

**CAFFEINE SUPPLEMENTATION AND REACTIVE AGILITY IN ELITE YOUTH
SOCCER PLAYERS**

by

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the Faculty of The Graduate School at
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APPROVAL PAGE

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ABSTRACT

Caffeine has been shown to provide ergogenic benefits to sports performance. However, limited research is available on the effects of caffeine on agility performance. This study examined the effects of 6 mg·kg⁻¹ body mass of caffeine on performance of a reactive agility test (RAT) in 17 elite, male, youth soccer players. Using a double-blind, repeated-measures design, players completed 4 days of testing on the RAT after a standardized warm-up. Height and body mass were measured and players were accommodated to the RAT on Day 1. Day 2 was used to establish the participants' baseline performance on the RAT. Players were randomly assigned to caffeine or placebo on Day 3 and the condition was reversed on Day 4. Caffeine or placebo was ingested in a gelatin capsule 1 hour prior to performing the RAT. During days 2, 3, and 4, players completed 3 randomized run-throughs of the RAT with at least one run-through to the right and left sides to assess players' performance to their dominant and non-dominant sides. There were no significant differences in players' reaction times among the experimental conditions for reaction time to the dominant side, however, there were significantly faster reaction times to their non-dominant side with caffeine $F(2, 15) = 4.185, p = .036, \eta^2 = .358$. There were no significant differences among experimental conditions on players' sprint times to their dominant and non-dominant sides. There were no significant differences among conditions on players' total times to complete the RAT to their dominant side, however, total times to their non-dominant side was approaching significance $F(2, 15) = 3.643, p = .051, \eta^2 = .327$. There were no significant differences among conditions on players' heart rates at any point of measurement. There were no

significant differences among conditions on player's RPE after the completion on the warm-up however, players' RPE at the conclusion of the RAT was significantly higher with caffeine $F(2, 15) = 5.905, p = .013, \eta^2 = .440$. Caffeine supplementation significantly improved players' reaction times to their non-dominant side and therefore may provide ergogenic benefit to elite, male, youth soccer players.

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CHAPTER I

INTRODUCTION

With minimal health risks, caffeine is one of the most widely consumed drug in the world (Graham, 2001). Even so, investigations into caffeine's usage in athletes for ergogenic benefits have only been evaluated since 1978. Since then, numerous investigators have looked at caffeine's potential ergogenic effects on endurance capacity. While many of the earlier investigations provided mixed results, more recent studies clearly indicate that caffeine has the potential to provide ergogenic benefit in time to exhaustion tests and 10 km performance (Bell & McLellan, 2003; Bell, McLellan, & Sabiston, 2002; Costill, Dalsky, & Fink, 1978). The degree that caffeine provides ergogenic benefits however, may be affected by the type of participants. Factors such as habitual caffeine usage and training status may play a role in the extent of caffeine's ergogenic effect (Bell & McLellan, 2002; Bruce et al., 2000).

More current literature on the ergogenic effect of caffeine has focused on anaerobic activities. Many of the earlier anaerobic studies included a Wingate test with mixed results. Several researchers have found no ergogenic benefits to performance on the Wingate test with caffeine (Collomp, Ahmaidi, Audran, Chanal, & Prefaut, 1991; Greer, McLean, & Graham, 1998; Lorino, Lloyd, Crixell, & Walker, 2006). In contrast, other studies have shown improvements in anaerobic performance with caffeine ingestion

using Wingate testing or similar protocol to assess anaerobic power (Anselme, Collomp, Mercier, Ahmaidi, & Prefaut, 1992; Bell, Jacobs, & Ellerington, 2001).

While the earliest investigations into caffeine's potential ergogenic benefit to anaerobic activities using a Wingate test or similar protocol provided equivocal results, researchers in this area moved to investigate caffeine's potential benefits to repeated sprint ability (RSA) performance. Numerous sports including soccer, basketball, and football require the ability to perform repeated sprints. The results from these investigations have provided promising outcomes, and indicate that caffeine has the potential to provide performance-enhancing effects in the physical and skill demands of sports activities (Collomp, Ahmaidi, Chatard, Audran, & Prefaut, 1992; Schneiker, Bishop, Dawson, & Hackett, 2006; Stuart, Hopkins, Cook, & Cairns, 2005). In more recent studies, caffeine supplementation resulted in a mean reduction in the fastest sprint time while also increasing heart rate and lactate concentrations (Carr, Dawson, Schneiker, Goodman, & Lay, 2008; Glaister et al., 2008). While it appears evident that caffeine has the ability to improve RSA, the latest area of caffeine research involves caffeine's effects on agility performance.

Before addressing caffeine's effects on athletic agility, it is important to address the debate in the literature on an appropriate definition of agility. According to a recent review by Sheppard and Young (2006), agility has been defined in the literature as the ability to change direction rapidly although some researchers have described agility as the ability to change direction rapidly and accurately. However, researchers have also described agility as a whole body change of direction as well as rapid movement and direction change of limbs (Sheppard & Young, 2006). The previous definitions however,

only address the physical characteristics of agility and fail to include the cognitive component of agility. Recently, agility has been defined as “a rapid whole-body movement with change of velocity or direction in response to a stimulus” (Sheppard & Young, 2006, p. 919). While this definition appears to be a more appropriate definition of agility, it may still be lacking. In most field and court sports, players react to opponent’s movements that are unknown. Therefore, a more appropriate definition of agility was suggested in a recent unpublished dissertation as “an unplanned, rapid, whole-body movement with change of velocity or direction in response to a stimulus” (Bettle, 2009, p. 13).

Caffeine may have the potential of improving performance by enhancing both the cognitive and physical components of agility performance. The enhancement of RSA indicates that caffeine may have the potential to improve the physical component of agility. The cognitive aspect or reaction time aspect may also be improved. Over several decades, caffeine’s effects on reaction time using simple hand movements have shown positive results (Cheney, 1935; Cheney, 1936; Durlac, Edmunds, Howard, & Tipper, 2002; Jacobson & Edgley, 1987; Smith, Tong, & Leigh, 1977; van Duinen, Lorist, & Zijdewind, 2005; Wenzel & Rutledge, 1962). Therefore, it would appear that caffeine might have the potential to improve sport-specific reaction time.

To date, few studies have tested caffeine’s effects on agility. Lorino et al. (2006) found no benefit from a $6 \text{ mg}\cdot\text{kg}^{-1}$ dose of caffeine on a proagility shuttle run. Because of the agility test used, this study only assessed the physical component of agility leaving out the important reactive component. Also, this study included recreationally active

participants and previous literature indicates that trained participants receive greater improvements with caffeine use (Collomp et al., 1992).

Pontifex, Wallman, Dawson, and Goodman (2010) were the first to evaluate caffeine's effects on a reactive agility test. They found that a caffeine supplement of $6 \text{ mg}\cdot\text{kg}^{-1}$ did not produce a significant improvement on the reactive agility test when compared to the placebo. The design of the study may have been problematic due to the single-blind design and the use of a light stimulus for the reaction test. The efficacy of generic cues such as the light stimulus used in this study have been called into question in the literature (Abernethy & Russell, 1987; Farrow, Chiver, Hardingham, & Sachse, 1998; Sheppard & Young, 2006).

The latest study to evaluate caffeine's effects on a reactive agility test was conducted by Duvnjak-Zaknich, Dawson, Wallman, and Henry (2011). Using a double-blind, counterbalance design, this group of researchers found that a $6 \text{ mg}\cdot\text{kg}^{-1}$ dosage of caffeine had the potential to improve reactive agility performance. While they were unable to find statistically significant differences between trials for total time, reaction time, movement time, or decision time, they found caffeine produced consistent improvement in all of the above components. While this study was a better designed study than the first conducted by Pontifex et al. (2010), which attempted to include reacting to a players movements instead of a light stimulus, this study included a small sample size ($N = 10$) which may have been the reason for not finding statistical significance.

The previously reviewed studies all involved adult participants. Few studies have been conducted to evaluate caffeine's effects on children in an athletic setting. A study

comparing caffeine's effect on obese versus non-obese children after a stepping exercise found that the 4 mg·kg⁻¹ body mass of caffeine altered blood free fatty acid and lactate levels differently between the two groups, however cardiorespiratory effects were not reported (Robertson et al., 1978). Another study compared caffeine's effects on 7 year-9 year old boys and girls at rest and submaximal exercise and found that 5 mg·kg⁻¹ body mass dosage of caffeine significantly increased blood pressure (BP) and lowered HR similarly in young boys and girls, but had no effect on metabolism in either (Turley & Gerst, 2006). The latest study evaluating caffeine's effects in children compared the effects of a 5 mg·kg⁻¹ body mass of caffeine between 26 boys (7 years-9 years) and 26 men (Turley, Desisso, & Gerst, 2007). In this study, the researchers found that metabolism was not affected by a moderate caffeine dosage in children or adults. The same dosage had a similar effect on BP in both groups, however the effect on HR was different with children showing a significant lowering effect between the caffeine and placebo while there was no effect in adults (Turley et al., 2007). Based on the small amount of literature on caffeine's effect on children during exercise, it appears that caffeine may act differently with children than in adults. This appears to be especially true with HR.

Purpose Statement

The purpose of this study was to examine the effects of ingesting 6 mg·kg⁻¹ body mass of caffeine on performance of a reactive agility test in elite, male, youth soccer players. The dependent variables were agility times (reaction time, sprint time, and total time to complete the agility test), rating of perceived exertion ([RPE] prior to start, and immediately following completion of test), and HR (before pre-trial warm-up, prior to

start, and immediately following completion of test). The independent variables were condition which was the baseline, placebo (maltodextrin; NOW Sports, Carbo Gain), or caffeine treatment ($6 \text{ mg}\cdot\text{kg}^{-1}$ body mass; Sigma Aldrich) trials for the dominant and non-dominant leg trials.

Hypotheses

1. It was hypothesized that caffeine ingestion would significantly decrease the reaction time for the fastest dominant leg trial.
2. It was hypothesized that caffeine ingestion would significantly decrease the reaction time for the fastest non-dominant leg trial.
3. It was hypothesized that caffeine ingestion would significantly decrease the sprint time for the fastest dominant leg trial.
4. It was hypothesized that caffeine ingestion would significantly decrease the sprint time for the fastest non-dominant leg trial.
5. It was hypothesized that caffeine ingestion would significantly decrease the total time to complete the agility test for the fastest dominant leg trial.
6. It was hypothesized that caffeine ingestion would significantly decrease the total time to complete the agility test for the fastest non-dominant leg trial.
7. It was hypothesized that there would be a significant difference among the baseline, caffeine, and placebo conditions on HR before warm-up.
8. It was hypothesized that there would be a significant difference among the baseline, caffeine, and placebo conditions on HR before the start of the test.
9. It was hypothesized that there would be a significant difference among the baseline, caffeine, and placebo conditions on HR at the conclusion of the test.

10. It was hypothesized that there would be a significant difference among the baseline, caffeine, and placebo conditions on RPE after warm-up.
11. It was hypothesized that there would be a significant difference among the baseline, caffeine, and placebo conditions on RPE at the conclusion of the test.

Definition of Terms

For the purpose of this study, terms that may be unfamiliar have been defined:

1. Elite, male, youth soccer players: Division I (premier league) U15 youth soccer players from a team in the southeastern United States.

Basic Assumptions

The researcher assumed that:

1. All participants were equally motivated to participate in this study.
2. Participants did not falsify self-reported measures of age, medication usage, smoking habits, and caffeine usage.
3. Participants did not consume caffeine for 24 hours prior to testing.

Delimitations

1. This study included elite, male, youth soccer players from the southeastern United States.

Limitations

1. Self-reported measures of age, medication usage, smoking habits, and caffeine usage.
2. Caffeine may affect people differently and specific individual differences, often due to genetic predisposition, cannot be controlled.

Significance of the Study

Caffeine's ability to improve endurance performance of various distances and time to exhaustion is well documented (Bell & McLellan, 2002; 2003; Bell et al., 2002; Bruce et al., 2000; Costill et al., 1978). While caffeine's effects on endurance performance have been thoroughly examined, caffeine's effect on anaerobic performance is still lacking in the literature. A few researchers have examined caffeine's effect on Wingate performance and repeated sprint ability with some results providing positive outcomes (Anselme et al., 1992; Bell et al., 2001; Carr et al., 2008; Collomp et al., 1992; Glaister et al., 2008; Schneiker et al., 2006; Stuart et al., 2005). A new area of caffeine supplementation research is caffeine's effect on agility performance. While there is disagreement in the literature of a specific definition of agility, agility tasks are found in numerous field and court sports. To date, only three studies have been conducted to examine caffeine's effects on agility tasks (Duvnjak-Zaknich et al., 2011; Lorino et al., 2006; Pontifex et al., 2010). However, these studies may be methodologically flawed by using either a pre-planned agility task (Lorino et al., 2006), reactive agility task using a light stimulus (Pontifex et al., 2010) that has been called into question in the literature (Abernethy & Russell, 1987; Farrow et al., 1998; Sheppard & Young, 2006), or a small sample size (Duvnjak-Zaknich et al., 2011). Because agility tasks are found in numerous sports, any means to improve agility performance would logically improve team play. Currently, research is lacking on the effects of caffeine supplementation on exercise performance in children. To the author's knowledge, only three studies have evaluated the effect of caffeine and the studies used aerobic tests (Robertson et al., 1978; Turley et al., 2007; Turley & Gerst, 2006). Therefore, results from this study will add to the current

body of knowledge of caffeine supplementation and agility performance by testing caffeine's effects on a reactive agility test in youth soccer players, an understudied population.

