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The Effects Of Caffeine Supplementation When Manipulating The Time Of Ingestion Prior To Simulated Rugby Union Activity

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This thesis is dedicated to,

My mother and sister for their unending love and support.

I could not have done any of this without you.

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ABSTRACT

The research completed for this project attempted to narrow the window of time for when caffeine should be ingested, prior to activity, in order to elicit an ergogenic effect on rugby union performance. Caffeine is a commonly used substance that is incorporated in a variety of sporting realms to enhance cognition and skill by targeting focus, enhancing wakefulness and allowing the athlete to sustain a higher level of performance for longer durations. The experimental design for this study mimicked work from a previous study that was conducted to understand the effect of caffeine on rugby specific performance. University club level rugby athletes were recruited for this study. The design involved completing a rugby specific circuit that included eight separate stations, requiring participants to complete ten rounds in total.

It was concluded that caffeine will enhance performance when ingested sixty minutes prior to activity but there are also enhancements in skill performance when ingested at thirty minutes prior to activity. It is understood that other factors such as caffeine dosage, exposure and tolerance, along with the specific activity completed should be considered to fully comprehend suitable timing of caffeine ingestion before engaging in activity.

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ABBREVIATIONS

1. Caffeine .... CAF
2. Placebo .... PLAC
3. Central Nervous System .... CNS
4. Ratings of Perceived Exertion .... RPE
5. Standard Deviation Between Subjects .... SD_B
6. Standard Deviation Within Subjects .... SD_W
7. Repetition Maximum .... RM
8. Blood Lactate .... BL
9. Body Mass .... BM
10. Body Mass Index .... BMI
11. Basal Metabolic Rate .... BMR
12. Counter Movement Jump .... CMJ
13. Loughborough Soccer Passing Test .... LSPT
14. Loughborough Intermittent Shuttle Test .... LIST

CHAPTER I

INTRODUCTION

Caffeine is one of the more prominent forms of supplementation used by athletes to strengthen performance in both competition and training. This specifically relates to activities that are endurance based but also stresses the three major metabolic pathways collectively (Oxidative, Glycolytic, Phosphagen). Examples of such sports include soccer, rugby, and field hockey.

The research looked at in more detail for this paper involves activities that are organized sports (rugby, soccer, basketball, hockey), but also individualized activities (cycling and track and field events). These activities have also been incorporated within this field of research to gain clearer insight to how caffeine supplementation can be administered effectively and efficiently to enhance performance on the physical level, as well as the cognitive level, for athletes' overall performance during a match or for improving training ability.

In team sports there will be several athletes involved with decisions in the game and the level of momentum can shift suddenly if one or more of the players suddenly find good rhythm and work in a zone of optimal performance. Alternatively, if performance of one or more of the players suddenly deteriorates, this too can have enormous impacts on the flow of the game. Sport and its spontaneity does pose extraneous variables since the decisions of other players cannot be predetermined and this is what makes sports exciting since predictions cannot be made before or during in regards to the developments or the outcome of the match. This is not the purpose behind this particular study, but rather to understand that there are areas of work that involve key moments in match play where the game can suddenly shift depending on how the players on the field react to certain situations. This cannot always be monitored and prevented but it's understood to be a factor in game like experiences. This study and review is looking at how the players respond physiologically to the effects of caffeine ingestion, if there is an enhancement in overall performance and also at what point this is most prevalent.

Individuals involved within sport; recreationally, at the college level, or professionally, are driven by the notion of developing optimal performance when engaging in their sport to best their opponent(s). A key variable considered when optimizing performance concerns the level of training the athletes are subjected to, individually and collectively as a squad. With effective training the players are able to build team cohesion and also enhance their level of skill individually and collectively as a team. Understanding that training effectively and efficiently will yield positive results when it comes to match day is pivotal for the coaches and for the athletes themselves. Correct nutrition is an aspect that athletes and coaches are able to modify to match the needs of the sport and for the individual athlete. This compliments the training because if the athlete is well hydrated and they have sufficient energy stores, then they will be able to focus and sustain the demands of their sport for longer periods as well as be more effective in play. This relates closely to events and organized sports, where the sports are more demanding aerobically and require greater levels of muscular endurance as these athletes are performing for longer periods of time. The level of skill must remain higher as most games and events are determined in the last portion of the match (Mohr, Krustrup, & Bangsbo, 2003; Green, 1997). There are also considerations to take with athletes that are involved with sports that have them working anaerobically. These individuals are performing sudden bursts and short sprints, and they need to recover whilst they are still moving. This is more prevalent in sports at a higher level since the level of skill is much greater and the level of fitness is also superior to that seen at semi-professional and college level events.

Supplementation is the next step for athletes and although a common tool implemented within most sports in the modern era, there is varied understanding into the correct methodology for optimizing the use of supplementation. It appears that players and coaches know what to supplement their events with, but understanding correct timing for ingestion and by how much, can offer an even greater benefit to athletes either in the beginning of their training or during a training session. There would also be a benefit when offering supplements to athletes prior to competitions or match day so the players are not just mentally ready but they are also physically prepared for the demands of the game. This can in some cases cause a placebo effect if the players have used the supplementation previously and they were successful in the following day of competition. In contrast, there is also the likelihood that caffeine can produce a negative effect upon the athletes based upon previous experiences along with limited knowledge as to what the proposed effects of caffeine might be. This is referred to as the nocebo effect where suggestions of certain substances can bring about negative effects in patients or research subjects. Within a study looking at the effects of caffeine on cycling performance, subjects had various testing days where they were given caffeine and told they were had received a caffeine treatment, not given caffeine and told they were had received a caffeine treatment, given caffeine and told they had not received a caffeine treatment, and not given caffeine and told they had not received a caffeine treatment (Foad, Beedie, & Coleman, 2008). The researchers within this study found that when the subjects were told they had received the caffeine supplement but were actually given a placebo, they had improvements in their cycling times. Likewise, when the subjects were given the caffeine supplement, and told that they had received a sugar pill, they performed worse in the cycling tests compared to when they had the caffeine treatment and also told that they had ingested caffeine. Therefore, the placebo effect, along with the nocebo effect, should be taken into account in such studies.

The purpose of this paper is to look at the research pertaining to the ergogenic effects that might occur in athletes in training or within a match when supplementing with the drug, caffeine. More specifically, understanding that effective timing of ingestion along with the dosage is key for optimizing performance for the individuals taking part in activity. Most of the research that relates to the effects of caffeine supplementation on performance is completed with aerobically trained athletes. These athletes are normally affiliated with organized sports events such as soccer, rugby, or lacrosse. The research also incorporates individualized athletic events such as cycling or sprinting (Costill, Dalsky, & Fink, 1977). The primary effects of caffeine on performance have been widely investigated (Doherty & Smith, 2005), and the researchers will determine if there is a suitable time frame for caffeine supplementation that offers the greatest benefits for enhancing sports performance and having that extra bit of energy, ability and urgency to outplay the competition. To understand how and when caffeine can be beneficial with particular interest towards using energy drinks with added supplements for enhancing performance, various articles have been included for this review.

