2008) state that having an athlete consume an energy drink in order to enhance athletic performance is no different than an athlete consuming anabolic steroids or pharmaceutical stimulants to improve their athleticism. Due to this statement, amongst other findings in research on cognitive function, it is important to understand how caffeine can affect athletes' neurocognitive function.

Testing neurocognitive function has become an accessible assessment with the modifications in modern technology. Currently, there are a variety of different computer-based neurocognitive testing protocols. One of the most commonly used tests in athletic training is the Immediate Post Concussion Assessment and Cognitive Testing (ImPACT). This test assesses five different components of the athlete's cognitive function pre- and post-concussion. The five components included are verbal memory, visual memory, reaction time, processing speed, and impulse control (Allen et al., 2011; ImPACT Applications, Inc., 2015; Nakayama et al., 2014).

Even though ImPACT is utilized for assessing cognitive function before and after a concussion, it is a useful tool to utilize when assessing cognitive function in general.

The purpose of this study was to determine caffeine's effect on neurocognitive function in collegiate males. The method for measuring neurocognitive function was ImPACT. This project utilized a pre-test/post-test design by comparing 12 college males who consumed Rockstar Punched (treatment) to 12 college males who consumed sparkling flavored water (control). Comparing a treatment to a control group, researchers were able to study the effects of neurocognitive function as measured by composite scores of ImPACT.

The research question that was addressed through this study was the following:

1. Is there an effect on neurocognitive function in collegiate males after the consumption of the Rockstar Punched energy drink compared to the control drink?

Research Findings

Current Neurocognitive Function Results Compared to Past Literature

Researchers of the current project determined caffeine does not have a statistically significant effect on neurocognitive function in collegiate males. These outcomes were based on the results from the five ImPACT composite scores. The verbal memory composite score evaluates attentional processes, learning, and memory within the verbal-domain (ImPACT Applications Inc., 2016). Next, the visual memory composite score evaluates visual attention and scanning, learning, and memory (ImPACT Applications Inc., 2016). The visual motor speed composite score evaluates visual processing, learning, memory, and visual-motor response speed (ImPACT Applications Inc., 2016). Reaction time composite score evaluate average response speed of an individual (ImPACT Applications Inc., 2016). Lastly, impulse composite scores provide a measure of errors on testing. This is useful in determining test validity and this score

indicates the sum of errors committed during different phases of the test (ImPACT Applications Inc., 2016). Current results contrasted those found within previous research that was mentioned within the literature review. Based on the past research, seven studies found decreases in reaction time after participants consumed caffeine (Adan & Serra-Grabulosa, 2010; Alford, Cox, & Wescott, 2001; Giles et al., 2012; Peacock, Martin, & Carr, 2012; Seidl et al., 2000; Smit & Rogers, 2002; Wesnes et al., 2013). In addition, four studies determined improvements with memory after caffeine consumption (Adan & Serra-Grabulosa, 2010; Alford, Cox, & Wescott, 2001; Giles et al., 2012; Wesnes et al., 2013) and three studies found improvements with attention after consumption of caffeine (Alford, Cox, & Wescott, 2001; Giles et al., 2012; Wesnes et al., 2013) that will be discussed later in this chapter. For clarity purposes, refer to Table 5.2. for an overview comparing composite scores to the main categories in previous literature: reaction time, memory, and attention/concentration.