CHAPTER II

REVIEW OF LITERATURE

Caffeine is one of the most widely consumed drugs and has minimal health risks (Graham, 2001). This chapter begins with an introduction to caffeine and its general physiological effects and includes a review of studies of caffeine and its effects on aerobic and anaerobic performance. A review of components of agility is introduced as well as a review of the current literature in reactive agility testing. The chapter concludes with a review of caffeine and agility research, a summary, and the purpose of the study.

Caffeine

Caffeine is a colorless, bitter tasting powder resembling cornstarch. It is considered a psychoactive drug because it is used primarily as a mood or behavior-altering drug. Caffeine's proper chemical name is 1,3,7-trimethylxanthine and its chemical form is $C_8H_{10}N_4O_2$. Numerous foods including chocolate and beverages contain caffeine with coffee, tea, and soft drinks being the most consumed (Fredholm, Battig, Holmen, Nehlig, & Zvartau, 1999). Some energy drinks also contain caffeine as well as some over-the-counter medications. It is estimated that 75% of the caffeine ingested in the United States is derived from coffee, 15% from tea, and 10% from soda (Spiller, 1998). Chocolate and medications containing caffeine make only limited contributions to total use (Spiller, 1998).

Physiological effects of caffeine use. The effects of caffeine are similar, although weaker, to that of amphetamines in that the central nervous system (CNS) is stimulated (Wilmore, 2004). Increased mental alertness and concentration, elevated mood, delayed onset of and decreased fatigue, improved reaction time, enhanced catecholamine release, increased free fatty acid (FFA) mobilization, and increased muscle triglycerides are some of the known effects of caffeine (Wilmore, 2004). Having a high absorption rate, caffeine's peak blood serum levels are reached within 1 hour (Reents, 2000). The half-life of caffeine, the time it takes to decrease caffeine's initial quantity by one half, is 4 to 6 hours (Graham, 2001). Patwardhan, Desmond, Johnson, and Schenker (1980) found women taking oral contraceptives had an extended half-life for caffeine. Specifically, women taking oral contraceptives had a significant increase in the half-life of caffeine compared to non-oral contraceptive taking women from approximately 10.7 hours to 6.2 hours, respectively. An increase in caffeine's half-life from oral contraceptive usage was also found by Abernethy and Todd (1985). Other factors such as cigarette smoking may also increase caffeine's half-life (Benowitz, Hall, & Modin, 1989).

Side effects of caffeine use. Restlessness, headaches, insomnia, nervous irritability, muscle twitching, tremulousness, psychomotor agitation, elevated HR and BP, and premature left-ventricular contractions may be experienced when caffeine is consumed by persons who do not regularly consume caffeine or who consume large dosages (McArdle, Katch, & Katch, 2007). Caffeine generally poses no health risks however, an overdose of caffeine can be lethal (McArdle et al., 2007). The lethal oral dose required to kill 50% of the population (LD_{50}) for caffeine is about 10 g or 150 mg \cdot kg body mass⁻¹ for a 70-kg person (McArdle et al., 2007). Small children who consume

35 mg · kg body mass⁻¹ may experience moderate toxicity from caffeine (McArdle et al., 2007). Many people consume caffeine daily with minimal side effects however, caffeine may be a potential ergogenic aid to sports performance when consumed by athletes.

Caffeine ingestion in athletes. While caffeine may have the potential to be ergogenic to sports performance, it is important to address that caffeine may be ergolytic to sports performance in certain situations. Because caffeine presents a diuretic effect on the kidneys, caffeine can cause unnecessary pre-exercise fluid loss if taken before exercise. In hot environments, this fluid loss can cause a detrimental effect on thermal balance and exercise performance (McArdle et al., 2007). However, in a research study conducted by Wemple, Lamb, and McKeever (1997), caffeine ingested during prolonged endurance exercise did not affect exercise-induced fluid losses. Due to increases in catecholamine output during exercise, that constricts renal arterioles and leads to a reduced glomerular filtration rate (GFR), Wemple et al. concluded that the diuretic effect of caffeine can only exert its effect on a limited amount of filtrate.

Though caffeine may be ergolytic in certain situations, it still remains unclear how caffeine provides ergogenic aid to sports performance. Several potential mechanisms have been proposed for the ergogenic effect of caffeine. Costill et al. (1978) first proposed the effects were the result of an increased use of fat as fuel for exercise therefore sparing liver and muscle glycogen. Metabolism may be affected by caffeine in one of two ways: directly on adipose and peripheral tissues or indirectly by stimulating epinephrine released from the adrenal medulla (McArdle et al., 2007). Epinephrine acts as an antagonist on adipocyte cells which normally repress lipolysis (McArdle et al., 2007). Caffeine increases cellular levels of adenosine monophosphate (cyclic AMP)

through the inhibition of adenosine receptors. Cyclic AMP activates hormone-sensitive lipases causing the release of FFAs into the plasma thus promoting lipolysis. High-intensity endurance exercise may benefit from these higher levels of FFA by increasing fat oxidation, thus conserving liver and muscle glycogen. By increasing the use of fat as a fuel source, liver and muscle glycogen are conserved which will lead to delayed muscle fatigue and performance benefits.

Another proposed mechanism for caffeine's ergogenic effect during exercise is the effect it has on the CNS (McArdle et al., 2007). The inhibition of adenosine receptors serves as a neuromodulator function calming neurons of the brain and spinal cord. Neuromuscular activity is thought to be facilitated by caffeine in four ways: (1) motor unit recruitment threshold is lower, (2) excitation/contraction coupling is altered, (3) nerve transmission is facilitated, and (4) ion transport within the muscle is increased (McArdle et al., 2007). Caffeine's ability to cross the blood-brain barrier may possibly reduce the preception of effort during exercise due to its analgesic effects on the CNS (McArdle et al., 2007). This may result in a lower RPE allowing an athlete to work at a higher intensity but perceive the intensity to be less exertion than normal. Caffeine usage enhances motoneuronal excitability thus facilitating motor unit recruitment (McArdle et al., 2007). The CNS is affected indirectly by caffeine through the blockade of adenosine receptors. The receptors most likely affected by caffeine are the A₁ and A_{2A} receptors (Fredholm et al., 1999).

Caffeine's effect on the CNS is the most promising mechanism for caffeine's potential ergogenic effects. Caffeine use may have potential for improvements in reaction time due to the enhanced functioning of the CNS. Because reaction time is an important

component in many sports, enhanced reaction time from caffeine usage would appear to have potential for improved sports performance.

Caffeine and Reaction Time

Quick reaction time (RT) is important in many sport activities. The ability to read and react to stimuli is an integral part of many field and court sports. Over several decades, studies have evaluated caffeine's effect on RT using simple hand movements showing positive results (Cheney, 1935; Cheney, 1936; Durlac et al., 2002; Jacobson & Edgley, 1987; Smith et al., 1977; van Duinen et al., 2005; Wenzel & Rutledge, 1962). Therefore, it appears possible that caffeine may improve sports-specific RT.

Caffeine and Sports Performance

The World Anti-Doping Agency (WADA) removed caffeine from the banned substance list in 2004 (World Anti-Doping Agency, 2011) and the National Collegiate Athletic Association (NCAA) set a high urinary level of 15 $\mu\text{g}\cdot\text{mL}$ for a positive test (National Collegiate Athletic Association, 2010), permitting the opportunity for further investigation on caffeine and sports performance. The earliest investigations into the ergogenic effects of caffeine on sports performance looked at the endurance aspect with the first study being conducted in 1978.

Endurance studies. Costill et al. (1978) are most commonly credited with being the first to study the effects of caffeine on metabolism and exercise endurance in human participants. For this study, 9 competitive cyclists (2 female), exercised on a bicycle ergometer until exhaustion at 80% VO_2_{max} . Two trials were completed by participants, 1 hour after ingesting decaffeinated coffee (Trial D), and the second 1 hour after ingesting coffee containing 330 mg of caffeine (Trial C). There was an increase in the average time

to exhaustion in the caffeine trial of 90.2 minutes compared to 75.5 minutes in the decaffeinated trial. Evidence of greater reliance on lipid metabolism in the caffeinated trial was shown from the measurements of plasma FFAs, glycerol, and respiratory ratios. On average, the RPE was significantly lower (less effort) for the caffeine trial as opposed to the decaffeinated trial. The authors concluded that the caffeine enhanced endurance performance resulted from the combined effects of caffeine on lipolysis and its positive influence on nerve transmission (Costill et al., 1987). The glycogen-sparing effect resulting from the increased reliance on lipolysis was the original proposed explanation of caffeine's potential ergogenic properties. Although coffee was used as the caffeine supplement in this study, more recent research studies have used pure caffeine with the majority taken in the form of a pill.

The effect of caffeine on 2000-m rowing performance was investigated by Bruce et al. (2000). Using a randomized double-blind crossover study, well-trained male rowers ($N = 8$) completed 3 familiarization trials of a 2000-m rowing test prior to 3 experimental trials on a rowing ergometer 1 hour after ingesting either caffeine (6 or 9 mg·kg⁻¹ body mass) or placebo (~ 500 mg glucose). Urinary caffeine concentration was similar for all participants prior to ingestion of caffeine, but rose for both the low and high doses. Also, plasma FFA was higher after caffeine ingestion than after the placebo prior to exercise. With caffeine, respiratory exchange ratio (RER) was lower than with the placebo during the warm-up indicating increased use of fat as a fuel source and glycogen conservation therefore increasing endurance. Both doses of caffeine showed similar ergogenic effects relative to the placebo with performance time decreasing by a mean of 1.2% and mean

power increasing 2.7%. Regardless of whether 6 or 9 mg·kg⁻¹ body mass was used, the results clearly show that caffeine improved short-term endurance performance.

Bell et al. (2002) studied the effects of combining both caffeine and ephedrine on 10-km run performance. In this study, participants included 10 men and 2 women who were recreational runners. Of the 12 participants, half were regular coffee consumers drinking more than 1 cup a day while the other half were irregular or non-caffeine users with an average of less than 3 cups per week. With the participants wearing a climatic suit to control temperature, a backpack weighing 11 kg, and a helmet, testing was conducted on a treadmill where the speed was regulated. A placebo, caffeine (4 mg·kg⁻¹), ephedrine (0.8 mg·kg⁻¹), or caffeine plus ephedrine was consumed by the participants 1.5 hours prior to testing. The caffeine trial resulted in a faster run time (46.0 mins ± 2.8 mins) compared to placebo (46.8 mins ± 3.2 mins). Although this study's main purpose was to investigate the combining of both ephedrine and caffeine, minimal improvement in 10-km running performance was shown from caffeine supplementation alone.

Caffeine's effect on sports performance may be different depending on the participants' normal caffeine usage. Two studies have evaluated the effect of a caffeine supplement on habitual users of caffeine and non-users of caffeine. The first to directly study the differences in the ergogenic effects of caffeine on caffeine naive and habitual caffeine consumers were Dodd, Brooks, Powers, and Tulley (1991). Based on a questionnaire detailing their caffeine usage, 17 moderately trained males were placed into two groups: habitual caffeine users (CH, $n = 8$) consuming above 300 mg·day⁻¹ and caffeine naive users (CN, $n = 9$) consuming 25 mg·day⁻¹ or less. Participants ingested either a gelatin capsule (C), 3 mg·kg⁻¹ body mass of caffeine (C3), or 5 mg·kg⁻¹ body

mass of caffeine (C5) prior to testing. Significant increases in resting HR and expired ventilation volume (V_E) were found after ingestion of both C3 and C5 and VO_2 significantly increased after C5 only in the CN group. During the incremental $VO_{2\max}$ test on a cycle ergometer, no significant differences were found on V_E , VO_2 , respiratory exchange ratio, or time to exhaustion in both CN and CH groups. The authors concluded that the effect of caffeine on $VO_{2\max}$ and anaerobic threshold are not different between CH and CN participants. In this study, VO_2 was only increased in the CN group after the C5 treatment thus seeming to suggest that at least a $5\text{ mg}\cdot\text{kg}^{-1}$ body mass of caffeine may be needed to see an effect from caffeine supplementation.