CHAPTER II

REVIEW OF LITERATURE

Caffeine on Individual Sprints Times and Performances: Ineffective Testing Parameters

There is data from various studies suggesting that the use of caffeine as a supplement to enhance performance can delay the effects of fatigue. Unfortunately, this work is non-conclusive and it appears that the results are negligible (Paton, Hopkins, & Vollebregt, 2001**)**. One key issue with these studies are the designs and simplicity of the experimental protocol. A common experimental design for the research looking at the effectiveness of caffeine supplementation are wingate sprint trials with a set resistance for a period of ten to thirty seconds. The other methodology commonly adopted involves sprint trials in a gym or on a track that are covering a distance of approximately twenty meters (±5) between two set cones. This is usually performed every ten to thirty seconds with a total number ranging from ten to fifteen sprints (Paton et al., 2001; Glaister et al., 2008; Schneiker, Bishop, Dawson, & Hackett, 2006; Carr, Dawson, Schneiker, Goodman, & Lay, 2008). A negligible effect of caffeine on repeated sprint performance has been reported previously (Paton et al., 2001) when team-sport athletes, involved with basketball, hockey, or rugby, completed a single trial of 10x20 m sprints, commencing every ten seconds. In order to determine the ergogenic effects of caffeine upon the athlete, suitable methodology and planning for the activity are pivotal. There needs to be greater emphasis on understanding and determining a desired intensity that the experiment has the athletes working at along with the time that is set to complete the sprints or the activity as a whole. This will also take into account the allotted time given for rest periods. This will allow the results to be more valid as the design replicates the sport that is being considered. This does not necessarily mean that the trials in such studies have been ineffective, as this can show how dosage and timing play an enormous factor for effective supplementation with athletes and their level of play.

For this study, it highlights the points that when developing a research piece looking into the effects of caffeine supplementation on performance, the participants for the work should be closely linked to the type of activity that will be used to determine what effects might be seen from the treatments. This study incorporated sports science students from the program, who were involved with sports at the club level, but with different levels of fitness, experience, skill acquisition and this variance can have an effect on the data collection. Also, this was only a small sample used and the researchers from this study explained within the discussion section that a greater sample size should be warranted for future studies to get a clearer understanding and more data to work with for evaluating the effects. Equally important to a larger sample size would be the use of more trials. This study was completed in a short space of time with a simple sprint based activity. Distance, time for work, and time spent in recovery can be modified to see if there is an effect. Along with modifications in the design, the protocol should be executed in a more structured manner to produce greater results that are more precise. With specific athletes from a designated sport, using a test design that mimics their sport, a large sample of participants that are able to perform three to four trials during the study with an increased number of researchers to help administer the tests and improve reliability and precision will enhance the study considerably.

Effective Testing Parameters

One of the studies incorporated within this review considered the use of caffeine supplementation and the effect this would have on sprint running performance and reaction time (Carr et al., 2008). Within this particular study, the methods incorporated involved a double blind randomized crossover study with ten subjects. The researchers were attempting to determine if ingesting $6mg*kg^{-1}$ prior to activity (60mins) would have an effect on performance. The testing protocol for this study looked into individual sprint times, total sprint times and reaction times (simple and choice). For the sprints, the subjects completed 5 sets of 6x20 meters. The tests for this experiment were made so it was simulating the types of activity and metabolic pathways an athlete would be subjected to if they were to be competing within an organized sports activity (Football, Hockey, Rugby). This would offer insight to coaches and players for how to optimize performance with the use of caffeine for enhancing overall performance in games. If the players are able to sprint for longer periods and perform a greater total amount of sprints during a match, then this will allow a great advantage in the run of play.

"They defined a repeated sprint bout as a minimum of three sprints with a recovery duration between sprints of twenty-one seconds or less" (Spencer et al., 2004). The researchers designed this protocol as best mimics the way an athlete moves and sprints during an actual match for soccer, hockey, or rugby (Carr et al., 2008). For the first, third, and fifth sprints, the subjects in the study were allotted 25 seconds rest period before the next sprint. For the second and fourth sprints, the subjects were given 60 seconds of rest before their following sprint in that specific set. In between the sets, the subjects were allotted a period of four-minutes rest before they were required to sprint again. The four minutes was separated into two minutes of passive rest (standing or sitting) and the final two minutes involved active rest (walking) so that the subjects were able to keep moving and stay mobile but also have sufficient recovery bouts before another set. This research work was compiled and implemented following on from the studies completed by Paton et al. (2001) and Schneiker et al. (2006). With this work, it was seen that the participants were able to produce faster times with the caffeine treatment trials compared to the placebo. A similar sprint distance was covered in this trial, compared to other studies that did not show caffeine to offer an ergogenic effect, but the researchers varied and also increased rest periods, and have the trials running for a greater time frame. This was not a larger sample of subjects and the subjects themselves were not all trained in the same events for team sport activities. They varied across different events such as hockey, basketball, tennis, and soccer.

Suitable Testing Parameters

From the research with Paton et al. (2001), there was no significant effect on sprint performance with the use of caffeine supplementation (Figure 1, [p. 9]). Specifically, the effects of the treatment on this experimental protocol did not produce any significant information on the use of caffeine supplementation for enhancing sprinting ability. The amount of caffeine that was administered to the subjects was $6mg*kg^{-1}$ of body mass. Research has shown this to be a sufficient amount to elicit an ergogenic effect either cognitively and/or physically (Bell & McLellan, 2002). Although, the results from the study completed by Paton, et al. (2001) for the effectiveness of caffeine supplementation prior to sprint performance were negligible. What was noted in this study was the simplicity of the experimental design and the manner in which the subjects completed the sprinting activity; the subjects ran 10x20 meter sprints, and were asked to do each sprint after a ten second rest period. Only the one set was completed with the two trials for each subject, the results were recorded and then the data was analyzed following the completion of data collection. This does not follow the research in later studies depicting the type of sprints that can be simulated to match that of a soccer game or for a rugby match.

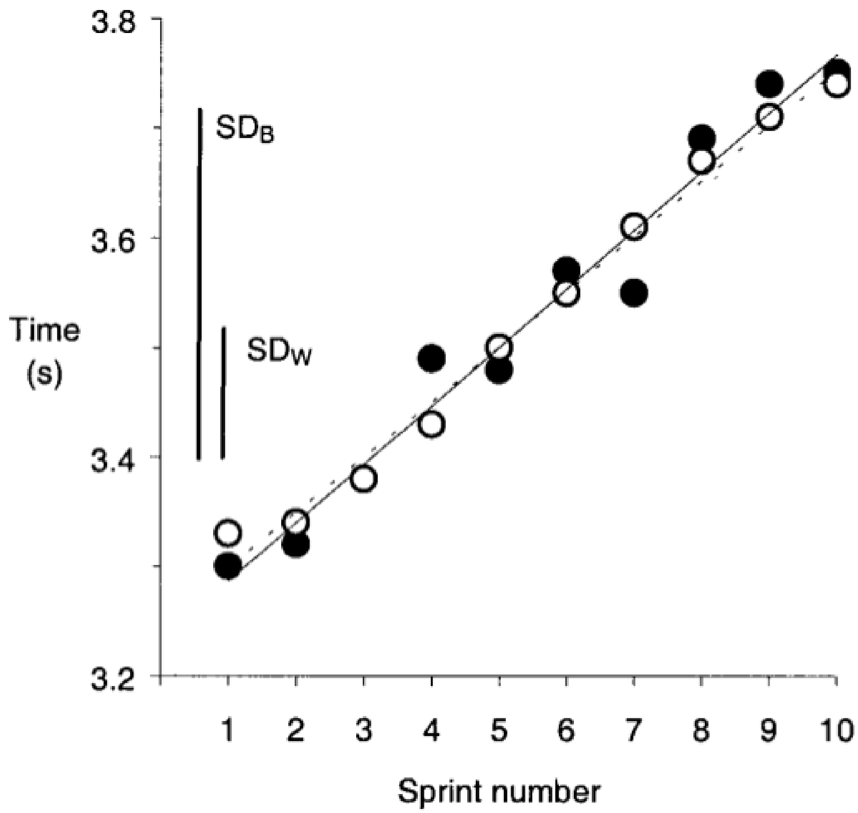

Figure 1. Effects of caffeine on repeated sprint bouts. Sprint time and line of best fit for the 10 sprints of the performance test after ingestion of caffeine (●) and placebo (o). Values are means; bars are standard deviations between subjects (SD_B) and within a subject (SD_W) for any sprint number.