Table 5.1

Composite Score Measurements and Past Literature

Composite Score Category	Reaction Time, Memory, and/or Attention/Concentration	Past Literature
Verbal Memory	Memory and Attention/Concentration	Memory (4) Attention/Concentration (3)
Visual Memory	Memory and Attention/Concentration	Memory (4) Attention/Concentration (3)
Visual Motor Speed	Reaction Time and Memory	Reaction Time (7) Memory (4)
Reaction Time	Reaction Time	Reaction Time (7)
Impulse Control	Attention/Concentration	Attention/Concentration (3)

Reaction Time

The current study did not reveal differences in reaction time in college students who ingested caffeine compared to a control group. These results are in contrast to previous research that found faster reaction times after taking caffeine (Adan & Serra-Grabulosa, 2010; Alford, Cox, & Wescott, 2001; Giles et al., 2012; Peacock, Martin, & Carr, 2012; Seidl et al., 2000; Smit & Rogers, 2002; Wesnes et al., 2013). Differences between the studies could have been attributed to methodology utilized by the different researchers. For example, five of the seven studies utilized a double blind and counterbalanced design. This meant that both researchers and participants were blinded to treatment received. In addition, all participants in the five projects received both the treatment and control during the testing process. Due to time constraints and limited resources, current researchers were unable to mimic the double blind and counterbalanced design of past studies and therefore incorporated a single blind design. Each participant was blinded to the type of drink he received (treatment or control) but the research team was aware of the intervention medium.

Another reason for the differences in results may have been due to the amount of caffeine participants consumed. Six of the past studies utilized caffeine amounts that are commonly found in market energy drinks (Alford, Cox, & Wescott, 2001; Giles et al., 2012; Peacock, Martin, & Carr, 2012; Seidl et al., 2000; Smit & Rogers, 2002; Wesnes et al., 2013). Every caffeine drink markets a different amount of caffeine ranging from 75 mg to 200 mg. The current researcher project incorporated a market energy drink, Rockstar Punched. The amount of caffeine utilized within the current research fell in between the amounts of past research at 120 mg of caffeine. However, unlike past research, current researchers were unable to find statistically significant

results for reaction time associated with the 120 mg of caffeine (Reaction Time: $F[_{1,22}]= .533$, $p= .473$, $n^2=.024$; Visual Motor Speed: ($F[_{1,22}]=.056$, $p=.815$, $n^2=.003$).

Lastly, the amount of time between caffeine consumption and neurocognitive testing was important for research methodology. The time between consumption and testing is important because of caffeine's half-life as well as the amount of time caffeine is believed to be at its peak in blood plasma in an individual. The peak in blood plasma of caffeine has been found to be between 30 and 120 minutes (Benowitz, 1990, Giles et al., 2012). Five of the past studies conducted had participants wait between 30 and 60 minutes from caffeine consumption to neurocognitive testing (Adan & Serra-Grabulosa, 2010; Alford, Cox, & Wescott, 2001; Giles et al., 2012; Peacock, Martin, & Carr, 2012; Seidl et al., 2000). In contrast, researchers of the current project had participants wait 90 minutes between caffeine consumption and testing. Current researchers selected this amount because it fell between the 30 to 120 minute time frame when caffeine is at its peak in blood plasma. In addition, researchers were mindful of real-life situations of when an athlete could potentially consume a caffeine drink, suffer a concussion during a practice or competition, and then begin a concussion assessment.

Memory

Within the present study, researchers did not find statistical significance on the memory composite scores for the treatment group compared to the control group; Verbal Memory: ($F[_{1,22}]=0.12$, $p=.735$, $n^2=.005$); Visual Memory: ($F[_{1,22}]=.016$, $p= .901$, $n^2=.001$); Visual Motor Speed: ($F[_{1,22}]=.056$, $p=.815$, $n^2=.003$). Four of the past studies conducted on caffeine's effects on neurocognitive function found improvements with memory (Adan & Serra-Grabulosa, 2010; Alford, Cox, & Wescott, 2001; Giles et al., 2012; Wesnes et al., 2013). Researchers of the past literature limited participants' outside caffeine intake. Participants were asked to refrain from

additional caffeine intake 18 to 24 hours prior to testing (Adan & Serra-Grabulosa, 2010; Giles et al., 2012; Wesnes et al., 2013). In contrast, current researchers asked participants to refrain from outside caffeine consumption for 48 hours. This time frame was chosen because current researchers wanted neurocognitive scores to be reflective of the control or treatment drink consumed the day of post-consumption testing. This small difference between methodologies could have caused current researchers to conclude the results of caffeine on neurocognitive function.