Bell and McLellan (2002) studied caffeine's ergogenic effects and found that there were differences between users and non-users. Based on a questionnaire, 21 participants (15 males and 6 females), who were classified as regularly active in aerobic activities, were placed into two groups. Participants ingesting ≥ 300 mg caffeine/day were classified as regular caffeine users while participants ingesting less than 50 mg caffeine/day were classified as non-users. After ingestion of either a placebo or $5\text{ mg}\cdot\text{kg}^{-1}$ of caffeine, participants completed six randomized exercise rides to exhaustion at 80% of maximal oxygen consumption on an electrically braked cycle ergometer. Trial 1 established a baseline $VO_{2\max}$ and screened participants for medical information while trials 2 and 3 were to familiarize the participants with the testing procedures. After 1, 3, or 6 hours of the treatment (placebo or caffeine), the participants completed exercise to exhaustion. While both groups (users and non-users) received ergogenic benefits from caffeine supplementation, the major finding of the study was that the ergogenic effect was greater and lasted longer in non-users. For non-users of caffeine, exercise times after

1, 3, and 6 hours were significantly greater than placebo exercise times. For the users of caffeine, only exercise times after 1 and 3 hours were significantly greater than placebo exercise times. Differences between the findings of Dodd et al. (1991) and Bell and McLellan (2002) are hard to interpret. Both studies used $5 \text{ mg}\cdot\text{kg}^{-1}$ of caffeine and found some difference between caffeine users and non-users, however only Bell and McLellan (2002) found differences with respect to caffeine's ergogenic effect between the two groups. The type of participants may be the reason for differences. In the study by Dodd et al., only male participants were included, while the study by Bell and McLellan (2002) included both male and female participants. There is a lack of research evaluating caffeine's effects on women. Little is known about how caffeine ingestion may effect women other than an increased half-life from contraceptive usage (Abernethy & Todd, 1985; Patwardhan et al., 1980).

Bell and McLellan (2003) looked at the effect of repeated caffeine ingestion on repeated exhaustive exercise endurance in a more recent endurance study. All participants (9 healthy, recreational cyclists) were caffeine users (ingesting $\geq 300 \text{ mg caffeine}\cdot\text{d}^{-1}$) as classified by their response to a questionnaire. In a double-blind randomized manner, participants ingested a placebo, $5 \text{ mg}\cdot\text{kg}^{-1}$ of caffeine, or $2.5 \text{ mg}\cdot\text{kg}^{-1}$ of caffeine 1 hour prior to exercise. On an electronically braked cycle ergometer, the testing protocol consisted of exercising to exhaustion at $80\% \text{ VO}_2 \text{ max}$. Two exercise rides were performed weekly on the same day, one in the morning (placebo or $5 \text{ mg}\cdot\text{kg}^{-1}$ of caffeine) and one 5 hours later in the afternoon (placebo or $2.5 \text{ mg}\cdot\text{kg}^{-1}$ of caffeine). Significant increases in exercise time to exhaustion were found from caffeine supplementation in the morning. The effect was maintained and was greater than the placebo regardless of whether

caffeine or placebo followed the initial dose in the afternoon. The results of this study indicate that resupplementation of caffeine during exercise is not necessary to provide an ergogenic effect 6 hours later.

The ergogenic effects of caffeine have been tested in numerous studies since 1978. Although many of the earlier studies provided mixed results and the degree of effects may depend on participants' level of training and use of caffeine, more recent studies have clearly shown that caffeine has the possibility to be ergogenic for both long-term and short-term endurance performance. Because results of multiple studies have generally shown caffeine to be ergogenic to endurance performance, more current literature focuses primarily on caffeine's effects on anaerobic performance. A Wingate testing protocol was used to test for anaerobic power in some of the earlier anaerobic studies.

Anaerobic studies. Collomp et al. (1991) found that caffeine did not provide any ergogenic effects during Wingate testing in one of the earlier studies on caffeine supplementation and anaerobic sports performance. Volunteers for the study included 6 healthy participants (3 males and 3 females) who were all classified as normally active with sports participation not exceeding 2 – 3 hours per week. Following standard Wingate testing procedures, all testing was performed on a Monark cycle ergometer. The Wingate testing protocol was completed twice, with participants ingesting caffeine ($5 \text{ mg}\cdot\text{kg}^{-1}$) for one trial and a placebo for another trial. Separated by a 3-day interval, testing was conducted according to a single-blind procedure in random order. No significant changes in either maximal anaerobic capacity or power and power decreases were found with caffeine supplementation although significant increases in both

catecholamine and blood lactate were found with the caffeine supplement when compared to the placebo trial. Results of this study indicated that in nonspecifically trained individuals, caffeine failed to improve performance during Wingate anaerobic testing.

The effects of caffeine on maximal anaerobic power were also tested by Anselme et al. (1992). Recreationally active men ($n = 10$) and women ($n = 4$) classified as engaging in sports for 3.5 hours per week consented to participate in this study. Using a randomized, double-blind procedure, participants ingested a caffeine supplement (250 mg) or placebo. A force-velocity exercise test was conducted on a cycle ergometer to determine maximal anaerobic power (W_{max}). W_{max} increased with ingestion of caffeine as compared to the placebo, but for every participant the highest workload was the same with or without caffeine. With caffeine, blood lactate concentration increased both at the end of pedaling and after 5 minutes of recovery. Due to the caffeine being administered as an absolute dosage, the results may have been skewed with the greater body mass participants receiving less of a benefit than the lower body mass participants. Therefore, a relative to body mass dosage may be more appropriate to study the effects of caffeine on sports performance.

Caffeine's effects on repeated Wingate exercise test was evaluated by Greer et al. (1998). Participants in this study included 9 physically active healthy men. Either a placebo (dextrose) or caffeine ($6 \text{ mg}\cdot\text{kg}^{-1}$) was ingested by the participants 1 hour prior to the exercise protocol. On two separate occasions, participants completed four 30-second Wingate sprints with 4 minutes of rest between each exercise bout. No improvement in performance was found with the caffeine supplement. In the first two Wingate tests,

caffeine showed no effect on power output (peak or average) and showed a negative effect in the latter two tests. Caffeine significantly increased plasma epinephrine concentration 60 minutes after ingestion when compared to the placebo, but the effect diminished once the exercise began. In this study, caffeine had no significant effect on blood lactate, contrary to previous studies that found increases. The results of this study indicate that caffeine supplementation provides no ergogenic benefits for power output on short-term, repeated intense exercise.

Similar to a previously reviewed endurance study, Bell et al. (2002) evaluated the effect of caffeine and ephedrine ingestion on anaerobic exercise performance. In this study, two groups were used. Group 1 consisted of healthy, untrained male participants ($n = 16$) who performed a 30 second Wingate test. Group 2 consisted of healthy, untrained male participants ($n = 8$) who performed a maximal accumulated oxygen deficit test to exhaustion at 125% $\text{VO}_{2\text{peak}}$. Participants ingested either caffeine ($5 \text{ mg}\cdot\text{kg}^{-1}$), ephedrine ($1 \text{ mg}\cdot\text{kg}^{-1}$), a combination of both, or a placebo 1.5 hours before testing. All trials were randomized and double-blind and were conducted on an electronically braked cycle ergometer. After ingestion of the drug just before exercise, and again 3, 5, and 10 minutes post exercise, blood samples were taken to assess lactate and glucose levels. Increased time to exhaustion and O_2 deficit during the maximal accumulated oxygen deficit as well as increased blood lactate, glucose, and catecholamine levels in both test groups were found with caffeine supplementation.

From the review of the early anaerobic studies, it appears that caffeine supplementation failed to improve performance in many of the Wingate testing protocols. While the earlier Wingate studies failed to find improvements with caffeine

supplementation, RSA is an area of new research interest. Many sports including track, football, basketball, and soccer require the ability to sprint repeatedly. These sports exhibit maximal or near maximal sprints accompanied by brief periods of rest or low intensity aerobic running. Therefore, due to the aerobic component, caffeine may be beneficial to these types of sports. More research of caffeine's effects on this area of sports performance is needed.

Repeated sprint performance. Collomp et al. (1992) also found that trained athletes may receive more of an ergogenic benefit from caffeine supplementation. Participants for this study included 14 men and women who were divided into two groups: trained (T) and untrained (UT). The T group (4 women and 3 men) consisted of participants who had been training 5 to 6 times per week for 4 months prior to the study and had been regionally competitive swimmers for 5 years. The UT group (5 women and 2 men) consisted of participants who were previously members of a swimming club for at least 3 years, but during the time of the study were only swimming occasionally. The UT participants participated in varied sports and were normally active for 2 to 4 hours each week. Following a warm-up, the testing procedure was conducted in a 25 m indoor pool and consisted of a sprint test of 2 x 100 m that was swam freestyle at maximal speed separated by 20 minutes of passive recovery. In a randomized double-blind order, one was caffeine supplementation (250 mg) and the other was the placebo trial, both following a standard meal.

Significant increases in maximal blood lactate were found from caffeine in both T and UT participants. The T participants were the only participants to find improvements in swimming velocity or any significant impairments during the second 100 m. Based on

the results of the study, the authors concluded that with exercises requiring a high anaerobic capacity, specific training is a necessity to see benefits in performance from caffeine supplementation. Because this study used an absolute dosage of caffeine similar to the study of Anselme et al. (1992) the caffeine could possibly have had a greater effect on the women in the study who, as a general rule, have a smaller body frame.

Paton, Hopkins, and Vollebregt (2001) found that caffeine ingestion had little effect on repeated sprints designed to simulate team-sports activities. Team-sport athletes ($N = 16$) volunteered to complete this study. In a randomized, double-blind crossover manner, caffeine ($6 \text{ mg}\cdot\text{kg}^{-1}$ of body mass) or a placebo was ingested by the participants 1 hour prior to completing a repeated 20-m sprint test. Participants completed a testing protocol consisting of 10 sprints, each performed within 10 s and followed by rest for the remainder of each 10 s. Relative to placebo, caffeine ingestion increased the mean time to complete 10 sprints by 0.1%. The findings of this study indicated that time to complete the 10th sprint was 14.4% longer when compared to the first sprint and caffeine increased this time by 0.7% relative to placebo. Caffeine was shown to be of little to no benefit on team-sport athletes in this study, however the testing protocol may be linked to the negative findings. Participants were allowed only the remainder of the 10 seconds of each sprint for rest, therefore, the time allowed for recovery may not have been long enough.

Stuart et al. (2005) also looked at the effect of caffeine on simulated team-sports performance of a rugby union game. High-level amateur male rugby players ($N = 11$) participated in this study. Caffeine ($6 \text{ mg}\cdot\text{kg}^{-1}$ body mass) or placebo (dextrose) were ingested by the participants 70 minutes prior to performing a rugby test. The test protocol simulated that of a rugby game and consisted of two 40 minute halves with seven circuits

in each with a 10 minute half time rest. Each circuit included measurement of sprint time (two straight-line and three agility sprints), power generation in two consecutive drives, and accuracy for rapidly passing balls. With the exception of second-drive power, caffeine improved mean performance in all tasks. It is important to point out that in this study, caffeine also improved agility sprints.

In another study, Schneiker et al. (2006) evaluated the effect of caffeine on intermittent-sprint ability in team sport athletes. Participants for the study included 10 moderately trained males who were recruited from Australian football, soccer, and hockey teams. Two exercise trials were completed by the participants 60 minutes after ingestion of either $6 \text{ mg}\cdot\text{kg}^{-1}$ caffeine or placebo. The testing protocol consisted of 2 x 36 minute halves that were performed on a front-access cycle ergometer. Both halves consisted of 18 x 4-s sprints with 2 minutes of active recovery at 35% $\text{VO}_{2\text{peak}}$ between each sprint. The total amount of sprint work performed was 8.5% greater during the caffeine trial than that of the placebo trial in the first half and showed a 7.6% increase in the second half. Mean peak power during sprints increased 7.0% during the caffeine trial as compared to the first half of the placebo trial and was 6.6% greater in the second half. A $6 \text{ mg}\cdot\text{kg}^{-1}$ dosage of caffeine was shown to enhance prolonged, intermittent-sprint ability in trained males.

In one of the most recent studies by Glaister et al. (2008), the effects of caffeine supplementation on multiple sprint performance were evaluated. Participants for this study included 21 physically active sports science students who completed 4 trials of the multiple sprint test (12 x 30 m; repeated at 35-s intervals). To limit the effects of learning on the outcome of the experiment, the first trial was for familiarization purposes. The

second trial consisted of establishing a baseline to evaluate the effects of both caffeine and placebo trials. In a randomized, double-blind protocol, trials 3 and 4 were the experimental trials in which the participants ingested either a gelatin capsule containing caffeine ($5 \text{ mg}\cdot\text{kg}^{-1}$ body mass) or placebo (maltodextrin) 1 hour prior to completing the indoor multiple sprint running trials. Plasma caffeine and primary metabolite concentration were assessed with venous blood samples. RPE was recorded after every third sprint and HR was monitored continuously during the trials. The fastest sprint time was reduced by 0.06-s with the caffeine supplement. An increase in mean HR of 3.4 bpm as well as increased levels of pre-test and post-test lactate concentrations were also found with caffeine supplementation. Contrary to previous studies, no significant effect was seen in RPE from caffeine supplementation although RPE did correspond with increases in sprint time and HR. A potential limitation of this study was the use of only male participants. The results could potentially be different with female participants. While there is a lack of caffeine research involving females, there is potential that caffeine may be different for females. Research indicates that the half-life of caffeine may be prolonged in women taking oral contraceptives (Abernethy & Todd, 1985; Patwardhan et al., 1980).