Paton, C. D., Hopkins, W. G., & Vollebregt, L. (2001). Little effect of caffeine ingestion on repeated sprints in team-sport athletes. *Medicine and Science in Sports and Exercise, 33*(5), 822-825.

For the study with Schneiker et al. (2006), the work that the subjects did was over a much longer period of time (70mins), and the subjects did their work on a cycle ergometer that was measuring peak power and mean power production (Figure 2, [p.11]). The subjects were asked to sprint maximally for a period of four seconds and then returned to a recovery pace. The subjects were also asked to rest (active) for duration of 120 seconds before they completed their next repetition on the bike. The subjects completed a total of 18, four-second sprints and this was done over two halves (2x36 minutes).

This research highlights the work that was completed by Carr et al. (2008), as it took into consideration the previous work by other researchers who were looking into the effects of caffeine supplementation on performance and recovery. The experimental design was modified in such a way that the results would offer some insight as to how caffeine can affect certain sports event but not others. Another aspect to be considered for the work that was done when looking into the effectiveness of caffeine supplementation on sprint performance include how minor adjustments in the experimental design can drastically alter the final results for the research itself. The simple designs, when the subjects completed a series of sprints, using the extra time to recover and then transition back to the start line before the next sprint did not appear to show how caffeine is able enhance performance. Another design that had the athletes exerting themselves maximally for up to thirty seconds, and then having two to four minutes to rest in between and following with ten to fifteen minutes break in the middle before they began the next series of work, did show how caffeine can offer performance enhancements. This design was made sport specific and the way the sprints were performed by the participants mimicked what could actually be seen in a competitive soccer, rugby, or basketball game. The researchers for this work also claim that the use of trained, sport specific subjects for the research would produce sound results compared to using untrained subjects (Collomp, Ahmaidi, Audran, Chanal, & Prefaut, 1991; Bell, Jacobs, & Ellerington, 2001; Greer, McLean, & Graham, 1998; Greer, Morales, & Coles, 2006). It appears that smaller adjustments in the experimental design can alter the outcome of the final results. More time and reviews should be administered when completing the methods portion for the study.

	Work Done (J) during the Sprint Immediately before Repeated-Sprint Bout 1	Work Done (J) during the Sprint Immediately after Repeated-Sprint Bout 1	Decrement (%)
The repeated sprint bout			
Placebo—first half	3971 ± 207.4	3458.2 ± 241.2	12.9 ± 11.6
Caffeine—first half	4239.7 ± 203.0	3859.8 ± 223.1	8.8 ± 10.4
Placebo—second half	3874.8 ± 210.2	3451.5 ± 193.5	10.8 ± 5.6
Caffeine—second half	4214.5 ± 253.5	3837.0 ± 219.5	8.6 ± 5.7
The repeated sprint bout			
Placebo—first half	3761 ± 225.1	3491.8 ± 224.8	7.1 ± 8.0
Caffeine—first half	4155.0 ± 238.8	3928.2 ± 230.0	5.3 ± 6.1
Placebo—second half	3892.4 ± 207.9	3506.6 ± 245.0	10.0 ± 10.5
Caffeine—second half	4062.9 ± 246.2	3892.4 ± 249.9	4.2 ± 5.6

Figure 2. Effects of caffeine on enhancing sprint performance. Performance decrements for repeated-sprint bouts 1 and 2 during each half of the intermittent-sprint test for placebo and caffeine conditions. Values are mean ± SEM (*N* = 10)

Schneiker, K. T., Bishop, D., Dawson, B., & Hackett, L. P. (2006). Effects of caffeine on prolonged intermittent-sprint ability in team-sport athletes. *Medicine and science in sports and exercise*, *38*(3), 578.

The Effects of Caffeine on Resistance Activity

A common method for activity and training for health within the United States is through weight lifting or resistance bearing activity. This is an area where the use of supplementation is openly practiced for a lot of the athletes who are taking part. This is to prepare the individual for the training session, and also to optimize recovery, as well as to see significant muscular enhancements following sessions. What remains unclear are the effects of caffeine on resistance training and weightlifting whilst competing. There is significantly more research compiled looking into the effects of caffeine on aerobic, endurance based activity and sport specific games, and the use of caffeine for resistance training and high intensity, anaerobic activity is a recent endeavor for a number of researchers within this field. Suggestions as to why caffeine can have a drastic improvement upon aerobic based activity are through free fatty acid mobilization and glycogen sparing (Essig, Costill, & Van Handel, 1980). This is not what is required physiologically when taking part in high intensity, anaerobic activity. In similar studies, caffeine has shown to blunt pain and reduce ratings of perceived exertion, which can ultimately extend the time until volitional failure if the individual is working in resistance based training (Doherty, Smith, Hughes, & Davison, 2004). It was concluded how caffeine provided a substantial benefit in sport specific, high intensity activity that was regarded more anaerobic than aerobic (Stuart, Hopkins, Cook, & Cairns, 2005). The lasting effects of caffeine on high intensity activity <3mins is equivocal (Sökmen et al., 2008). Astorino, Rohmann, and Firth (2008), (Figure 3, [p.13]) found a significant effect, 11-12% increase in the total weight lifted at 60% of 1RM to failure during bench press and leg press, following the consumption of $6mg*kg^{-1}$ of body mass caffeine in comparison to placebo treatment. In another study with the use of resistance activity and caffeine supplementation, it was seen how 2.5mg*kg^{-1} BM caffeine did enhance 1RM in untrained male subjects (Beck, Housh, Malek, Mielke, & Hendrix, 2008). Unfortunately, with this amount of transparency involving caffeine supplementation and the effects it might have on resistance training activity, along with the lack of studies completed in this specific area, more research must be conducted. Factors to be considered are the subjects that are used, (trained or untrained), and also their exposure to caffeine within a regular diet. This can play a vital role in determining the effects caffeine could potentially have for enhancing performance.

Parameter	Caffeine	Placebo
1-RM bench press (kg)	116.4 ± 23.6	114.9 ± 22.8
Repetitions at 60% 1-RM (reps)	19.9 ± 4.3	18.4 ± 4.0
Weight at 60% 1-RM (kg)	69.9 ± 14.3	68.9 ± 13.3
Total weight lifted (kg)	1,369.7 ± 383.1	1,226.2 ± 357.3
1-RM leg press (kg)	410.6 ± 92.4	394.8 ± 95.4
Repetitions at 60% 1-RM (reps)	23.9 ± 13.0	22.5 ± 11.0
Weight at 60% 1-RM (kg)	247.9 ± 57.5	238.6 ± 55.5
Total weight lifted (kg)	5,945.9 ± 3,275.6	5,358.0 ± 2,148.5

Figure 3. Effect of acute CAF ingestion on resistance training performance. Bench press and leg press performance was similar ($P > 0.05$) with caffeine versus placebo. Participants completed more repetitions at 60% 1RM at a higher absolute load and lifted more total weight in both exercises, but it failed to reach significance ($P > 0.05$).