In addition to restricting caffeine consumption, test-retest considerations of the current study could have caused the current outcomes. The typical time frame of test-retest considerations for the ImPACT is a minimum of five days (Nakayama et al., 2014). However, researchers considered it unfeasible to ask college males to refrain from outside caffeine intake for five days and to come back to the testing center after that amount of time for post-consumption testing. Therefore researchers shortened the time frame to 48 hours. A few of the previous researchers stated times between testing sessions and times varied amongst them. For example, Alford, Cox, & Wescott (2001) stated that the study separated test days within a week. In contrast, one study did not take baseline measurements of neurocognitive tasks. Instead, participants arrived to the testing center, ingested their scheduled beverage and 30 and 60 minutes following that began testing procedures. There was no mention of time between participants receiving each treatment. In addition, Wesnes et al. (2013) stated the two testing days were to be separated by at least one day and no more than 16 days.

Attention/Concentration

The present study did not find statistical significance on the attention/concentration based composite scores for the treatment group (Visual Motor Speed: ($F[_{1,22}]= .056$, $p=.815$, $n^2= .003$;

Impulse Control: ($F[_{1,22}]$= .003, p=.955, n^2=.000). In contrast to these findings, three articles published data indicating improvements with attention/concentration. Similar to memory and reaction time, these improvements and statistically significant findings could be due to the methodology utilized. Researchers of the current project did not restrict participant's activity during the 90-minute wait time between caffeine consumption and neurocognitive testing. By not restricting activity during this time, there was a potential for each individual to have mental fatigue to occur prior to testing. This fatigue could have occurred because individuals could have participated in games, homework, or any other activity during the time frame while remaining in the laboratory. Researchers did not dictate the type of activity that occurred throughout the 90-minute wait period. An interesting finding during the exhaustive literature review is that previously published articles do not disclose the types of activity participants partook in throughout the various wait periods.

Conclusion of Research Findings

Based on an exhaustive literature review on the part of the researchers of the current study, there has been no research conducted that has assessed the effects of caffeine on ImPACT composite scores. Therefore, researchers mimicked methodology of past research conducted on the effects of caffeine on neurocognitive function (Adan & Serra-Grabulosa, 2010; Alford, Cox, & Wescott, 2001; Giles et al., 2012; Peacock, Martin, & Carr, 2012; Seidl et al., 2000; Smit & Rogers, 2002; Wesnes et al., 2013). Although current researchers did not determine statistically significant results from caffeine on ImPACT composite scores, they were able to conclude findings based off the research question associated with the study. The findings from the current study lead researchers to conclude clinical relevance that allows researchers to make some generalized conclusions.

Limitations

There were a few limitations associated with the current study that could have led to the reported results. One of those limitations included researchers having participants wait 90 minutes between caffeine intake and testing. Researchers determined this 90-minute wait time because it was important to simulate the potential amount of time that would elapse between an athlete consuming caffeine and sustaining a concussion and potentially taking ImPACT. This wait time could have produced a limitation for the current study because not all athletes would have this amount of time occurring between caffeine consumption and the ImPACT assessment. Although researchers did choose an amount of time when caffeine is thought to be at peak plasma levels within an individual, the chosen time was at a higher end (30-120 minutes) (Benowitz, 1990, Giles et al., 2012).

Another limitation was that current researchers utilized a small sample size. However, this small sample size was similar to that of past researchers. Most of the past research on this topic examined anywhere between 10 to 48 participants (Adan & Serra-Grabulosa, 2010; Alford, Cox, & Wescott, 2001; Giles et al., 2012; Peacock, Martin, & Carr, 2012; Seidl et al., 2000; Smit & Rogers, 2002). Current researchers fell in the middle of that range by evaluating 24 participants. Nevertheless, when assessing the general population, these numbers are low because they limit the generalizability of results to a small portion of the population.