Carr et al. (2008) also conducted a study of caffeine's effects on RSA. For this study, 10 university males with a background in team-sport training and competition served as participants. First, participants completed a trial to familiarize themselves with the testing procedure prior to the experimental trials. Participants then completed two repeated sprint-running tests on different days approximately 7 days apart 1 hour after ingesting either the caffeine ($6 \text{ mg}\cdot\text{kg}^{-1}$) or placebo. The testing protocol consisted of a 20

m distance with a 180° turn at 10 m to accommodate gym space. Each set involved 6 x 20 m sprints, 10 m out and 10 m back, with a departure time of 25 s on sets 1, 3, and 5 with sets 2 and 4 having a departure time of 60 s. Significantly faster times across sets 1, 3, and 5 were found with caffeine supplementation. Also, across sets 2 and 4, total sprint times were significantly faster during the caffeine trial than during the placebo trial. Significantly higher blood lactate levels after set 3 and set 5 were found in this study which is consistent with the findings of other studies. The results of this study indicate that caffeine taken 1 hour prior to performance can enhance repeated sprint running.

With the few studies that exist on the effects of caffeine supplementation and repeated sprint performance, the results are promising. Although varying amounts of caffeine were used in these studies it was common for a level of 6 mg·kg⁻¹ body mass to be used. The newest area of research into the effects of caffeine supplementation and sports performance, however, is agility. In the next section, components of agility are addressed prior to a review of the caffeine and agility research.

Agility

Debate in the literature exists as to what is an appropriate description of agility. According to a recent review of the agility literature, agility has been defined as the ability to change direction rapidly, however, some researchers have described agility as the ability to change direction rapidly and accurately (Sheppard & Young, 2006). Some authors however, have described agility as whole body change of direction as well as rapid movement and direction change of limbs (Sheppard & Young, 2006). The previous definitions address the physical characteristics of agility, however leave out the cognitive component. Recently, agility has been defined as “a rapid whole-body movement with

change of velocity or direction in response to a stimulus” (Sheppard & Young, 2006). Although this definition includes the cognitive characteristic and the physical component, it may still lack an important component of agility. Most field and court sports involve reacting to an opponent’s movement that is unknown. Therefore, a recent unpublished dissertation suggests that a more appropriate definition of agility is “an unplanned, rapid, whole-body movement with change of velocity or direction in response to a stimulus” (Bettle, 2009, p. 13). This description may be the most appropriate because it also includes the reactive component to agility. Because of the lack of agreement in the current literature as to a concise definition of agility, a review of the important component of agility follows.

Physical components. Many of the descriptions of agility have only addressed the physical components. Terms such as the ability to change direction, accelerate and decelerate, start and stop, and to maintain balance and control while performing the previous tasks have all been used to describe agility (Baker & Newton, 2008; Barnes et al., 2007; Bloomfield, Polman, O'Donoghue, & McNaughton, 2007; Little & Williams, 2005; Young, McDowell, & Scarlett, 2001). These descriptions above however, have led researchers to suggest that they are best described as change of direction speed (CODS) tasks (Young, James, & Montgomery, 2002). These tests are referred to as closed skill tests because the movements are pre-planned and there is no response to a stimulus. The previous descriptions in the literature have all failed to address the cognitive aspects of agility. The cognitive aspect is not only an important component in successful game play, but it has been shown to limit agility performance (Gabbett, Kelly, & Sheppard, 2008).

Cognitive components. Researchers have shown that superior anticipation and decision-making ability are important aspects of successful team performance (Abernethy, Wood, & Parks, 1999). Consequently, recognizing the cognitive aspect is important when describing agility. According to Chelladurai (1976), agility tasks can be classified into four distinct categories. The first classification is simple agility. These types of agility tasks have no spatial or temporal uncertainty (Chelladurai, 1976). An example of this type of task is a gymnast's floor routine which is a pre-planned activity, initiated when the athlete desires, and with movements that the athlete has pre-planned (Chelladurai, 1976). The second classification is temporal agility. These types of agility tasks involve temporal uncertainty, but the movement is pre-planned (Chelladurai, 1976). An example of this task is a sprint start that is a pre-planned activity, initiated in response to a starter's pistol in which there is no certainty as to when the pistol will fire (Chelladurai, 1976). The third classification of agility is spatial agility. These types of agility tasks involve spatial uncertainty but the timing of the movement is pre-planned (Chelladurai, 1976). This type of agility task is found in volleyball and racquet sport serves received in which the umpire determines a narrow window of time for the server to serve the ball to the opponent, however, there is no certainty on the part of the receiver as to where the serve will be directed (Chelladurai, 1976). The final classification of agility is universal agility, which involves both spatial and temporal uncertainty (Chelladurai, 1976). Examples of this type of agility are seen in sports such as ice hockey and football during offensive plays in which the athlete cannot predict with certainty when or where opposition players will move (Chelladurai, 1976).

The previous classifications of agility indicate the importance of the cognitive component in agility movements. The final classification of agility, universal, is most representative of sport-specific situations because players must react to two stimuli and cannot have a fixed, pre-planned movement. These skills are then referred to as open skill movements because they involve unplanned movements. Because this is more representative of sport-specific movements, reactive agility tests have been used by researchers to assess both the cognitive and physical aspects of agility.

Reactive agility. Most of the literature on agility has focused on pre-planned CODS tasks. This, as previously discussed, is neglecting an important aspect of agility, the cognitive component. The ability to “read and react” is a crucial aspect in many sports. Therefore, researchers have attempted to evaluate this component using reactive agility tests (RAT). Many researchers have attempted to employ tests that require a change of direction in response to generic cues such as a light bulb or computerized direction indicator (Besier et al., 2001; Chelladurai, 1977; Hertel, Denegar, Johnson, Hale, & Bucklet, 1999). Using generic cues for reaction tests however have been questioned in the literature (Abernethy & Russell, 1987; Farrow, Young, & Bruce, 2005; Sheppard & Young, 2006). Because the efficacy of using a light stimulus as a means of testing sport-specific reactive agility has been questioned, more sport-specific reactive agility tests have developed.

Farrow et al. (2005) attempted to differentiate between higher skilled and lesser skilled players using a pre-planned agility task and reactive agility when responding to a life size interactive video of a netball player initiating a pass. The second purpose was to assess the test-retest reliability of the testing approach. Higher-skilled players were

significantly faster in both the reactive and planned test conditions relative to the lesser-skilled players. The moderate-skilled group was significantly faster than the lower-skilled group in the reactive test condition. They also found that their testing protocol had good test-retest reliability. The authors concluded that the decision time component of the reactive agility test contributed to the significant differences between the two conditions.

Sheppard, Young, Doyle, Sheppard, and Newton (2006) evaluated the reliability and validity of a new reactive agility test that includes anticipation and decision-making components in response to movements of the tester as opposed to a light stimulus. The test was found to be an acceptably reliable test and the test was valid in distinguishing between players of differing performance levels in Australian football. In addition, they found that the traditional closed skill sprint and sprint with change of direction were not adequate in distinguishing between players of different levels of Australian football.

Using the test developed by Sheppard et al. (2006), Gabbett et al. (2008) evaluated the speed, CODS, and RAT of rugby players. They found the RAT could distinguish between first grade players who had faster speed, movement, and decision times on the RAT than second grade players, while no significant differences were found between groups on CODS. While movement times on the RAT were significantly related to 10 m and 20 m sprint times and CODS, no significant relationships were found between measures of decision time and response accuracy during the RAT and measures of linear speed and CODS.

The previous reviewed literature to the author's knowledge is all that exists in this relatively new field of study. The reactive or cognitive portion of agility has been neglected in the literature and should be addressed. While studies exist using reactive

agility tests to distinguish between classes of Australian football and rugby, recently research has begun to test caffeine's effects on RAT.

Caffeine and Agility

Lorino et al. (2006) were the first to evaluate caffeine's effects on athletic agility. Using what has become the standard caffeine dosage in the literature of $6 \text{ mg}\cdot\text{kg}^{-1}$, no significant differences were found in agility assessed by the proagility run or a Wingate test in young adult males. Two potential issues with this study were the use of untrained participants and the type of agility test used. Trained participants have been found to have greater improvements with caffeine use (Collomp et al., 1992). Therefore, the use of untrained participants for the purposes of assessing athletic agility may not have been appropriate. Also, the use of the proagility shuttle run, that only assesses the physical component of agility and not the cognitive/reactive component, may not translate to on-field performance. After this first attempt at assessing caffeine's effects on agility performance, researchers turned to RAT tests to assess caffeine's effect on both the physical and cognitive aspects of agility performance.

Caffeine and reactive agility. As previously discussed, caffeine has been shown to improve simple reaction time. Over several decades, studies evaluating caffeine's effect on RT using simple hand movements have shown positive results (Cheney, 1935; Cheney, 1936; Durlac et al., 2002; Jacobson & Edgley, 1987; Smith et al., 1977; van Duinen et al., 2005; Wenzel & Rutledge, 1962). These improvements in reaction time from caffeine may be linked to its effects on the CNS lowering the threshold for motor unit recruitment, altering excitation/contraction, enhancing nerve transmission, and increasing ion transport within the muscle (McArdle et al., 2007). This appears to show

caffeine may improve the cognitive component of agility. Previous studies of sprint ability have also shown improvements in the physical component of sprinting. Because of improvement in both cognitive (reaction time) and physical (sprinting) aspects of agility with caffeine, studies testing caffeine's effect on a RAT have been conducted.

Pontifex et al. (2010) were the first to look at caffeine's effect on a RAT. After ingestion of caffeine ($6 \text{ mg}\cdot\text{kg}^{-1}$ body mass) or placebo, participants completed a RAT followed by a RSA test. The RAT agility test consisted of 10 trials (10.2 m separated by 30 seconds) followed by 7 minutes of active recovery followed by a RSA test (5 sets of 6 x 20 m sprints with 25 or 60 seconds of recovery). The RSA was then followed by 5 minutes of active recovery and another RAT. Consistent with previous findings, the results indicated that caffeine improved performance in a RSA test in both total time and best sprint test. Caffeine was found to have no significant difference when compared to the placebo on the RAT. A potential issue with the study was that it was a single blind study which may have subjected the study to experimenter expectancy effects. Also, the RAT used a light stimulus for participants' reactions. Such generic cues and the efficacy of such cues have been called into question in the literature (Abernethy & Russell, 1987; Farrow et al., 1998; Sheppard & Young, 2006).

Duvnjak-Zaknich et al. (2011) is the most recent study investigating caffeine's effect on a RAT. Using a double-blind, counterbalance design, these researchers found a $6 \text{ mg}\cdot\text{kg}^{-1}$ dose of caffeine had the potential to improve reactive agility performance in moderately trained male team-sport athletes. Participants completed 80 minutes (4 x 20 minutes) simulated team-game, intermittent running protocol interspersed with a RAT between each quarter. The RAT consisted of five trials in which measurements of total

time, reactive time, decision time, movement time, and decision-making accuracy were obtained. While they found no significant differences between trials for total time, reaction time, movement time, or decision time, they did find that caffeine produced consistently faster results in all of the above measured factors. The authors also attempted to assess caffeine's effects when players were fresh as well as fatigued and found that caffeine may be beneficial to RAT in both conditions. The authors of this study attempted to make their test more sport-specific by including a video of a "life-sized opponent" in a defensive pursuit scenario, however the sample size was small ($N = 10$) and may be associated with the lack of statistical significance.

Because caffeine's effect on a RAT is a relatively new area of study, only two studies have addressed this area of concern. Because numerous field and court sports involve reading and reacting to an opponent, any means to increase performance in this area would logically improve team play. As such, more research is justified in this field of study.

Caffeine and Exercise in Children

The previously reviewed studies all involved adult participants. There is a limited amount of research on caffeine's effect on exercise in children. Caffeine's effect on obese versus non-obese children after a stepping exercise found that the 4 mg·kg⁻¹ body mass of caffeine altered blood free fatty acid and lactate levels differently between the two groups however cardiorespiratory effects were not reported (Robertson et al., 1978). Another study compared caffeine's effects on 7 year-9 year boys and girls at rest and during submaximal exercise and found that 5 mg·kg⁻¹ body mass of caffeine significantly increased BP (both diastolic and systolic) and lowered HR during exercise similarly in

young boys and girls but had no effect on metabolism in either (Turley & Gerst, 2006). The latest study evaluating caffeine's effects in children compared the effects of a 5 mg·kg⁻¹ body mass of caffeine between 26 boys (7 years-9 years) and 26 men (Turley et al., 2007). In this study, the researchers found that metabolism was not affected by a moderate caffeine dosage in children or adults. The same dosage had a similar effect on BP in both groups however the effect on HR was different with children showing a significant lowering effect from the caffeine supplement when compared to the placebo while there was no effects in adults (Turley et al., 2007). Based on the limited amount of literature on the effect of caffeine in children during exercise, it appears that caffeine's effect on children may be different than in adults. This appears to be especially true with HR.