Astorino, T. A., Rohmann, R. L., & Firth, K. (2008). Effect of caffeine ingestion on one-repetition maximum muscular strength. *European journal of applied physiology*, *102*(2), 127-132.

In a study completed by Green et al., (2007), interesting results were found which gave insight as to what effects might be produced through caffeine use prior to resistance training. This particular study utilized seventeen subjects, thirteen males and four females, who each had previous experience with resistance based activity before the study commenced. Each of the subjects were involved with an eight-week strength training program leading up to the study and were selected for the study because of their understanding and skill with resistance activity. The researchers for this study made an experimental design using the bench press and the leg press to determine how caffeine might enhance performance. The researchers watched and recorded the amount of repetitions completed by the subjects, (instructed to go until failure), the peak heart rate (PHR) that was achieved during the set, and ratings of perceived exertion following each set.

For familiarization, the subjects came to the lab and were asked to complete a number of sets on the bench press and leg press and determine what they considered to be their ten repetition max (10RM). They each began with a set at for 50% of their max, executing maximum of twelve repetitions and then went up to 80% 1RM, completing a reduced number of reps. They then selected the weight for their 10RM and performed ten repetitions, and increased the weight until they could not complete the required ten repetitions unassisted. This was typically found within three bouts. The same method was used for determining 10RM on the leg press. On the testing day, the subjects came to the lab and received their treatment, either $6mg*kg^{-1}$ of body mass caffeine in capsule form, or a similar capsule acting as the placebo. The experiment was completed in a double blind, randomized, counter-balanced crossover manner. The subjects waited a period of sixty minutes and then began a light stretch, performed one set on either the bench press or leg press, around 50% of 10RM, executing twelve reps, and then they began the testing procedure. The subjects were asked to complete as many reps as possible until volitional failure. The subjects completed three sets and had a time of three-minutes passive recovery between each set. After completing the bench press or the leg press, the subjects then waited a period of five minutes and then completed the next lift, incorporating the same methods.

For the bench press activity, the researchers compiled the data and found there to be no significant difference between the two treatment trials with the subjects. The number of repetitions completed, peak heart rate and ratings of perceived exertion did not have a significant difference. On the third set for the leg press, the researchers did see a difference between the caffeine treatment and the placebo treatment with the subjects' results. The subjects performed more repetitions with the caffeine treatment, 12.5 ± 4.2 vs. 9.9 ± 2.6. The subjects had greater peak heart rates, 158.5 ± 11.9 vs. 151.8 ± 13.2. Along with these results, there was not a significant difference between ratings of perceived exertion. This suggests that with caffeine supplementation, the subjects were able to produce more total work and yet, not be able to feel a significant difference in the levels of fatigue following their third set. This gives insight as to how caffeine might offer slight improvements in performance with resistance-based activity by preventing early onset fatigue during work and a way to blunt pain. The researchers stated that more work should be completed but discovered the potential benefits of using caffeine as a supplement prior to resistance training.

Duncan and Oxford (2011) compiled a separate study looking into how caffeine can be used as an ergogenic aid in resistance based activity. Thirteen, moderately trained male participants were used as subjects for this study with each of the subjects competing for the university in rugby, soccer or basketball (national level). This was a double blind, randomized, crossover designed study where the subjects came to the lab for testing on three separate occasions and consumed either $5mg*kg^{-1}$ of body mass caffeine or a placebo supplement, sixty minutes prior to activity. This was in a beverage form, with the use of an artificially sweetened solution combined with caffeine. The mood state of the subjects was measured sixty minutes before activity and prior to ingestion of the treatment. It was measured again immediately following exercise. For the familiarization days, subjects came to the lab and used the bench press to find their 1RM in three to five sets. For testing days, the subjects performed a five-minute warm-up on the cycle ergometer with low resistance, and then executed their set on the bench press, working at 60% 1RM, performing one set until volitional failure. Other measurements taken into account for this study were peak heart rate, ratings of perceived exertion and peak blood lactate. Trials for the two treatments were performed 24-72 hours between one another to allow for appropriate rest for the subjects in this study.

For the results, subjects that ingested the caffeine treatment were able to perform more repetitions on the bench press, 22.4 ± 3.0 vs. 20.4 ± 3.4. Peak heart rate averages appeared to be higher for the caffeine treatments, 164.7 ± 17.5 vs. 157.2 ± 16.9. Peak blood lactate also appeared higher for the caffeine treatments compared to the placebo, 7.22 ± 0.83 vs. 6.53 ± 0.94. Along with these results, there was not a significant difference in ratings of perceived exertion. This type of research is highlighting how caffeine can be incorporated as an effective supplement to enhance performance by allowing the individual to prevent early onset of fatigue and to blunt pain induced from the resistance training. This also recognizes the effectiveness of the caffeine treatment since the subjects could perform more reps, work toward a higher peak heart rate, and produce more blood lactate and not feel any significant difference between the two tests. This was an acute response for the subjects but also encouraging work. More research should be employed to determine what other exercises, other than the bench press and leg press, can yield improved performances on resistance activity with the use of caffeine supplementation.

Energy Drinks for Supplementation

When it comes to sport specific training, training for a club team, recreational activity, or for overall health and well-being, the use of energy drinks with added supplementation is becoming more prevalent due to the suggested performance enhancing effects. This is also due to the number of energy drinks now available that can easily be purchased over the counter at local pharmacies or at supermarkets (Figure 4, [p.18]); each with suggested effects written on the side of the can or bottle stating how consumption of this beverage will allow the individual to delay fatigue, work for longer periods, improve skill and enhance precision within their task. Besides multivitamins, it has been reported that energy drinks are the most popular dietary supplement within the American young population today (Froiland, Koszewski, Higst, and Kopecky, 2004; Hoffman et al., 2008). The use of these energy drinks is primarily for the suggested effects that are seen on the side of the product, and how this can significantly enhance one's training performance (Petróczi et al., 2008). There is an array of ingredients within these supplemental energy drinks, with each offering some benefit to overall performance. The key ingredients that present the greatest benefit to enhancing athletic ability are the carbohydrates and the caffeine (Campbell et al., 2013). The basis of this review is looking closely at how caffeine supplementation can be incorporated to enhance performance, and according to the International Society of Sports Nutrition, ingestion of 3-6mg*kg^{-1} of body mass is recommended for enhancements in performance (Goldstein et al., 2010).