In addition, there are multiple ingredients contained in an energy drink. These ingredients also could have caused the current results because it did not isolate caffeine. One project conducted by Giles et al. (2012) performed a study utilizing four different treatments that isolated caffeine and taurine but also combined both ingredients. These researchers determined that taurine has an effect on neurocognition. The energy drink utilized within the current study

also included multiple ingredients, such as taurine and caffeine. Based on the literature by Giles et al. (2012), the combination of taurine and caffeine in Rockstar Punched may have been a limitation to making conclusions about the effects of caffeine on composite scores of ImPACT.

Two of the past researchers stated a possible limitation within their studies was the knowledge of differences between treatment and control drinks (Alford, Cox & Wescott, 2001; Smit & Rogers, 2002). This could have been due to the sensory differences participants could have experienced between the two. These sensory differences included more carbonation with one compared to the other and the difference in flavor of the two drinks causing one to be less liked amongst participants. Current researchers also determined the treatment and control used with the study could have led to a possible limitation. Although the treatment and placebo were blinded and looked similar, taste was varying between the two. After the conclusion of the study, a few subjects anecdotally stated whether they thought they did or did not receive the treatment drink. This was based on the taste and the individual's previous knowledge on the taste of energy drinks. Researchers did not formally ask participants if they thought they received the treatment or control, which could have affected outcomes of this study.

In addition, another possible limitation could have been asking participants to refrain from outside caffeine intake for too long. Current researchers had participants refrain from outside caffeine for 48-hours before the post-consumption testing session. This time frame was chosen because the typical time frame of test-retest considerations for the ImPACT is a minimum of five days (Nakayama et al., 2014). However, researchers considered it unfeasible to ask college males to refrain from outside caffeine intake for five days, therefore shortening it to 48 hours. In contrast, previous researchers stated the maximum amount of time they had

participants refrain from outside caffeine was 24 hours (Adan & Serra-Grabulosa, 2010; Alford, Cox, & Wescott, 2001; Giles et al., 2012; Peacock, Martin, & Carr, 2012; Wesnes et al., 2013).

Similar to controlling caffeine intake between testing, another potential limitation was not controlling caffeine intake prior to baseline measurements. Researchers wanted baseline data to mimic normative baseline data for each individual regardless of dietary, activity, or sleep considerations. One published article by Wesnes et al. (2013) purposely utilized partially sleep-deprived individuals in order to mimic a mental and physically fatigue state within their participants. This was done because researchers believe that under these conditions is when an individual would consume an energy drink. Although some comparisons can be made between the current research and Wesnes et al. (2013), it should be noted that the differences in inclusion criteria render future research considerations.

Lastly, another limitation could have been not restricting participant's activity during the 90-minute wait time between caffeine consumption and neurocognitive testing. By not restricting activity during this time, there was a potential for each individual to have mental fatigue occur prior to testing. This fatigue could have occurred because individuals could have participated in games, homework, or any other activity during the time frame while remaining in the laboratory. Researchers did not dictate the type of activity that occurred throughout the 90-minute wait period. An interesting finding during the exhaustive literature review is that published articles do not disclose the types of activity throughout wait periods. Therefore, more research is needed about specifics of each methodology before conducting future studies.

Clinical Relevance

Even though this particular study did not yield statistically significant results from caffeine consumption, clinical findings were concluded from the present study. These findings

will be useful to clinicians for future reference. Based on the results, we can assume that if an athlete has consumed caffeine 90 minutes before taking baseline ImPACT, composite score results should not be altered or misrepresented by the consumption of caffeine. This is important for clinicians and athletic trainers because we need to have accurate baseline results of the ImPACT for concussion injury purposes.