Overall Summary

Caffeine has been shown to be ergogenic in endurance activities as well as some anaerobic activities such as repeated sprint performance. Caffeine has also been shown to improve simple reaction times. While debate exists in the literature as to an exact definition of agility, it is clear that agility is comprised of two components: a physical component and a cognitive component. While caffeine has been shown to improve the physical components such as increasing time to exhaustion in the endurance studies and improving sprinting ability, caffeine may have the potential to improve the cognitive component as the shown in the studies of caffeine and simple reaction time. Many field and court sports involve not only a physical component such as the ability to accelerate and decelerate to change direction, but also a cognitive component of reading and reacting to opponents' movements. This cognitive or reactive component has not been

addressed in much of the agility literature. Because of the improvements shown with caffeine and simple reaction time (Cheney, 1935; Cheney, 1936; Durlac et al., 2002; Jacobson & Edgley, 1987; Smith et al., 1977; van Duinen et al., 2005; Wenzel & Rutledge, 1962), it would appear logical to think that caffeine may improve sport-specific reaction times.

To this date, only two studies have attempted to address how caffeine affects sports-specific agility (Duvnjak-Zaknich et al., 2011; Pontifex et al., 2010). The study by Pontifex et al. (2010) however, failed to address sport-specific reactive agility by using a light stimulus as opposed to reacting to an opponent. The use of generic cues such as the light stimulus used in these reactive agility tests has been questioned in the literature (Abernethy & Russell, 1987; Farrow et al., 1998; Sheppard & Young, 2006). Also, using a single-blind design as opposed to double-blind may have further methodologically flawed the study by Pontifex et al. (2010). Furthermore, a small sample size may be linked to the lack of statistical significance in the study by Duvnjak-Zaknich et al. (2011) because moderate to large effect sizes indicated a possible improvement with caffeine. Because there is a paucity of literature on caffeine's effects on reactive agility tasks and the studies that do exist fail to address a more sports-specific test or include a small sample size, a study of caffeine's effects on a sports-specific reactive agility test is warranted. Therefore, the purpose of this study was to test the effect of $6 \text{ mg}\cdot\text{kg}^{-1}$ body mass of caffeine on a sport-specific RAT in elite, male, youth soccer players.

CHAPTER III

METHODOLOGY

Participants

Participants in this study included 17 male elite, premier league youth soccer players from the Southeastern United States with ages ranging from 13 years to 15 years. All players were free of injury at the time of study. Because of the players' elite status, all participants were of similar conditioning level and expertise. One of the players was a goal keeper.

Instrumentation

Caffeine questionnaire. Participants completed a questionnaire created by the primary investigator on their age, smoking habits, attention deficit hyperactivity disorder (ADD/ADHD) medication usage, dominant foot (defined as the foot that the player would use to kick a penalty shot), and caffeine intake (see Appendix A). This questionnaire was completed in consultation with the child's parent/legal guardian.

Preparticipation screening questionnaire. The American Heart Association/American College of Sports Medicine questionnaire (American College of Sports Medicine, 2010) was used in addition to the questionnaire created by the primary investigator to screen participants for any potential medical problems that might be made worse by exercise and/or caffeine usage. This questionnaire was also completed in consultation with the child's parent/legal guardian.

Height. A stadiometer (SECA; Hanover, MD) was used to measure height to the nearest 0.1 centimeters. For the measurement, participants were asked to remove their shoes.

Body mass. A digital scale (SECA; Hanover, MD) was used to measure body mass to the nearest 0.1 kilograms. For the measurement, participants were asked to remove their shoes and the measurements were taken with participants wearing shorts and a shirt.

Agility timing. Brower timing gates (Brower Timing System; Draper, UT) were used to measure both the physical and cognitive components of the reactive agility test task. All times were reported as a raw time in seconds, to the nearest 1/100th of a second.

RPE. RPE (Borg scale, 6 – 20) was collected at the completion of the warm-up and at the conclusion of testing (Borg, 1998).

HR. HR was recorded 1 hour after taking the supplement (or resting HR for the baseline testing), immediately before the start of the test, and at the conclusion of testing immediately following the 3 reactive agility testing conditions using HR monitors (Polar Electro, Model F1 A1).

Procedures

Permission was granted from the University Institutional Review Board prior to conducting this study (see Appendix B). All participants read and signed an assent form prior to completing the questionnaires or collecting any data (see Appendix C).

Parents/legal guardians read and signed a parental consent for their child's' participation in this study (see Appendix D). Participants were informed of their right to withdraw from the study at any time without negative consequences.

Volunteers for the study first completed questionnaires to screen for health issues that may be exacerbated by caffeine usage as well as to assess normal caffeine intake. Each participant's height and body mass were recorded prior to completing any testing. The appropriate caffeine dosage was determined by the recorded body mass. A 3-day notice was given to participants prior to testing and participants were asked to refrain from caffeine use for 24 hours prior to testing. Participants were also asked to refrain from consumption of food or beverage within 1 hour of testing.

Using a randomized, repeated-measures, double-blind, counter-balanced experimental design, participants completed 4 days of testing on the RAT (Sheppard et al., 2006). Day 1 was to familiarize the participants to the testing protocol. Day 2 was to establish a baseline to evaluate the placebo and caffeine's effects on the RAT. Days 3 and 4 were the experimental trials in which the participants randomly received either a gelatin filled capsule with caffeine ($6 \text{ mg}\cdot\text{kg}^{-1}$ body mass; Sigma Aldrich) or a placebo (maltodextrin; NOW Sports, Carbo Gain) 1 hour prior to testing. Randomization to the condition was accomplished using an Internet based randomization program (Research Randomizer). The treatment was reversed in Day 4 for a counterbalanced design.

Prior to any testing, players completed their standard warm-up prior to soccer matches which consisted of a 10-minute possession game interspersed with squat jumps and concluded with 5-10 near maximum sprints of no more than 10 meters in distance. To measure both the cognitive and physical aspects of agility as previously discussed, a RAT was used. Using a modified testing protocol similar to Sheppard et al. (2006), each of the four days consisted of participants completing 3 trials of the RAT test with at least

one trial occurring to the left and one trial occurring to the right in a randomized manner (see Figure 1).

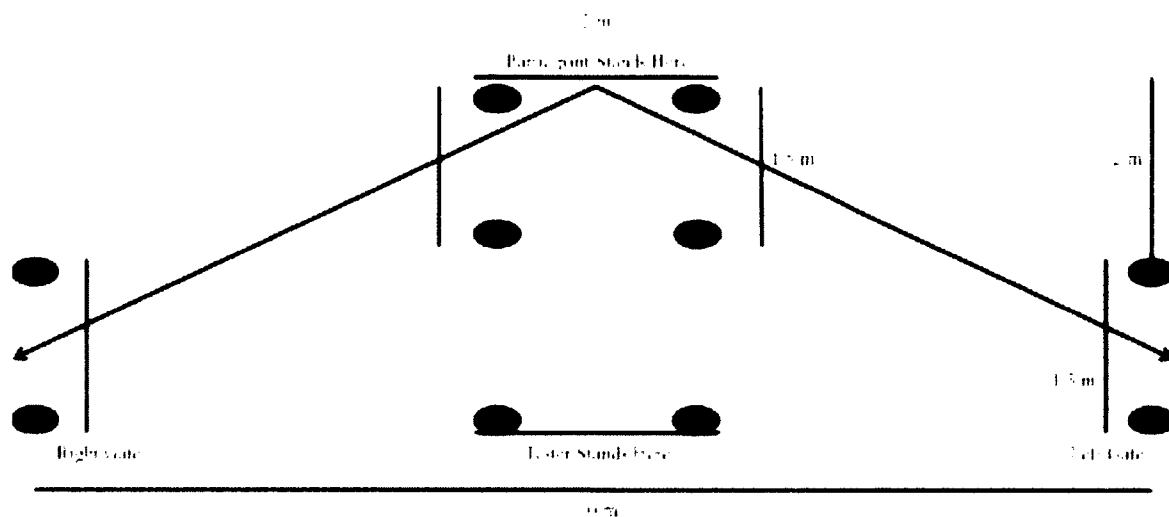


Figure 1. Random Agility Test

Participants were given 30 seconds of rests between each trial. The tester stood opposite of the participant on a 2 meter starting line. The tester performed a randomized combination of the following conditions: step forward with right foot and change direction to the left and step forward with the left foot and change direction to the right. The participant reacted to the testers movements and finished through a timing gate in the appropriate direction. For condition one, the participant was expected to finish through the right gate and for condition two, the participant was expected to finish through the left gate.

Timing gates were placed 1.5 meters apart from each other with the finishing gates being placed 10 meters apart (3 meters to the left and right of the 2 meter start line). The finishing gates were placed 2 meters in front of the starting line. Accuracy (decision-making accuracy) and speed of movement were emphasized to the participants. Measurements for this test included reaction time (the amount of time it takes for the participant to break the first timing gate beam) and sprint time (the time it takes the participant to sprint from gate 1 to the finishing gate). The reaction time served as a measurement of the cognitive component of agility and the sprint time served as a measurement of the physical component. At the completion of testing on both Days 3 and 4, a manipulation check was conducted. The participants were asked to identify which experimental treatment (caffeine or placebo) they believed they received during the session and their reasons for that choice (see Appendix E).

This information was used to determine if confounding variables such as participants correctly guessing the treatment may have affected the results. At the completion of the study, participants were debriefed and told the purpose of the research. Participants were instructed to report any unanticipated adverse events as the result of this research to the primary investigator.

Data Analyses

Differences among the baseline, caffeine, and placebo conditions on sprint times (Dominant, Non-Dominant), fastest reaction times (Dominant, Non-Dominant), and fastest total times to complete the agility test (Dominant, Non-Dominant) were analyzed using 6 one-way repeated measures analysis of variance (RMANOVA) through a multivariate analysis of variance (MANOVA) approach. Within each day of testing

(baseline, caffeine, placebo), only the fastest conditions and the correct reactive decisions to the dominant and non-dominant side were used in data analyses. Differences among the baseline, caffeine, and placebo conditions on RPE after the warm-up and at the conclusion of the test were analyzed using 2 one-way RMANOVA through a MANOVA approach. Differences among the baseline, caffeine, and placebo conditions on HR 1 hour after taking the supplement, before starting the test, and at the conclusion of the test were analyzed using 3 one-way RMANOVA through a MANOVA approach. A post hoc test using a Bonferroni adjustment was used to determine the direction of significance if significance was found in the original analysis. Predictive analytics software (IBM SPSS, Version 19.0) with an alpha level of .05 was used for all analyses in order to control the familywise error rate.

CHAPTER IV

RESULTS

The participants in this study included 17 elite male U15 youth soccer players from the southeastern United States. The participants' ages ranged from 13 years-15 years and 16 of the 17 players in this study were classified as right foot dominant. The questionnaire revealed that 10 of the 17 players were classified as "caffeine naive" (consuming less than 50 mg of caffeine per day). Other descriptive statistics are presented in Table 1.

There were no significant differences among the baseline, caffeine, and placebo conditions on players' reaction times to their dominant side (see Table 2). Thus, hypothesis 1 was not confirmed. There were significant differences among the baseline, caffeine, and placebo conditions on players' reaction times to their non-dominant side (see Table 3). Therefore, hypothesis 2 was confirmed. A post hoc test using a Bonferroni adjustment revealed a significantly faster reaction time with caffeine compared to the placebo conditions ($M = -.095$, $SE = .032$, $p = .027$) while no significant difference was found between the baseline and caffeine conditions ($M = -.052$, $SE = .031$, $p = .352$) or the baseline and placebo conditions ($M = -.043$, $SE = .032$, $p = .599$).

There were no significant differences among the baseline, caffeine, and placebo conditions on players' sprint times to their dominant side (see Table 2). Consequently, hypothesis 3 was not confirmed. There were also no significant differences among the

baseline, caffeine, and placebo conditions on players' sprint times to their non-dominant side (see Table 3). Therefore, hypothesis 4 was not confirmed.

There were no significant differences among the baseline, caffeine, and placebo conditions on players' total times to complete the RAT to their dominant side (see Table 2). Hence, hypothesis 5 was not confirmed. The difference among the baseline, caffeine, and placebo conditions on players' total times to complete the RAT to their non-dominant side was approaching significance (see Table 3). A post hoc test using Bonferroni adjustment did reveal a significantly faster total time to complete the RAT with caffeine compared to placebo conditions ($M = -.100$, $SE = .036$, $p = .043$) while no significant difference was found between the baseline and caffeine conditions ($M = -.061$, $SE = .029$, $p = .157$) or the baseline and placebo conditions ($M = -.039$, $SE = .029$, $p = .597$). As a result, hypothesis 6 was confirmed.