Food or drink	Serving	Caffeine, mg*
Instant coffee	250 mL (8 oz) cup	60 (12–169)†
Brewed coffee	250 mL (8 oz) cup	80 (40–110)†
Short black coffee or espresso	1 standard serving	107 (25–214)‡
Starbucks Breakfast Blend brewed coffee (Venti size)	600 mL (20 oz)	415 (300–564)§
Iced coffee (commercial brands)	500 mL bottle (16 oz)	30–200
Frappuccino	375 mL (12 oz) cup	90
Tea	250 mL (8 oz) cup	27 (9–51)†
Iced tea	600 mL (20 oz) bottle	20–40
Hot chocolate	250 mL (8 oz) cup	5–10
Chocolate milk	60 g	5–15
Dark chocolate	60 g	10–50
Viking chocolate bar	60 g	58
Coca-Cola	375 mL (12 oz) can	49
Pepsi cola	1375 mL (12 oz) can	40
Jolt soft drink	1375 mL (12 oz) can	75
Red Bull energy drink	250 mL (8 oz) can	80
Red Eye Power energy drink	250 mL (8 oz) can	50
V Energy drink	250 mL (8 oz) can	50
Smart Drink - Brain fuel	250 mL (8 oz) can	80
Lift Plus energy drink	250 mL (8 oz) can	36
Lipovitan energy drink	250 mL (8 oz) can	50
Black Stallion energy drink	250 mL (8 oz) can	80
AMP Energy tallboy	500 mL (16 oz) can	143
Spike Shotgun energy drink	500 mL (16 oz) can	350
Fixx energy drink	600 mL (20 oz) can	500
Ammo energy shot	30 g (1 oz)	170
Jolt endurance shot	60 g (2 oz)	150
PowerBar caffeinated sports gel	40 g sachet	25
PowerBar double caffeinated sports gel	40 g sachet	50
GU caffeinated sport gel	32 g sachet	20
Carboshotz caffeinated sports gel	50 g sachet	80
PB Speed sports gel	35 g sachet	40
PowerBar Acticaf Performance bar	65 g bar	50
Jolt caffeinated gum	1 stick	33
No-Doz (Australia)	1 tablet	100
No-Doz (U.S.)	1 tablet	200
Extra Etrength Excedrin	1 tablet	65

Figure 4. Caffeine content of common foods, drinks and nonprescription preparations.

Burke, L. M. (2008). Caffeine and sports performance. *Applied Physiology, Nutrition, and Metabolism*, *33*(6), 1319-1334.

Although, there is evidence to suggest that smaller amounts of caffeine, $2mg*kg^{-1}$ of body mass, within energy drinks can also enhance the performance when participating in activities that are aerobically based and with resistance type activity (Ivy et al., 2009). Also noted in the review is how these energy drinks contain other ingredients such as taurine, B-vitamins, herbs, that compliments the effects of caffeine to increase arousal, alertness and the ability to raise performance (Campbell et al., 2013). Therefore, there have been numerous studies completed in recent years, used to determine what effect these store bought energy drinks, with smaller doses of caffeine, might have on performance. A number of studies have shown there to not be a significant enhancement on overall performance and for the final results to be negligible (Forbes, Candow, Little, Magnus, & Chilibeck, 2007). When compiling the research and gaining clearer insight to the methodology, whether or not the subjects used in the trials were trained or untrained, along with the timing of ingestion and the dosage of caffeine, there were a number of questions left unanswered and it was concluded that more research should be done (Campbell et al., 2013). To understand how and when caffeine can be beneficial with particular interest towards using energy drinks with added supplements for enhancing performance, various articles have been included for this review.

Research with the Use of Commercial Energy Drinks for Enhancing Performance

A study that looked into the effects of caffeine supplementation used the commercially developed energy drink, Red Bull, to determine improvements on aerobic based exercise (Ivy et al., 2009). Sporting events such as soccer, rugby and cycling require athletes to have a greater VO2 Max in order to be successful. The only opportunity in these events for caffeine supplementation will be prior to the start of the event. There are periods in racing where the cyclists can take smaller drinks handed to them from coaching staff during races such as the Tour De France. In soccer, there is an opportunity to take in some form of supplement at half-time. At these stages, the supplements are normally to replenish electrolytes and carbohydrates. Supplementation of caffeine at these stages would be ineffective as the greatest effects of caffeine are apparent one hour after ingestion (Bell & McLellan, 2002). The purpose of this study was to determine if the Red Bull energy drink, when ingested prior to activity, would elicit a performance enhancing effect upon the subjects.

There were a number of independent variables for this study such as the use of carbohydrate supplementation and how this might play a role upon performance of an athlete. Also, induced fatigue after a certain time frame was a factor and the investigators were keen to see when this would likely become apparent among the participants in their study. Red Bull is an energy drink with a number of other ingredients that might have an effect upon performance such as taurine which has been suggested to elevate one's mood, increase alertness and allows a person to be more focused and concentrated in what they are doing (Mandel et al., 1985). This was an interesting and a soundly structured study not only because of what was found in the results but because of how the experimental design was arranged by the researchers for the test subjects. The subjects that took part in this experiment were asked to complete a certain amount of work in the fastest possible time. This differed from various other studies where the researchers created an experimental design involving predominantly sprints. The average time for the subjects to complete the work in this experiment with both treatments was approximately one hour. Therefore, the work was predominantly endurance based.

Caffeine typically peaks in the blood 30-60 minutes after consumption (Blanchard & Sawers, 1983; Cole et al., 1996; Essig, Costill, & Van Handel, 1980; Graham & Spriet, 1995; Liguori, Hughes & Grass, 1997.) The work and design of this study was well implemented as it closely monitored extraneous variables affecting the final results when collecting and analyzing the data. The subjects in this study were all trained, competitive, cyclists at the elite level who were comfortable with the testing protocol on the cycle ergometer. This was a key factor following on previous studies looked at for this review as it has already been stated how the use of trained subjects for the specific sport that is being tested will produce more reliable results. For the preliminary stages of the experiment, the subjects in this study were familiarized with protocol for this experiment; riding on the bike within the lab to become comfortable with the mechanisms, the duration of the bike ride and with the intensity. Performance was measured as time to complete a standardized amount of work equal to 1 hour of cycling at 70% W_{max}. For testing day, the subjects either received 500ml of Red Bull energy drink (equivalent to 2 cans Red Bull), which contains 2.0g taurine, 1.2g glucuronolactone, 160mg caffeine, 54g carbohydrates, 40mg niacin, 10mg pantothenic acid, 10mg vitamin B6, and 10ug vitamin B12, or they received a placebo drink that was the same color, texture, taste to replicate the drink but without the added effects of the other. A double blind, randomized, placebo-controlled, two-period, within-participants' crossover experimental design was used. There was verbal instruction and encouragement on both testing days and before the tests the subjects were asked to write out a 2-day exercise and dietary log, along with a twelve hour fast before coming to the lab. The two trials involving the treatments were separated by one week and completed at the same time of day to maintain reliability for the testing procedures. The treatment was administered forty minutes before the exercise began and ten minutes before the subjects were asked to mount the bike to commence the cycling, the subjects were required to void. Then as they began cycling they were offered 300 ml of water every twenty minutes thereafter.

The results showed that when the subjects consumed the energy drink forty minutes before the time trial on the bike, the subjects had an enhanced performance compared to consuming the placebo treatment. Ten of the twelve subjects in this experiment showed an enhanced performance with the time trial after consuming the energy drink. The average improvement on performance across all subjects was 4.7% and the point at which this became most apparent was during the 30-40-minute period of the bike ride. This added weight to the notion from previous research stating that caffeine will take effect upon the subject 30-60 minutes after consumption. Other results of this experiment included how there was not a significant difference between the ratings of perceived exertion for the subjects between the two treatments. This offers insight to further research within this field of study looking at using caffeine along with other supplementation to enhance performance along with delaying early onset muscular fatigue and blunting pain. Previous research has suggested that caffeine with taurine might allow for a greater pain tolerance for an athlete when competing in log duration endurance based activities (Cole et al., 1996). Blood glucose level for the energy drink trials with the subjects was higher, 10 minutes before the time trial commenced, but then 10 minutes into the cycling, the blood levels for the energy drink tests returned to the baseline level and remained there for the rest of the time on the bike, as well as following the completion of the exercise. Therefore, there was not a significant difference between the two treatments for levels of glucose within the subjects, even though the Red Bull drink did have 54g carbohydrates. When selecting the subjects for this study, the researchers utilized twelve subjects that all competed in competitive cycling and mean age 27.3 ± 1.7 year, mass 68.9 ± 3.2 kg. There was not much variance between the subjects in regards to their age and body mass as this could be a confounding variable for the results as the amount of caffeine that was administered to the subjects was the same for each person. In other studies, the caffeine supplementation for the subjects was made relative to the person's body mass (i.e. 3-6mg*kg^{-1}). This could play a heavy factor with the individuals in the study, as there might be certain subjects that have a much greater tolerance to caffeine because they are exposed to it more frequently compared to others. This validates the purpose for the dietary log prior to the test day and for the twelve hour fasting before as this will allow the subjects to have less variation when exposed to treatments and thus eliminates any confounding variables. Caffeine is a commonly used substance, and not just for supplemental reasons, but within everyday food and drink. The dietary log gives clearer insight to the amount of exposure some of the subjects might have to caffeine.