The purpose of this study was to investigate the potential effects caffeine had on neurocognitive function as determined by composite scores of ImPACT. If caffeine did have an effect on ImPACT, there would be many issues with how current athletic trainers or clinicians implement ImPACT to their athletes. In addition, if there was a statistically significant result on ImPACT composite scores, clinicians, and athletic trainers would need to make sure athletes did not consume an energy drink or caffeine prior to their testing. However, according to the results from this study, we can allow athletes to consume caffeine 90 minutes prior to ImPACT assessments because it should not alter the results.

Future Research

Due to the findings associated with the study and limitations associated with it, researchers concluded that more research should be performed on caffeine's effects on ImPACT. Study limitations should be addressed in order to add to existing literature about caffeine's effects on composite scores of ImPACT. Minimal alterations to these limitations could provide further information for the current topic. Some of those alterations could include utilizing females as well as increasing the number of participants to open up an application to a broader population and provide more data. In addition, decreasing and/or increasing the amount of time between caffeine consumption and ImPACT should be considered. This could be accomplished by splitting subjects into groups and testing caffeine's effects on ImPACT with multiple time

frames between consumption and testing. For example, having treatment and control groups wait 30, 45, 60, 90, and/or 120 minutes in-between caffeine consumption and ImPACT allows for more variability in data. Widening of the time frame between consumption and testing would also assess the multiple times in which caffeine is at its peak in an individual. Furthermore, increasing the test-retest time of the ImPACT could be important when assessing caffeine's effects. By doing so, future research could follow the five-day test-retest considerations of ImPACT (Nakayama et al., 2014). This test-retest time frame has been suggested to make it more difficult for an individual to remember the module components of ImPACT and making the test more reliable (Nakayama et al., 2014).

It is estimated that up to 73% of athletes consume brand name energy drinks (Drug Free Sport, 2010). However, caffeine comes in many different forms as it is contained in tea, soft drinks, energy drinks, and a variety of different medications and supplements (Mandel, 2002). Therefore, considering other sources of caffeine, besides only energy drinks, could be relevant for future research. It is also estimated that more than 30% of the adolescent and young-adult population in America consumes energy drinks and this rate of energy drink consumption has increased in the younger population over the past decade (Attila & Cakir, 2010; Hoffman, 2010; NCCIH Website, 2016). Because of this, research on this topic should also be expanded to the adolescent population. To our knowledge, there is no other publication that has addressed caffeine's effects on ImPACT composite scores. The current study is a base for more research to be built on and to continue exploring this topic.

Conclusion

It is well know that caffeine is one of the most consumed substances in the United States (Giles et al., 2012; Hartley et al., 2004; Hoffman, 2010; Ruxton, 2008). Ever since the debut of

Red Bull Energy Drink in 1997, energy drinks have become a leader in the caffeine drink market (Malinauskas et al., 2007). Caffeine has become a frequently researched topic partly because of its effects on neurocognitive function (Adan & Serra-Grabulosa, 2010; Alford, Cox, and Wescott, 2001; Giles et al., 2012; Peacock, Martin, & Carr, 2012; Seidl et al., 2000; Smit & Rogers, 2002; Wesnes et al., 2013). In addition, studies have shown caffeine can produce some effects for athletes and students who need to gain focus, decrease fatigue, and improve cognitive function (Adan & Serra-Grabulosa, 2010; Alford, Cox, & Wescott, 2001; Giles et al., 2012; Peackock, Martin, &, Carr, 2012; Seidl et al., 2000; Smit & Rogers, 2002; Wesnes et al., 2013).

ImPACT is a commonly utilized tool for assessing an athlete's cognitive function pre- and post-concussion. Although ImPACT is generally used for assessing if an athlete suffered a concussion, it has other applications because it evaluates the overall neurocognitive function of an athlete. This test can be an effective way to test neurocognitive function not only on athletes, but the general public as well. Further research is advised to determine the effects caffeine has on the composite scores of ImPACT.