There were no significant differences among the baseline, caffeine, and placebo conditions on players' HR 1 hour after taking the supplement, before completing the RAT, and at the conclusion of the RAT (see Table 4). Consequently, hypotheses 7, 8, and 9 were not confirmed. There were no significant differences among the baseline, caffeine, and placebo conditions on players' RPE after the completion on the warm-up (see Table 5). Therefore, hypothesis 10 was not confirmed. There were significant differences among the baseline, caffeine, and placebo conditions on players' RPE at the conclusion of the RAT (see Table 5). As a result, hypothesis 11 was confirmed. A post hoc test using a Bonferroni adjustment revealed a significantly higher RPE at the conclusion of the RAT with caffeine compared to the baseline condition ($M = -1.412$, $SE = .446$, $p = .018$) while no significant difference was found between the placebo and caffeine conditions

($M = .412$, $SE = .462$, $p = 1.000$) or the baseline and placebo conditions ($M = -1.000$, $SE = .374$, $p = .050$)

Table 1

Descriptive Statistics of Sample ($N = 17$)

Characteristic	<i>M</i>	<i>SD</i>
Age (years)	14.1	0.5
Height (cm)	172.0	4.8
Body mass (kg)	61.1	5.2
Caffeine dosage (mg)	366.49	31.41
Daily caffeine usage (mg)	53.2	64.6

Table 2

Dominant Side Analyses of Reactive Agility Test Components

Characteristic	<i>M</i>	<i>SD</i>	<i>N</i>	<i>df</i>	<i>F</i>	<i>p</i>	η^2
Reaction time			17	2	1.215	.324	.139
Baseline (s)	0.837	0.089					
Caffeine (s)	0.797	0.109					
Placebo (s)	0.847	0.106					
Sprint time			17	2	0.126	.883	.017
Baseline (s)	1.001	0.043					
Caffeine (s)	1.001	0.062					
Placebo (s)	1.001	0.053					
Total time			17	2	1.214	.325	.139
Baseline (s)	1.848	0.117					
Caffeine (s)	1.806	0.139					
Placebo (s)	1.854	0.105					
Within group error				15			

Table 3

Non-Dominant Side Analyses of Reactive Agility Test Components

Characteristic	<i>M</i>	<i>SD</i>	<i>N</i>	<i>df</i>	<i>F</i>	<i>p</i>	η^2
Reaction time			17	2	4.185	.036	.358
Baseline (s)	0.872	0.131					
Caffeine (s)	0.820*	0.095					
Placebo (s)	0.915*	0.153					
Sprint time			17	2	0.531	.599	.066
Baseline (s)	0.987	0.073					
Caffeine (s)	0.997	0.045					
Placebo (s)	1.002	0.059					
Total time			17	2	3.643	.051	.327
Baseline (s)	1.880	0.144					
Caffeine (s)	1.819	0.116					
Placebo (s)	1.919	0.186					
Within group error				15			

Note. * Significantly different at $p < .05$.

Table 4

Heart Rate Analyses for Baseline, Caffeine, and Placebo Conditions

Characteristic	<i>M</i>	<i>SD</i>	<i>N</i>	<i>df</i>	<i>F</i>	<i>p</i>	η^2
After 1 hour			17	2	2.280	.137	.233
Baseline (bpm)	76.47	6.00					
Caffeine (bpm)	71.29	6.39					
Placebo (bpm)	74.18	7.12					
Before test			17	2	1.644	.226	.180
Baseline (bpm)	111.41	9.41					
Caffeine (bpm)	110.47	9.15					
Placebo (bpm)	107.18	8.01					
Conclusion of test			17	2	0.563	.581	.070
Baseline (bpm)	145.00	7.09					
Caffeine (bpm)	145.76	10.47					
Placebo (bpm)	141.76	12.14					
Within group error				15			

Table 5

RPE Analyses for Baseline, Caffeine, and Placebo Conditions

Characteristic	<i>M</i>	<i>SD</i>	<i>N</i>	<i>df</i>	<i>F</i>	<i>p</i>	η^2
After warm-up			17	2	1.913	.182	.203
Baseline	7.82	0.95					
Caffeine	8.82	2.04					
Placebo	8.41	1.46					
Conclusion of test			17	2	5.905	.013	.440
Baseline	11.18*	1.02					
Caffeine	12.59*	1.33					
Placebo	12.18	1.07					
Within group error				15			

Note. RPE = Rating of perceived exertion; *Significantly different at $p < .05$.

CHAPTER V

DISCUSSION AND CONCLUSIONS

The purpose of this study was to assess the effects of $6 \text{ mg}\cdot\text{kg}^{-1}$ of caffeine on the performance of a RAT to the dominant and non-dominant sides in 17 elite, male, youth soccer players from a team in the southeastern United States. In particular, caffeine's effects on both the cognitive (reaction time) and physical (sprint time) components of agility were examined. Caffeine's effects on HR and RPE during the RAT were also evaluated.

Characteristics of the Participants

This study included elite, male, youth soccer players from a U15 team in the southeastern United States. All participants were between the ages of 13 years and 15 years of age. Due to their elite status, all players were of similar conditioning level and expertise. All soccer players in this study were free from injury at the time of data collection. One of the soccer players in this study was a goal keeper. To further describe the elite level of these players, one player of this team was a member of the U.S. National team.

This study was similar to other caffeine and sports performance studies in that participants were athletes (Bruce et al., 2000; Collomp et al., 1992; Costill et al., 1978; Duvnjak-Zaknich et al., 2011; Paton et al., 2001; Pontifex et al., 2010; Schneiker et al., 2006; Stuart et al., 2005). Participants in this study however were "elite" athletes and few

authors describe their participants as “well-trained” or “highly-trained” athletes (Bruce et al., 2000; Collomp et al., 1992; Paton et al., 2001). This study is similar to a few studies in that youth were utilized as participants to assess caffeine’s effect on exercise (Turley et al., 2007; Turley & Gerst, 2006). Most researchers evaluating caffeine’s effect on exercise have utilized adults as participants and the results of the two previously cited studies indicate caffeine’s effect on youth can be different than that of adults.

Background of the Problem

Since the original investigations into the ergogenic properties of caffeine in 1978 by Costill and colleagues, caffeine has been shown to provide performance-enhancing effects in a number of athletic events. Caffeine has been shown to enhance endurance performance from time to exhaustion to 2,000 m performance (Bell & McLellan, 2002; 2003; Bruce et al., 2000; Costill et al., 1978). While caffeine’s effects on endurance performance have dominated the caffeine research literature, caffeine’s effects on anaerobic activities have also been investigated. Early studies evaluated caffeine’s effect on performance of a Wingate test and found no enhanced performance for the caffeine supplement (Collomp et al., 1992). Other studies however found improved performance from caffeine supplementation (Anselme et al., 1992; Bell et al., 2001). While caffeine has been shown to enhance both aerobic and anaerobic performance, the most recent caffeine studies have evaluated caffeine’s effects on agility performance.

Before discussing the caffeine and agility literature, it is important to define agility. The literature provides no concise definition of agility. Most of the definitions focus on the physical aspect and use statements that describe those qualities. It is important however, to recognize that agility also encompasses a cognitive component and

this too must be included in a definition of agility. While many definitions for agility exist, the one used for this study was inclusive and defined in a recent unpublished dissertation as “an unplanned, rapid, whole-body movement with change of velocity or direction in response to a stimulus” (Bettle, 2009, p. 13). According to this definition, a task must be an open skill with no pre-planned response. This is a more inclusive definition that recognizes the cognitive component of agility and is more representative of game play.

Now that agility has been defined, the previous research on caffeine and agility performance can be discussed. Few studies exist in the literature assessing caffeine’s effect on athletic agility. Lorino et al. (2006) were the first researchers to assess the effect of caffeine on agility performance and found no significant differences. However, their study used a proagility run that is pre-planned and may not truly evaluate agility performance according to the definition previously discussed. Their study also included young adult males as participants, and because agility is sport-specific in nature, the type of participants may also represent a flaw in this study. More recent studies have evaluated caffeine’s effect on a RAT that more closely represent the definition of agility as unplanned in nature and changing direction in response to a stimulus.

Before addressing caffeine and RAT studies, it is important to discuss the physiological effects for which caffeine might improve RAT performance. Over several decades, studies have found improvement in simple reaction times from caffeine supplementation (Cheney, 1935; Cheney, 1936; Durlac et al., 2002; Jacobson & Edgley, 1987; Smith et al., 1977; van Duinen et al., 2005; Wenzel & Rutledge, 1962).

Improvements in reaction time from caffeine have been linked to caffeine’s effect on the

CNS which lowers the threshold for motor unit recruitment, alters excitation/contraction coupling, enhances nerve transmission, and increases ion transport within the muscle (McArdle et al., 2007). Because caffeine has been shown to enhance simple reaction time, logically, caffeine could have the potential to improve reaction time (or the cognitive component of agility) in a sport-specific setting.

Pontifex et al. (2010) were the first to evaluate the effects of caffeine on a RAT and found that when compared to the placebo, caffeine showed no significant difference in performance. An issue with this test however was the use of a light stimulus to assess participants' reaction times. The use of a light stimulus is generic and is not representative of a game play situation in which a player reacts to another player's movement (Abernethy & Russell, 1987; Farrow et al., 1998; Sheppard & Young, 2006). Therefore, this study may not be representative of caffeine's effects on reactive agility during game play.

Duvnjak-Zaknich et al. (2011) is the most recent group to investigate caffeine's effect on a RAT. They attempted to make the test more sport-specific using a video of a life-sized opponent in a defensive pursuit scenario. These researchers used a RAT that consisted of 5 trials and measured total time, reactive time, decision time, movement time, and decision-making accuracy. They found no significant differences in these measurements, however caffeine produced consistently faster results in all of these measurements. While caffeine was found to produce faster results, the lack of statistical significance may be due to the small sample size ($N = 10$).

Because there appears to be limited research evaluating caffeine's effect on reactive agility performance, more research evaluating caffeine's effect on this area of

sports performance is warranted. Also, there appears to be a lack in the current body of knowledge into caffeine's effect on adolescent sports performance. Therefore, the purpose of this study was to assess the effects of $6 \text{ mg}\cdot\text{kg}^{-1}$ of caffeine on the performance of a RAT and to assess caffeine's effect on both the cognitive (reaction time) and the physical (sprint time) components of agility to both the dominant and non-dominant sides in 17 elite, male, youth soccer players.

Discussion of the Results

Reaction time. Caffeine ingestion produced a significant improvement in player's reaction times to their non-dominant side. However, caffeine ingestion produced no significant improvement in players' reaction times to their dominant side. Therefore, the hypothesis that caffeine ingestion would significantly decrease participants' reaction time for the fastest non-dominant leg trial was supported while the hypothesis that caffeine ingestion would significantly decrease reaction time for the fastest dominant leg trial was not supported.

The finding that caffeine improved reaction time is consistent with previous literature assessing caffeine's effect on simple reaction time which also showed improvements (Cheney, 1935; Cheney, 1936; Durlac et al., 2002; Jacobson & Edgley, 1987; Smith et al., 1977; van Duinen et al., 2005; Wenzel & Rutledge, 1962). Caffeine's effect on the CNS may be the reason for the improvements in reaction time. Caffeine lowers the threshold for motor unit recruitment, alters excitation/contraction coupling, enhances nerve transmission, and increases ion transport within the muscle (McArdle et al., 2007).

The findings from this study are also consistent with another research study finding improvements from caffeine in the reactive component of a RAT (Duvnjak-Zaknich et al., 2011). These researchers found no significant differences in total time, reactive time, decision time, movement time, and decision-making accuracy, however caffeine produced consistently faster results in all of these measurements. While these researchers did find that caffeine consistently produced faster results, the lack of statistical significance may be due to the small sample size ($N = 10$). Therefore, the current study appears to be the first to find a statistically significant difference in the reaction time portion of a RAT. Furthermore, the study conducted by Duvnjak-Zaknich et al. did not analyze reaction times to the dominant and non-dominant sides. Therefore, this study appears to be the first to attempt to address how caffeine affects RAT performance to dominant and non-dominant sides.

There was a difference in caffeine's effect on reaction times to the players' dominant and non-dominant sides. While it is speculative to conclude, this finding may be due to the players' elite status. Because these players were elite players and had years of practice, they were "more skilled" to their dominant side and therefore had little, if any, room for improvement to their dominant side. Because the dominant side of anyone (including elite athletes) is used more often, the neurons that carry the messages to and from the brain to the motor units become more efficient and faster. This may be the reason for the difference between the dominant and non-dominant side findings. This speculation appears to be supported in a study analyzing hand dominance and motor unit firing behavior (Adam, De Luca, & Erim, 1998).