Further Research with the Use of Commercial Energy Drinks for Enhancing Performance

A separate study completed for determining the effects of caffeine on performance through ingestion of a commercial pre-exercise energy drink, did yield some interesting results (Campbell, Richmond, & Dawes, 2016). For this work, the investigators used nineteen college-aged students as subjects (eight males, eleven females), in a randomized, double blind, parallel grouped design. This involved baseline testing, waiting a period of 48 hours, and then completing post-testing with either the use of a placebo (n = 9), or a commercial, non-caloric, pre-exercise, energy drink (Redline Power Rush by VPX), with 2.4mg*kg^{-1} BM caffeine (n = 10). For the subjects, age 22.4 ± 3.2 years, body mass 69 ± 12.7 kilograms, BMI 23.9 ± 2.9 and height 168.7 centimeters. The design for this study included four tests, but with three independent variables that would be later analyzed. The first test that would be completed would be for measuring power output. The researchers used the vertical jump test and when instructed, the subject would step onto the mat and perform a counter movement jump, with arm-swing and push off, jumping as high as they could. The mat recorded the data. The researchers also wanted to look at the effects and change for muscular endurance, and two testing modalities were used for this fitness component. The YMCA Bench Press (American College of Sports Medicine [ACSM], 2013), measuring upper body muscular endurance, was administered; subjects had to maintain a cadence of thirty repetitions per minute, with the male subjects using a 36.3kg barbell, and the female subjects using a 15.9kg barbell. If the subjects failed to maintain the rhythm with the timer, then they stopped and the measurements were taken. The researchers also measured trunk muscular endurance, with the use of the U.S. Navy's Physical Readiness curl-up test. This was also completed until failure and there was no difference in how the test was administered between male subjects and female subjects. The final test involved ten, twenty-meter sprints that were completed consecutively with a ten second rest between each sprint.

Sprint times were measured with stopwatches and a mean sprint time was found with the ten sprint times combined. The tests were completed in this same order on the test day. For the post testing, the subjects received the treatment in a double blind randomized fashion, thirty minutes before activity. Previous studies using a non-caloric energy drink with a similar testing modality, had subjects ingesting treatment ten to sixty minutes before activity. (Candow, Kleisinger, Grenier, & Dorsch, 2009). With this knowledge, the researchers for the present study chose a midrange point and opted for the time of ingestion to be at thirty minutes prior to testing.

The final results for this experiment found there to be no change in baseline and post-test performance for the power vertical jump tests, the upper body muscular endurance test with YMCA Bench Press, or for the intermittent sprints. However, there was an improvement for the ten subjects that received the caffeine treatment and then completed the curl-up test, measuring trunk muscular endurance, in the post-test compared to the placebo group. There was a 21% improvement on performance for the subjects who received the caffeine treatment, and 15% decrease in performance for the subjects that received the placebo in their post-test. Although there was a large difference between the groups for the curl-up test, no group x time was recorded (P = 0.120).

The study is enlightening based on the relationship between this work and with previous research where the researchers altered the dosage of caffeine and also the timing of ingestion. These two variables can play a factor with the results and although the investigators did see from previous research that compiled a similar study with a non-caloric energy drink, this was not sufficient in having an ergogenic effect on the final performance. Within the discussion section it was mentioned how the dosage of

2.4mg*kg^{-1} BM perhaps was not enough for the subjects, and also the tolerance of caffeine may have been a factor for the ten subjects that did receive the treatment before the activity. As noted already, previous tests have shown that smaller quantities of caffeine can elicit a performance enhancing effect. This could be related to the tolerance to caffeine and also the diet of the subjects and if they refrained from caffeine usage leading up towards the experiment. Also, whether or not the caffeine was complimented with other ingredients such as carbohydrates. This was a non-caloric beverage and therefore could have played a considerable factor in the outcome of the experiment. Caffeine has also been shown to produce a greater effect when in an anhydrous form (Bell & McLellan, 2002).

The Use of Caffeine Supplementation with Organized Sports

A study that was incorporated for the use of this review looked into how caffeine might produce an ergogenic effect within organized sports, specifically soccer (Foskett, Ali, & Gant, 2009). The purpose of this work looked into the effects of caffeine on performance when taking part in activities replicating the types of skills and movements seen in a soccer match. The duration of the entire exercise for this program did mimic the time for a standardized soccer match, making it a total of ninety minutes, disregarding injury time or the situation for which a match will proceed into extra time and then penalties. For this ninety-minute period the participants, (12 male professional soccer players, age 23.8 ± 4.5 years, BM 71.4 ± 7.4 kg), were involved in intermittent sprints, jogging and walking tests. The way in which this study was created allowed the researchers to mimic as close as possible to how the body reacts and responds when playing in a competitive soccer match. This is difficult to execute because depending on the opponent and the type of match the players are involved with, this can alter the level of work that players are subjected to and also vary the intensity the team could be working towards. In order to closely replicate these demands and sudden spontaneous moments in a match, the experimental design involved six cycles of three different activities. The subjects would perform a counter movement jump (CMJ), followed by the Loughborough Soccer Passing Test (LSPT) and then the majority of the time was spent with the Loughborough Intermittent Shuttle Test (LIST).

This was a randomized, double blind, crossover study. The treatment for the subjects was either a placebo or the caffeine pill, $6mg*kg^{-1}$ BM, and was ingested in an anhydrous capsule form. Both treatments were accompanied with 500ml of water and ingested sixty-minutes prior the activity. The purpose of this experiment was to look into how caffeine will affect the skill related and the physical components required for a soccer athlete during activity replicating that which would be seen during a regular match. Research has shown that caffeine can have a positive effect upon physical aspects of a person's performance, but it can also improve a person's ability to think more clearly, greater awareness in terms of alertness and better decision-making (Gillingham, Keefe, & Tikuisis, 2004; Lohi et al., 2007; McLellan et al., 2005; McLellan et al., 2005; Tikuisis, Keefe, McLellan, & Kamimori, 2004). For the LSPT, the subjects prepared themselves during the familiarization for this experiment, several times in order to get accustomed to the movement and the direction required for the most effective and most successful completion of this portion in the research. This is where the researchers were able to determine if the caffeine supplement did show a cognitive enhancement within the twelve soccer players that took part in this study as this portion involved some higher order thinking and split second decision making by the subjects.