In conclusion, researchers were able to determine 120 mg of caffeine from an energy drink, consumed 90 minutes prior to follow-up neurocognitive testing, has no statistically significant effect on the composite scores of ImPACT. Therefore, caffeine does not appear to be an obstacle for clinicians when assessing data of an individual's ImPACT scores. However, as previously mentioned, additional research is needed in order to assist allied health care professionals in order to make evidence-based decisions.

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APPENDIX A. INFORMED CONSENT

Health, Nutrition, and Exercise Sciences
Department # 2620, PO Box 6050
Fargo, ND 58108-6050
701-231-5590

Title of Research Study: The effects of caffeine on neurocognitive function and the ImPACT test.

This study is being conducted by:
Erin Heine, HNES Graduate Student, erin.heine@ndsu.edu
Dr. Katie Lyman, HNES Assistant Professor, Katie.Lyman@ndsu.edu, office number: 701-231-8208.

Why am I being asked to take part in this research study? We are looking for 25 males between the ages of 18-28 years in the Fargo-Moorhead area. Participants will be included in the research if the applicant is between the ages of 18 and 28 years old, a non-NCAA athlete and the applicant is recreationally active. Participants will be excluded from the research if they have a prior history of heart conditions, diabetes, seizures, or epilepsy or have sustained a concussion or traumatic brain injury within six months prior to study.

What is the reason for doing the study? The purpose of this study is to determine caffeine's effect on neurocognitive function, specifically as introduced by an energy drink. The research will utilize the ImPACT test pre- and post-energy drink consumption. In addition, it will compare an energy drink-receiving population to a placebo drink population in pre- and post-consumption testing. It is important to know how caffeine can affect athlete's cognitive function. Knowing if consuming caffeine prior to competition will limit an athlete's abilities halfway through competition is vital in helping the athlete perform to the best of their ability and be reliable to their team. Also, this will help athletic trainers determine if concussion results from the ImPACT test are skewed due to caffeine consumption prior to ImPACT testing at baseline and after an athlete has suffered a concussion.

What will I be asked to do? You will report for a two-time session to the Bentson Bunker Fieldhouse (BBF). You will be asked to complete a Health History Questionnaire, and sign an Informed Consent. You will sign up for a initial baseline ImPACT test. Baseline testing will be held at the computer lab in BBF. ImPACT test stands for Immediate Post Concussion Assessment and Cognitive Testing. The ImPACT is an objective measure to determine subtle changes in cognition that occur with a concussion. ImPACT consists of three sections that include demographics, post-concussion symptoms scale, and neurocognitive test modules. The ImPACT will be used as a baseline and comparison for the second testing day. After completion of the baseline test, subjects will then register for a second testing day. The initial and second visit must be separated by no more or less than 48-hours. You will be asked to refrain from consuming caffeine outside of the study during that 48-hour period. You will be randomized and blinded into two different groups, placebo and energy drink. After the 48-hour separation period, you will return to the testing center. Based on the group you are placed into, you will receive

either the placebo, which will consist of Clear American Strawberry Sparkling Water and red color additive to make it similar to the energy drink group, which will consist of the popular energy drink Rockstar Punched.

Where is the study going to take place, and how long will it take? The study will be completed on the North Dakota State University campus in the Bentson Bunker Fieldhouse computer lab. Filling out all of the paperwork (consent form and Health History) and all of testing will be completed in two visits and should last no more than 45 minutes for the first session and 1.5-2.5 hours for the second session.

What are the risks and discomforts? You may feel effects of caffeine consumption which can include headache, nervousness, tachycardia, and or insomnia. However, normal caffeine amounts found in popular energy drinks will be distributed during this study reducing the risk of these side effects.

What are the benefits to me? This study could yield useful information, however you are not expected to get any benefit from being in this research study.

What are the benefits to other people? Knowing if consuming caffeine prior to competition will limit an athlete's abilities halfway through competition is vital in helping the athlete perform to the best of their ability and be reliable to their team. Also, this will help athletic trainers determine if concussion results from the ImPACT test are skewed due to caffeine consumption prior to ImPACT testing at baseline and after an athlete has suffered a concussion.