Adam et al. (1998) evaluated the effect of hand dominance on motor unit firing. These researchers found that daily preferential use altered physical and mechanical properties of skeletal muscle. In particular, in the motor units of the dominant hand, mean values for recruitment threshold, initial firing rate, average firing rate at target force, and discharge variability were lower when compared with the non-dominant hand. Also, there were peaks of longer latency in the dominant hand than in the non-dominant hand. The lower average firing rates, lower recruitment thresholds, and greater firing rate/force delay in the dominant hand allowed twitch fusion and force buildup to occur at lower firing rates. The authors suggested that a lifetime of preferred use might cause adaptations in the fiber composition of the dominant muscle such that mechanical effectiveness of its motor units increases.

If this finding also occurs in the muscles of the legs, this may be the reason for finding improvements in reaction time with caffeine to the non-dominant side, but not the dominant side. As previously discussed, one of the ways caffeine alters the CNS is by lowering the threshold for motor unit recruitment (McArdle et al., 2007). Based on the results of the Adam et al. (1998) study, it may be possible that to the players' dominant side, the threshold for motor unit recruitment was already at its lowest level and therefore, there was no room for further improvement from the caffeine supplement to the dominant side.

Sprint time. No significant differences were found with caffeine ingestion on the sprint time portion of the RAT. Consequently, the hypotheses that caffeine ingestion would significantly decrease the sprint time for the fastest dominant and non-dominant leg trials were not supported. This is an inconsistent finding with other studies assessing

only caffeine's effect on sprint times which found improvements from the caffeine supplement (Carr et al., 2008; Glaister et al., 2008; Stuart et al., 2005). Previous studies have included longer run distances with sprint times being the major component of interest. The main purpose of this study was to assess reactive agility performance that occurs in a small area of the field; therefore, the distance of 4.5 m used in this study may not have been long enough to detect a statistically significant difference from the caffeine supplement.

Another possibility is that the sample size in this study was too small to detect a significant difference. Because elite athletes were chosen as participants in this study, it was difficult to find a large sample of players who met the inclusion criteria. However, eta squared indicated a weak model explaining only 1.7% and 6.6% for the dominant and non-dominant sprint time analyses respectively. Therefore, sample size may not be to blame for the lack of statistical significance. It is important to note that while not statistically significant, the mean caffeine sprint time was faster when compared to the placebo time to the non-dominant side (Baseline = .0987, Caffeine = .0997, Placebo = 1.002). This would indicate that there is potential for caffeine to improve non-dominant side performance in elite youth athletes. This again may be related to the players' elite status and the neural firing processes previously discussed.

Total time. No significant differences were found with caffeine ingestion on the total time it took players to complete the RAT. Therefore, the hypotheses that caffeine ingestion would significantly decrease the total time to complete the agility test for the fastest dominant and non-dominant leg trials were not supported. However, the level of significance ($p = .051$) for players' total time to the non-dominant side indicated that

caffeine did produce improvement. Despite the lack of statistical significance, the finding of improved total time to complete a RAT is consistent with a previous study that also found improvement (Duvnjak-Zaknich et al., 2011). However, Duvnjak-Zaknich et al. (2011) this study did not examine the effect caffeine had on players' dominant and non-dominant sides.

It is interesting to note that the results indicated almost statistically significant improvement in total time with caffeine to the non-dominant side, but not the dominant side. This was most likely produced by the significantly improved reaction time component of the RAT to the non-dominant side. This indicates that even though no significant improvement was found in sprint times to either side, caffeine may affect performance of a RAT and therefore may affect play in a game situation. If caffeine has the ability to improve reaction time, indicated by results of this study, improved reaction time would allow a player to elude an opponent; therefore the improvement in reaction time alone could be the difference in a game.

HR. No significant differences were found with caffeine ingestion on players' heart rates after one hour of taking the supplement, before the RAT, or at the conclusion of the test. Therefore, the hypotheses that there would be significant differences among the baseline, caffeine, and placebo conditions on HR before warm-up, before the start of the test, and at the conclusion of the test were not supported.

The hypothesis of increased HR from caffeine supplementation was based on the fact that caffeine increases the level of circulating epinephrine (Graham, 2001). Therefore, it would appear logical that caffeine supplementation would increase HR. An increased HR from caffeine supplementation is also supported in the caffeine and

exercise performance literature (Bell & McLellan, 2002; Glaister et al., 2008). However, numerous other studies have found no significant increase in HR from caffeine supplementation (Bell & McLellan, 2003; Bruce et al., 2000; Costill et al., 1978; Duvnjak-Zaknich et al., 2011; Pontifex et al., 2010).

While physiologically, it is logical that caffeine should produce a significant effect on HR by increases in epinephrine, the physiology of youth is different than adults. Children are not miniature adults and therefore their physiological responses are different. The few studies that have examined caffeine's effects on youth sports performance have found that HR decreases in youth both at rest and at exercise (Turley et al., 2007; Turley & Gerst, 2006). While the exact mechanisms are unclear, a potential reason for the differing HR response has been speculated to be a baroreflex mediated response (Robertson et al., 1978; Waring, Goudsmit, Marwick, Webb, & Maxwell, 2003). Blood pressure may have slightly increased with the caffeine supplement and therefore blunted caffeine's effect on HR, thus causing no significant difference in HR with caffeine. This may potentially explain the reason for the differences in youth compared to adult HR response to caffeine supplementation.

RPE. Caffeine produced no significant difference in RPE after warm-up. However, RPE at the conclusion of the test was significantly increased with caffeine supplementation. Therefore, the hypothesis that there would be a significant difference between conditions on RPE after warm-up was not supported while the hypothesis that there would be a significant difference between conditions on RPE at the conclusion of the test was supported. Caffeine ingestion has been shown in previous studies to lower participants' RPE (Bell & McLellan, 2002; Costill et al., 1978). Other studies, however,

have found caffeine to produce no effect on RPE (Bell et al., 2002; Bruce et al., 2000; Duvnjak-Zaknich et al., 2011; Glaister et al., 2008; Schneiker et al., 2006). While this study did document a statistically higher RPE with the caffeine supplement, it is important to note that it may not be practically significant. The mean RPE scores of both the baseline and caffeine were 11 and 12 respectively. Because RPE is reported in a whole number, this finding may not be indicative of an actual relevant change in perceived difficulty of the task.

Post-trial questionnaire. Analysis of the post-test questionnaire revealed that 4 of the 17 players were able to correctly guess the caffeine treatment trials. Players were asked to provide descriptions supporting their choice and these descriptions included "I think this because I felt hyper and my heart rate was up," "I felt extremely energetic and focused in," "Normal movements became slightly faster," and "In the warm-ups, I felt a lot more energetic than before I took the pill." The post-test questionnaire analysis of this study is consistent with previous studies in that participants were able to correctly guess the caffeine treatment (Carr et al., 2008; Duvnjak-Zaknich et al., 2011). Compared to these previous studies that reported this measurement, a lower percentage of participants correctly guessed the caffeine treatment in this study. In the current study, 23.5% of the participants were able to correctly guess the caffeine treatment. This is compared to 80% and 40% in previous studies (Carr et al., 2008; Duvnjak-Zaknich et al., 2011). The 23.5% indicates that in the current study, the treatment was better blinded than with other studies which decreases the likelihood that confounding variable such as correctly guessing the treatment influenced the results of the current study.

Overall Conclusions and Future Research Consideration.

Numerous studies have provided evidence that caffeine has the potential to improve performance in various sports activities (Anselme et al., 1992; Bell & McLellan, 2002; 2003; Bruce et al., 2000; Carr et al., 2008; Collomp et al., 1992; Costill et al., 1978; Glaister et al., 2008; Pontifex et al., 2010; Schneiker et al., 2006; Stuart et al., 2005). While the majority of the literature has focused on caffeine's effects on endurance performance, limited research has also been conducted on caffeine's effects on agility performance. Lorino et al. (2006) used a proagility test with a preplanned movement. This may not be representative of the agility needed during game play because this test lacks a cognitive component in which a player reacts to an opponent's movements. Pontifex et al. (2010) used a RAT in an attempt to address the cognitive component of agility, however lights were used as the stimulus for movement. Such generic cues are not representative of game play because players react to opponent's movements and not a light stimulus in play situations. In an attempt to be sports-specific, the most recent caffeine and RAT study used a video of an opponent to simulate reaction and to assess players' performance with and without caffeine (Duvnjak-Zaknich et al., 2011). While the use of a video provides consistency of movement between each test, this again is not most representative of game play where the movement of an opponent during play is not always consistent and the depth of a cut depends on the game situation.

In this study, an attempt was made to simulate actual game play by using a live soccer player as a defender to stimulate reaction. While every attempt was made to have the cuts of the defending soccer player be consistent, the step may have been slightly

different between tests. This slight difference does allow the testing components of this study to more closely translate to actual game play. Therefore, the use of an actual soccer player to stimulate participants' reaction in this study is unique.

Similar to other caffeine and reactive agility studies, an improvement of the reactive component of the RAT was found in this study (Duvnjak-Zaknich et al., 2011). The uniqueness of this study was the examination of caffeine's effect on performance of the RAT to the players' dominant and non-dominant side. To the author's knowledge, this is the first study to attempt to evaluate caffeine's effect on dominant and non-dominant side performance in a RAT. There were differences between the two sides with significant improvements seen toward the non-dominant side. This may be due to the participants in this study being elite soccer players. From years of practice, the neurons to their dominant side have become highly efficient and therefore improvements in reaction time from caffeine supplementation can only be found to the non-dominant side.

The results of this study indicate that caffeine supplementation using $6 \text{ mg}\cdot\text{kg}^{-1}$ does improve performance on a RAT. In particular, caffeine appears to have a significant effect on the reactive component and an approaching significance effect on the total time to complete the RAT to the non-dominant side in this sample of elite, male, youth soccer players. Caffeine produced no significant effect on HR. This finding was different from studies using adult participants that found an increase in HR with caffeine supplementation (Bell & McLellan, 2002; Glaister et al., 2008). However, this finding is somewhat consistent with other youth and caffeine studies in that HR was significantly lowered while no significant difference was found in the current study (Turley et al., 2007; Turley & Gerst, 2006). RPE was not significantly affected after the warm-up,

however caffeine produced a significantly higher RPE at the conclusion of the RAT. While this finding did reach statistical significance, it is important to note that this may not be practically significant as both the caffeine and placebo numbers were 12 and RPE is reported as a whole number. While this study included a larger sample size than the latest caffeine and RAT (10 compared to 17 in this study), more research is needed with larger sample sizes to test the effects of caffeine on a RAT. Additionally, this study included elite athletes in an athletic setting while most other studies used “recreationally active” or “moderately trained participants.” Also, this study included youth athletes and few studies have assessed caffeine’s effect on youth in an athletic setting (Turley et al., 2007; Turley & Gerst, 2006). Therefore, more research is needed to assess caffeine’s effects on youth sports performance, in particular elite players. To the author’s knowledge, this is the first study to examine caffeine’s effect in youth athletes on performance of a RAT.

One important factor to keep in mind is the legality of caffeine’s use as an ergogenic aid. While caffeine is currently not banned by WADA, it is banned at high urinary concentration of 15 $\mu\text{g}\cdot\text{mL}$ by the NCAA. Therefore, athletes and coaches should use caution and abide by their sport sanctioning body rules on the use of caffeine supplementation during competition. Previous studies have indicated that the 6 $\text{mg}\cdot\text{kg}^{-1}$ dosage that was used in this study is well below the NCAA level, however these studies used adults as participants. Just as HR was different with youth, this too may be different in this population. Therefore, caution should be used when providing caffeine supplementation to youth. Overall, this study shows that caffeine does have the potential

to improve performance of a RAT. Therefore, caffeine may be beneficial in improving performance during a soccer match in elite, male, youth soccer players.

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APPENDICES

APPENDIX A

Caffeine Questionnaire

Name: _____

Caffeine Questionnaire

*Listed below are questions regarding your age, smoking habits, caffeine allergies, dominant foot, and **daily** caffeine consumption. Please answer all questions as honestly and as accurately as possible. This questionnaire is to be completed in consultation with your parents and/or legal guardian.*

Age

ADD/ADHD Medications

Are you currently taking any medications for ADD/ADHD?

 Yes No**Smoking Habits**

Do you smoke?

 Yes No**Caffeine Allergies**

Do you have any known allergies to caffeine?

 Yes No**Dominant Foot** (defined as the foot you would kick a penalty shot with) Left Right

Daily Caffeine Consumption

Listed below is a list of several foods and drinks containing caffeine. Please indicate beside each item how many times **PER DAY** (on average) each item is consumed.

Soft Drinks

All are listed as 12-ounce beverages unless other wise noted.