The times for the completion of the LSPT, having ingested the caffeine pill, were significantly faster compared to when the subjects had ingested the placebo. The movement time around the course was not significantly different for the participants with comparing the results of the caffeine and the placebo. The differences lay within the penalties and the number of seconds taken away from the final time. If the subjects missed a pass, they were inaccurate with movements within their box, or they made any fault during this test, then time was added on to their sum completion time. If the subjects were able to perform effectively and efficiently, they were deducted time from their sum total. This showed the researchers that when the athletes had ingested the caffeine supplement, they were more alert and more accurate with their skills during the LSPT portion of the experiment. There were no significant differences between the subjects' sprint times when comparing the results of the caffeine and placebo treatments. The CMJ were significantly higher when the subjects had ingested the caffeine supplement. There was not a significant difference between the ratings of perceived exertion between the two treatments and there was not more caffeine within the urine samples between either treatment during the experiment and following.

The researchers' main purpose for this experiment was determining the effects caffeine ingestion prior to activity would have on the physical components required of a soccer player during a match. Another aim was looking into the effects caffeine would have on the skill related components such as accuracy with passing, footwork and decision making during a game. They found that caffeine did have an effect on the physical components of the subjects but also had a very large effect for the subjects' cognitive ability. At the highest level in sports, there is certainly a strong influence on the game from the standpoint that players need to be superior in strength, speed and overall athleticism. What's just as valuable across all sports is the ability to react and interpret the game and then implement strategies to overcome your opponent. Intelligence and timing in sport plays just as big a role as does the physical aspect and this study does show how effective caffeine supplementation can make for a better performance both physically and cognitively.

Effects of Caffeine within Simulated Rugby Union Matches

When looking at the research on ergogenic aids, and the effects that might be seen on players competing in organized sporting events, a study was completed looking at how supplementing caffeine may affect rugby union players during a simulated match (Stuart et al., 2005). To gain a broader understanding as to what effect caffeine can have through supplementation on the athlete, a variety of sports should be looked at and in this particular study the researchers selected rugby union. There is continuous mounting evidence for enhanced performance during short-term intense exercise lasting four to ten minutes with the use of caffeine supplementation (Bruce et al., 2000; Doherty et al., 2004). These are the types of movements that can be seen during a rugby match. A match will last eighty minutes in total but is split into two forty-minutes halves, with various scrums, lineouts and fouls that allow the game to slow down momentarily. During these incidents and aspects of a match, the players have long enough to come to a slow walk or remain static before play starts up again. It's also been made evident that in team sports matches, the outcome is often determined late in the game when the players are fatigued and they are more susceptible to making mistakes during match play (Mohr et al., 2003; Green, 1997). The way in which this study was designed, was so that the researchers could mimic the types of movements seen in a rugby union match and allow the subjects to work in a capacity very close to a true game like experience. Then, they would be able to effectively test the effects of caffeine supplementation for rugby union.

For this particular study, the researchers utilized nine competitive, male rugby players that had just completed their last season match. The players were training to approximately 4.8 ± 0.8 h*wk-1. The collective age of the players came to 25 ± 4 years, body mass 98 ± 22 kilograms, and height 181 ± 4 centimeters. The study was a double blind, randomized crossover design and the subjects came for testing for a total of three sessions. The first session was a familiarization, followed by the two treatment sessions. The two treatments were either $6mg*kg^{-1}$ BM or placebo (dextrose). This was ingested seventy minutes before testing began. The design of the experiment involved two halves, with seven circuits completed in each half, coming to a combined total of fourteen circuits, with eleven separate stations per circuit. A circuit involved five sprints, (two straight line and three agility), two power drives with and without a ball, a passing test measuring the accuracy of the subject, and also three stations that involved walking or active rest. The subjects were allotted a time of thirty seconds to complete their station and whatever time was left was utilized for rest and recovery before moving towards the next station. With all of this combined, the subjects were working for a period of thirty-nine minutes, per half, with a ten-minute half time rest period. This design was created to mimic the types of energy systems a player would use during a rugby match and the types of movements that are generally performed.

For the results, it was made evident to the researchers how the caffeine treatment did improve times and accuracy for each of the athletes within each station, except for the second power drive were the results for the caffeine treatment and the placebo had no difference. The most exciting finding for the researchers was the improved accuracy for the passing station with caffeine. The subjects managed a 10% increase in their level of accuracy for this station compared to the placebo. Prior to testing, the subjects were also asked whether or not they believed they had ingested caffeine or the placebo and none of the subjects were able to feel or suggest a difference before commencing the test. The researchers also discussed how the subjects were asked to refrain from large amounts of caffeine in food or beverage form 48 hours before testing and then explained how abstention from caffeine several days produced an additional performance enhancement of 1.5%. Each of the subjects explained how they were regular caffeine users, but not excessive but this highlights the efficacy of caffeine and other ways in which minor manipulations prior to sporting events can offer performance enhancements.

Varying Times of Ingestion with Caffeine and the Effects on Performance

When compiling the literature for this review, a study was found that looked into the effects of caffeine based up time of ingestion, and the difference in effect between regular users of caffeine and non-users (Bell & McLellan, 2002). There is an enormous amount of research that has been completed looking into the effects of caffeine and it appears that there is obvious crossover with certain aspects. For example, most studies have opted to use caffeine that is between 3-6mg*kg^{-1} BM. Dosages of this quantity should produce similar ergogenic effects on the individual to that seen with high doses (Cadarette, 1982). It's also been generally ingested between thirty to seventy minutes prior to testing with the subjects. With this knowledge, sufficient dosage and the timing has yet to be determined as each person varies in sensitivity with caffeine. Caffeine itself has a half-life of four to six hours and this implies that caffeine will remain in the blood of the individual for approximately three to four hours following ingestion (Bell & McLellan, 2002). The ergogenic effect that comes from the use of caffeine is related to the circulatory level of the drug that is in the blood and therefore maximal effects are assumed occur one hour after ingestion when peak blood concentration is observed (Bonati et al.,1982). Although, certain studies have suggested that waiting a period of up to three hours following caffeine ingestion might be more optimal, as the caffeine induced effect on lipolysis is much greater than immediately following ingestion (Nehlig & Debry, 1994). However, the theory that the ergogenic effect of caffeine is due to free fatty acid mobilization doesn't have support from more recent literature (Graham, 2001; Graham, Helge, MacLean, Kiens, and Richter, 2000).

For this particular study, twenty-one subjects were used (fifteen males and 6 females) in order to determine the differences in the effects of caffeine between regular users (≥300mg caffeine/day) and non-users (<50mg caffeine/day). Within the subjects, following a questionnaire that was completed prior to the data collection, it was clarified that thirteen of the test subjects were regular users of caffeine and that eight of the test subjects were non-users. The other purpose of this study was looking at the effects of caffeine ingestion at separate intervals (1h, 3h and 6h following ingestion of 5mg*kg^{-1}

BM caffeine). The research completed for this study had contrasting thoughts towards when caffeine would elicit the greatest ergogenic effect upon the subject. Most studies have completed research where the subjects would consume the supplement approximately one hour before testing, as this appears to be point when there is the greatest amount of caffeine available within the blood (Bonati et al, 1982). Other research suggests that due to glycogen sparing and increased free fatty acid mobilization, that the greatest effects of the caffeine will be apparent three hours following ingestion (Nehlig et al, 1994). Therefore, within the study the researchers created an experimental protocol were the subjects would complete an exercise ride on a cycle ergometer, working at 80% of their VO2 Max, until exhaustion. The subjects came to the lab for testing on nine separate occasions with the first visit used for performing a medical exam and then determining VO2 max for the subjects. The second and third visits were used for familiarization towards the testing and the final six visits were used for testing. This study was a randomized, double blind, crossover design where the subjects either ingested $5mg*kg^{-1}$ BM caffeine at 1h, 3h, or 6h before their exercise ride to exhaustion, or they ingested a placebo (dextrose).