Do I have to take part in the study? Your participation in this research is your choice. If you decide to participate in the study, you may change your mind and stop participating at any time without penalty or loss of benefits to which you are already entitled.

What are the alternatives to being in this research study? Instead of being in this research study, you can choose not to participate.

Who will see the information that I give? We will keep private all research records that identify you. Your information will be combined with information from other people taking part in the study. When we write about the study, we will write about the combined information that we have gathered. We may publish the results of the study; however, we will keep your name and other identifying information private.

We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. For example, your name will be kept separate from your research records. Your name and research records will be stored in different places under lock and key. If you withdraw before the research is over, your information will be removed at your request, and we will not collect additional information about you.

Will I receive any compensation for taking part in this study? You will have the chance to win $10.00 for participating in the study if you reach completion of the study. There will be a drawing at the end for 10 people to have the chance to win $10.00.

What happens if I am injured because of this research? If you receive an injury in the course of taking part in the research, you should contact Dr. Katie Lyman at the following phone number 701-231-8208. If needed, she may refer you to local care facilities. Payment for this treatment must be provided by you and your third party payer (such as health insurance or Medicare). This does not mean that you are releasing or waiving any legal right you might have against the researcher or NDSU as a result of your participation in this research.

What if I have questions?
Before you decide whether to accept this invitation to take part in the research study, please ask any questions that might come to mind now. Later, if you have any questions about the study, you can contact the researcher, Erin Heine at 605-661-7453 or erin.heine@ndsu.edu or Dr. Katie Lyman at 701-231-8208 or katie.lyman@ndsu.edu.

What are my rights as a research participant?
You have rights as a participant in research. If you have questions about your rights, or complaints about this research, you may talk to the researcher or contact the NDSU Human Research Protection Program by:

- Telephone: 701.231.8995 or toll-free 1-855-800-6717
- Email: ndsu.irb@ndsu.edu
- Mail: NDSU HRPP Office, NDSU Dept. 4000, PO Box 6050, Fargo, ND 58108-6050.

The role of the Human Research Protection Program is to see that your rights are protected in this research; more information about your rights can be found at: www.ndsu.edu/irb .

Documentation of Informed Consent:
You are freely making a decision whether to be in this research study. Signing this form means that

1. you have read and understood this consent form
2. you have had your questions answered, and
3. you have decided to be in the study.

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

_____ _____

Your signature Date

_____

Your printed name

Signature of researcher explaining study	Date
Printed name of researcher explaining study	

APPENDIX B. HEALTH HISTORY QUESTIONNAIRE

Health History Questionnaire

Please answer the following questions to the best of your ability. For the following questions, unless otherwise indicated, circle the single best choice for each question. As is customary, all of your responses are completely confidential and may only be used in group summaries and/or reports. All information collected is subject to the Privacy Act of 1974. If you have any physical handicaps or limitations that would require special assistance with this questionnaire, please let your trainer know. This form is in accordance with the American College of Sports Medicine guidelines for risk stratification when followed correctly by your trainer. Your trainer should be certified with a national organization in order to use these forms correctly.

Name:_____ Ht.:_____ Wt.:_____

Gender:_____ Age:_____ Birthdate:_____

Address: _____

City:_____ State:_____ ZIP:_____ Phone:_____

Emergency Contact:_____ Phone: _____

Personal Physician:_____ Phone:_____

E-mail:_____

1. Have you ever had a definite or suspected heart attack or stroke? ..... Yes No
2. Have you ever had coronary bypass surgery or any other type of heart surgery? ..... Yes No
3. Do you have any other cardiovascular or pulmonary (lung) disease (***other than*** asthma, allergies, or mitral valve prolapse)? ..... Yes No
4. Do you have a history of: diabetes, thyroid, kidney, liver disease. ..... Yes No **(circle all that apply)**
5. Have you ever been told by a health professional that you have had an abnormal resting or exercise (treadmill) electrocardiogram (EKG)? ..... Yes No
6. If you answered YES to any of Questions 1 through 5, please describe:

_____

_____

_____

_____

7. Do you currently have any of the following:

a. pain or discomfort in the chest or surrounding areas that occurs when you engage in physical activity? ..... Yes No

b. shortness of breath ..... Yes No

c. unexplained dizziness or fainting ..... Yes No

d. difficulty breathing at night except in upright position ..... Yes No

e. swelling of the ankles (recurrent and unrelated to injury) ..... Yes No

f. heart palpitations (irregularity or racing of the heart on more than one occasion) ..... Yes No

g. pain in the legs that causes you to stop walking (claudication) ..... Yes No

h. known heart murmur ..... Yes No

Have you discussed any of the above with your personal physician? ..... Yes No

8. Are you pregnant or is it likely that you could be pregnant at this time? ..... Yes No
If yes, what is your expected due date?_____

9. Have you had surgery or been diagnosed with any disease in the past 3 months? ..... Yes No
If yes, please list date _____ and surgery/disease_____

10. Have you had high blood cholesterol or abnormal lipids within the past 12 months or are you taking medication to control your lipids? ..... Yes No

11. Do you currently smoke cigarettes or have quit within the past 6 months? ..... Yes No

12. Have your father or brother(s) had heart disease prior to age 55 OR mother or sister(s) had heart disease prior to age 65? ..... Yes No

13. Within the past 12 months, has a health professional told you that you have high blood pressure (systolic $\geq$ 140 OR diastolic $\geq$ 90)? ..... Yes No

14. Currently, do you have high blood pressure or within the past 12 months, have you taken any medicines to control your blood pressure? ..... Yes No

15. Have you ever been told by a health professional that you have a fasting blood glucose greater than or equal to 110 mg/dl? ..... Yes No

16. Describe your regular physical activity or exercise program:

type:_____
frequency: _____ days per week
duration: _____ minutes
intensity: *low* *moderate* *high* **(circle one)**
BMI: _____

17. If you have answered YES to any of questions 7-16, please describe:

_____

_____

_____

P04-020

18. Are you currently under any treatment for any blood clots? ..... Yes No

19. Do you have problems with bones, joints, or muscles that may be aggravated with exercise? ..... Yes No

20. Do you have any back/neck problems? ..... Yes No

21 Have you been told by a health professional that you should not exercise? ..... Yes No

22. Are you currently being treated for any other medical condition by a physician? ..... Yes No

23. Are there any other conditions (mitral valve prolapse, epilepsy, history of rheumatic fever, asthma, cancer, anemia, hepatitis, etc.) that may ***hinder*** your ability to exercise? ..... Yes No

24. During the past six months, have you experienced any ***unexplained*** weight loss or gain (greater than ten pounds for no known reason)? ..... Yes No

25. If you have answered YES to any of questions 18-24, please describe:

_____

_____

_____

26. Please list below all prescription and over-the-counter medications you are currently taking:

Medicine:	Reason for taking:	Dosage:	Amount/Frequency:

27. Are there any medicines that your physician has prescribed to you in the past 12 months which you are currently not taking? ..... Yes No
If so, please list:

_____

_____

_____

I have answered the Health History Questionnaire questions accurately and completely. I understand that my medical history is a very important factor in the development of my fitness/wellness program. I understand that certain medical or physical conditions which are known to me, but that I do not disclose to my trainer, may result in serious injury to me. If any of the above conditions change, I will immediately inform my trainer of those changes. I, knowingly and willingly, assume all risks of injury resulting from my failure to disclose accurate, complete, and updated information in accordance with the attached questionnaire. I also understand that in order to properly risk stratify my Health History Questionnaire, my trainer should have a minimum of a national certification as a personal trainer. My trainer also verbally explained this statement to me to my understanding.

Client's Signature: _____ Date: _____

Trainer's Signature: _____ Date: _____