Red Bull (8.2 oz) 80.0 mg ____

Jolt 71.2 mg ____

Pepsi One 55.5 mg ____

Mountain Dew 55.0 mg ____

Mountain Dew Code Red 55.0 mg ____

Diet Mountain Dew 55.0 mg ____

Kick Citrus 54.0 mg ____

Mellow Yellow 52.8 mg ____

Surge 51.0 mg ____

Tab 46.8 mg ____

Diet Coke 45.6 mg ____

Shasta Cola 44.4 mg ____

Shasta Cherry Cola 44.4 mg ____

Shasta Diet Cola 44.4 mg ____

RC Cola 43.0 mg ____

Diet RC 43.0 mg ____

Dr. Pepper 41.0 mg ____

Diet Dr. Pepper 41.0 mg ____

Diet Sunkist Orange 41.0 mg ____

Mr. Pibb 40.0 mg ____

Sugar-Free Mr. Pibb 40.0 mg ____

Red Flash 40.0 mg ____

Sunkist Orange 40.0 mg ____

Slim-Fast Cappuccino Delight Shake 40.0 mg ____

Ruby Red 39.0 mg ____

Storm 38.0 mg ____

Big Red 38.0 mg ____

Pepsi-Cola 37.5 mg ____

Pepsi Twist 37.5 mg ____

Diet Pepsi Jazz 37.5 mg ____

Diet Pepsi 36.0 mg ____

Wild Cherry Pepsi 38.0 mg ____

Diet Wild Cherry Pepsi 36.0 mg ____

Diet Pepsi Twist 36.0 mg ____

Aspen 36.0 mg ____

Coca-Cola Classic 34.0 mg ____

Cherry Coke 34.0 mg ____

Lemon Coke 34.0 mg ____

Vanilla Coke 34.0 mg ____

Diet Cherry Coke 34.0 mg ____

Snapple Flavored Teas (Reg. or Diet) 31.5 mg ____

Canada Dry Cola 30.0 mg ____

A&W Crème Soda 29.0 mg ____

Nestea Sweet Iced Tea 26.5 mg ____

Nestea Unsweetened Iced Tea 26.0 mg ____

Lipton Diet Green Tea with Citrus (16.9 oz) 23.0 mg ____

Barq's Root Beer 23.0 mg ____

A&W Diet Crème Soda 22.0 mg ____

Slim-Fast Chocolate Flavors 20.0 mg ____

Lipton Brisk, All Varieties 9.0 mg ____

Canada Dry Diet Cola 1.2 mg ____

Other Beverages and foods

Coffee (6 oz) 125 mg ____

Decaffeinated coffee (6 oz) 5 mg ____

Tea (6 oz) 50 mg ____

Hot cocoa (6 oz) 15 mg ____

Chocolate Bar 20 mg ____

Over-the Counter Medications

Anacin 32 mg ____

Appetite-Control Pills 100-200 mg ____

Dristan 16 mg ____

Excedrin 65 mg ____

Extra Strength Excedrin 100 mg ____

NoDoz 200 mg ____

Triamicin 30 mg ____

Vanquish 33 mg ____

Vivarin 200 mg ____

Prescription Medications

Cafergot 100 mg ____

Fiorinal 40 mg ____

Darvon Compound 32 mg ____

Please list below any other caffeine-containing products that you consume that were not included in the above list and the approximate amount.

APPENDIX B

University Institutional Review Board Approval



August 18, 2011

James Bradley Jordan, Jennifer Caputo, Richard Farley, Jwa Kim, John Coons
Department of Health and Human Performance
jbj2m@mtmail.mtsu.edu, jenn.caputo@mtsu.edu, richard.farley@mtsu.edu

Protocol Title: "Caffeine Supplementation and Reactive Agility in Elite Youth Soccer Players"
Protocol Number: **12-019**

Dear Investigator(s),

The MTSU Institutional Review Board, or a representative of the IRB, has reviewed the research proposal identified above. The MTSU IRB or its representative has determined that the study poses minimal risk to participants and qualifies for an expedited review under 45 CFR 46.110 Category 1 and 4.

Approval is granted for one (1) year from the date of this letter for 30 maximum participants.

According to MTSU Policy, a researcher is defined as anyone who works with data or has contact with participants. Anyone meeting this definition needs to be listed on the protocol and needs to provide a certificate of training to the Office of Compliance. **If you add researchers to an approved project, please forward an updated list of researchers and their certificates of training to the Office of Compliance (c/o Emily Born, Box 134) before they begin to work on the project.** Any change to the protocol must be submitted to the IRB before implementing this change.

Please note that any unanticipated harms to participants or adverse events must be reported to the Office of Compliance at (615) 494-8918.

You will need to submit an end-of-project form to the Office of Compliance upon completion of your research located on the IRB website. Complete research means that you have finished collecting and analyzing data. **Should you not finish your research within the one (1) year period, you must submit a Progress Report and request a continuation prior to the expiration date.** Please allow time for review and requested revisions. Your study expires **August 18, 2012.**

Also, all research materials must be retained by the PI or faculty advisor (if the PI is a student) for at least three (3) years after study completion. Should you have any questions or need additional information, please do not hesitate to contact me.

Sincerely,

A handwritten signature in cursive script that reads "Emily Born".

Emily Born
Research Compliance Officer
Middle Tennessee State University
eborn@mtsu.edu

APPENDIX C

Assent Form

Middle Tennessee State University Institutional Review Board Proposal for Research Using Human Participants Assent Document for Research Study	MTSU IRB Approved Date 8/18/11
PI: James Bradley Jordan Title of Study: The Effects of Caffeine Supplementation on Performance of a Reactive Agility Test in Elite Youth Soccer Players Institution/Hospital: Middle Tennessee State University	Version Date: July 2011
This assent document applies to: <u>Children 13-15 years of age</u>	
Name of participant _____ Age _____	
<p>Below are the answers to some of the questions you may have. If you have any questions about what is written below or have any other questions about this research, please ask them. You will be given a copy of this consent form.</p>	
<ol style="list-style-type: none"> 1. Why are you doing this research? This research will allow us to determine if caffeine is beneficial to elite youth soccer players' agility performance. 2. What will I do and how long will it take? You will run through a reactive agility test in which you will react to another soccer player's movement as you would during one of your soccer matches. You will complete 4 trials of this test. The first trial will be for you to practice the test. The second trial will be to measure your agility time without any supplement. In the third and fourth trials, you may or may not receive the caffeine supplement (6 mg·kg⁻¹ body mass). The caffeine dosage would be equivalent to around 2 ½ 16 oz. Monster energy drinks if you weight 155 lbs. It will take part of 4 normal practice sessions over a 2-week period of time. 3. Do I have to be in this research study and can I stop if I want to? You do not have to be in this research study, and if you decide to start but don't want to finish, you can stop if you want. 4. Could it make me sick [or sicker]? The caffeine should not make you sick, however, if you do feel bad after taking the caffeine please notify a researcher or your parents. 5. Will anyone know that I am in this research study? All efforts, within reason, will be made to keep the data in your research record private but we cannot promise total privacy. The data we collect on you may be shared with others (for example, <i>doctors or MTSU IRB</i>) if you or someone else is in danger or if we have to do so by law. 6. How will this research help me or other people? You will learn caffeine's potential benefits to agility performance. This information may help you improve your soccer play. You will also learn about the research process through your participation. 7. Can I do something else instead of this research? You do not have to be in this research study, but there is nothing else you can do instead of this research study. 8. Who do I talk to if I have questions? You can talk to your parents or your parents can call the people in charge of the study. James Bradley Jordan can be reached at (615) 838-5352 or my faculty advisors Jennifer Caputo, Ph.D. at (615) 898-5547 and Richard Farley, Ph.D. at (615) 898-5298. 	
_____ Date	_____ Signature of patient/volunteer
Consent obtained by: _____ <div style="display: flex; justify-content: space-between;"> Signature Printed Name and Title </div>	

APPENDIX D

Parental Consent Form

**Middle Tennessee State University Institutional Review Board
Parental Informed Consent Document for Research**

MTSU
IRB Approved
Date: 8/18/11

Principal Investigator: James Bradley Jordan
Study Title: The Effects of Caffeine Supplementation on Performance of a Reactive Agility Test in Elite Youth Soccer Players
Institution: Middle Tennessee State University

Name of participant: _____ **Age:** _____

The following information is provided to inform you about the research project and your child's participation in it. Please read this form carefully and feel free to ask any questions you may have about this study and the information given below. You will be given an opportunity to ask questions, and your questions will be answered. Also, you will be given a copy of this consent form.

Your child's participation in this research study is voluntary. He or she is also free to withdraw from this study at any time. In the event new information becomes available that may affect the risks or benefits associated with this research study or your willingness to participate in it, you will be notified so that you can make an informed decision whether or not to continue your participation in this study.

For additional information about giving consent or your rights as a participant in this study, please feel free to contact the MTSU Office of Compliance at (615) 494-8918.

1. Purpose of the study:

Your child is being asked to participate in a research study because your child is an elite youth soccer player. The purpose of this study is to evaluate a caffeine supplement's effect on a reactive agility test in male elite youth soccer players.

2. Description of procedures to be followed and approximate duration of the study:

In consultation with you, your child will be asked to complete questionnaires to screen for health issues that may be exacerbated by caffeine usage as well as to assess normal caffeine intake. Your child's height and weight will then be recorded prior to completing any testing to determine the appropriate caffeine dosage. You and your child will then be given notice of testing and will be asked to have your child refrain from caffeine use for 24 hours prior to testing. This washout period is very important to not only assess the caffeine's supplement effects on the agility test but also as a safety precaution to prevent a caffeine overdose.

Your child will then complete 4 trials of a reactive agility test. Trial 1 will be to familiarize your child with the testing protocol. Trial 2 will be to establish a baseline to evaluate the placebo and caffeine's effects on the reactive agility test. Trials 3 and 4 will be the experimental trials in which your child may or may not receive the caffeine supplement (6 mg·kg⁻¹ body mass; Sigma Aldrich) or a placebo (maltodextrin; NOW Sports, Carbo Gain) 1 hour prior to testing. Measurements of heart rate (pulse) and blood pressure will be taken both pre-and post-test to evaluate caffeine's effects on both measures as well as helping to ensure the safety of your child while participating in this study. The trials will be separated by at least 24 hours but no more than 72 hours apart. The 6 mg·kg⁻¹ body mass is equivalent to around 2 ½ 16 oz. Monster energy drinks for a 70 kg or 155 lb person. At the completion of trials 3 and 4, your child will be asked to identify which experimental treatment (caffeine or placebo) they believed they received during the session and their reasons for that choice. This information will be used to determine if correctly guessing the treatment may have affected the results.

3. Expected costs: There will be no expected financial cost to you other than your time and transportation of your child to the soccer field.

4. Description of the discomforts, inconveniences, and/or possible risks that can be reasonably expected as a result of participation in this study: Caffeine consumption may lead to restlessness, headache, insomnia, nervous irritability, muscle twitching, tremulousness, psychomotor agitation, elevated heart rate and blood pressure, and in some cases premature left-ventricular contractions. These side effects are not expected in the moderate dosage your child will be consuming during the study. The most

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common side effect from this dosage may be insomnia. The running trials may lead to mild soreness in the leg muscles however because your child is an elite soccer player this is unexpected.

5. **Compensation in case of study-related injury:** No compensation will be given in the case of study related injury.
6. **Anticipated benefits from this study:**
 - a) The potential benefits to science and humankind that may result from this study are to learn whether caffeine is potentially ergogenic (performance enhancing) during agility tasks. Previous research has indicated that caffeine has the potential to be ergogenic during endurance exercise however, little research has tested caffeine's effects on agility. This will allow sports governing bodies to set a restriction and/or more strenuous restriction on caffeine's usage. Also, if caffeine remains a legal supplement it will allow athletes to take the substance to enhance training as well as improve performance during competition.
 - b) The potential benefits to you and your child from this study are to learn caffeine's potential effects on sports performance. You and your child will also learn about the research process by active participation in this study.
7. **Alternative treatments available:** No alternative treatments are available.
8. **Compensation for participation:** No compensation for participation in this study will be given.
9. **Circumstances under which the Principal Investigator may withdraw you from study participation:** You may be withdrawn from the study if your child does not meeting the requirements of the study. Participants who miss a testing session may also be excluded from the study.
10. **What happens if you choose to withdraw from study participation:** No penalties will result from withdrawing from this study.
11. **Contact information.** If you should have any questions about this research study or possibly injury, please feel free to contact James Bradley Jordan at (615) 838-5352 or my Faculty Advisors, Jennifer Caputo, Ph.D. at (615) 898-5547 and Richard Farley, Ph.D. at (615) 898-5298.
12. **Confidentiality.** All efforts, within reason, will be made to keep the personal information in your child's research record private but total privacy cannot be promised. Your information may be shared with MTSU or the government, such as the Middle Tennessee State University Institutional Review Board, Federal Government Office for Human Research Protections, if you or someone else is in danger or if we are required to do so by law.
13. **STATEMENT BY PERSON AGREEING TO PARTICIPATE IN THIS STUDY**
I have read this informed consent document and the material contained in it has been explained to me verbally. I understand each part of the document, all my questions have been answered, and I give permission for my child to participate in the study.

Date

Signature of patient/volunteer

Consent obtained by:

Date

Signature

Printed Name and Title

APPENDIX E

Post-Trial Questionnaire

Name: _____

Post-Trial Questionnaire

1. What experimental treatment do you believe you received for this trial?

_____ Caffeine

_____ Placebo

2. Please list/describe the reason for your choice.