For the results, it was made clear that the non-users had a much more pronounced effect towards the caffeine compared to the regular users of caffeine. There were able to cycle for longer periods at all three times, with the ingestion of caffeine one hour prior to the cycling being the longest ride (ingestion of caffeine 1h before testing – 32.7 ± 8.4 minutes for non-users). However, the subjects that were regular users of caffeine managed to have slightly different results for the testing at separate intervals. It appeared that the time that subjects were able to cycle the longest period was for the 3h ingestion of caffeine (ingestion of caffeine 3h before testing – 28.1 ± 7.8 minutes). This was an interesting finding for the researchers as it showed how there is a difference in sensitivity and response with caffeine based on the consumption and use of the drug. The non-users were able to cycle for much longer than the non-users, but the regular users of caffeine had the longest cycling period with the ingestion of caffeine 3h before testing. This compliments work from various other researchers prior to this particular study but also creates more questions. The key aspect of this experiment is that caffeine does have a great ergogenic effect on overall performance with the regular users of caffeine having a 19% improvement in performance and the non-users showing a 28% improvement in their overall performance. A larger sample size would offer more accurate results and also the use of athletes would offer greater insight towards the findings, but this work is encouraging.

CHAPTER III

METHODOLOGY

Experimental Design

This research was a double blind, randomized, crossover study and the population for this study was the athletes on the Women's and Men's Club Rugby Team at Eastern Kentucky University. Visits were separated by a period of seven days (1 week) to allow the subjects sufficient time for optimal recovery before they engage in the next testing day.

Participants

The Women's and Men's Club Rugby Team at Eastern Kentucky University are between the ages of 18 and 24 years old. The two squads are made up of players with varying levels of experience with rugby union (1-7 years competitive playing). The two teams have players who have played together and also new players who are incoming freshman.

Familiarization

The participants came to the lab for testing on five separate occasions. For the first visit the subjects came to the lab for completion of their documentation and for a medical screening prior to testing. This involved measurements for blood pressure and heart rate; they each did a BodPod test and discussed with the researchers, what they will be subjected to when completing the testing for this research. They were also afforded the opportunity to ask any questions they had about the procedures before testing began. Participants completed a health history questionnaire and they were also asked a series a questions to determine the amount of caffeine they generally ingest on a daily and weekly basis. After completing the necessary paperwork and health screening in order to take part in testing, the participants then went through the testing procedure. They had the opportunity to run through the circuits as many times as they deemed suitable so they knew how they needed to move through at a sufficient rate but also be able to effectively complete each station to the best of their ability.

Testing

For test days 2, 3, 4 and 5, participants came to the lab and they ingested either the placebo or caffeine in milligrams relative to their body mass ($3mg*kg^{-1}$). Participants then proceeded to wait a period of thirty minutes or sixty minutes before they began the testing. Testing involved a circuit, with series of eight stations that was completed ten times; approximating a period of time similar to that of one half of a rugby union match (40 minutes). Each participant had a maximum time of thirty seconds on each station. Whatever time was left over when the participants completed the station was used for recovery and then for making their way towards the next station. The idea behind this testing protocol is that the types of movements and energy systems incorporated are similar to that which is seen in a regular rugby union match.

Circuit #1

- Station 1 – 20-meter sprint
    - This was a straight-line sprint without the ball and measured for the time to complete the 20-meter distance.

- Station 2 – Sled Push 15-meter
    - Participants had to push a sled over 15-meters in the fastest possible time. The male participants had two 45lb plates on the sled for their trial and the female subjects pushed the sled without added weight.

- Station 3 – Push Ups
    - Participants began performing pushups when instructed and they needed to complete as many repetitions as possible within a 10-second time frame.

- Station 4 - Passing Accuracy
    - Subjects were instructed to pass a ball as rapidly as possible at a target placed 5-meters from the player with its center being 1.7 meters (approx. 67") above the ground (target dimensions 1x1 feet). After each pass, the participant picked up another ball from the ground and repeated the pass, moving in a clockwise pattern. The time to complete this activity was approximately 10-15s. The number of successful target hits out of seven balls passed was counted.

- Station 5 – Offensive Sprint
    - This was an executed agility run with a ball in hand around a set of cones totaling a distance of 25-meters, measured by time.

- Station 6 – Medicine Ball Throws
    - This station involved throwing the medicine ball above a line set on the wall as many times as possible in ten seconds. The ball was required to hit the ground between each toss. The weight of the ball was 20lbs for male participants and 10lbs for female participants.

- Station 7 – Tackle Sprint
    - The tackle sprint involved making a tackle on a tackle bag, picking up a ball and running backward 15 meters, placing the ball, and then running forward 15 meters. This station was measured for time to completion.

- Station 8 – RPE
    - Subjects had thirty seconds to walk towards *Station 1* and gain some active recovery, similar to movements that might occur during a match. They were asked to give a rating from 1-10 for how they felt (ratings of perceived exertion).

Data Collection

For the data collection, the results collected were for the varying, individual stations, of the circuit. Each station had a set time (30 seconds) so the participants were not timed for quickest completion time for all the stages or for the all of the circuits. It took each of the participants approximately the same time (40-minutes) to complete the testing protocol on test days. The collected data was for the time that it took for the participants to run a twenty-meter sprint. Then, the participants were measured for how long it took them to push the sled over 15-meters. Following this station, the participants completed their pushups and the collected data was for the number of repetitions completed in a 10-seconds time period. The participants were then measured on passing accuracy ability. They completed this station with the research assistant, who assisted in retrieving the balls for them. Participants had to throw the seven rugby balls at a target placed five meters away and 1.7 meters (67 inches) above the ground. The number of times they were able to hit the target was measured visually by the research team and then recorded. The participants then had to complete an agility, offensive run, in the fastest possible time with a rugby ball in hand. Time to complete this run was measured and then recorded. The next station involved a medicine ball toss above a set marker on the wall. Participants were asked to throw a medicine ball (20lbs for males, 10lbs for females) above a set line on the wall as many times as possible in ten seconds. The ball had to hit the ground between throws, before the participant could pick up the ball again. The final measured station was a rugby specific sprint. This was a modified sprint that involved a tackle bag and the participant was timed on how long it took them to successfully complete this sprint. The final station was for measuring RPE (ratings perceived exertion). This involved walking back to the first station and stating to the research team how they were feeling on a scale from 1-10. The participants had a thirty-second time frame, similar to the other stations, to complete this final portion of the circuit. Collectively, time to complete all eight stations within the circuit totaled 4 minutes.

Data Analysis

Data was analyzed utilizing ANOVA, with alpha set at 0.05, for significant differences in performance with LSD post hoc testing. The data for placebo trials, 30 minutes pre exercise consumption, were normalized and comparisons were made between mean values for trials at 30 and 60 minutes pre exercise caffeine consumption. Analyses that were considered and executed for determining the effect on performance were for long timing supplementation; measuring each trial (placebo and caffeine 30 minutes and placebo and caffeine at 60 minutes), chronological for assessing results based on visitation and general supplementation with comparisons between all placebo trials collectively to pre exercise caffeine ingestion at 30 and 60 minutes. This was separated further with three categories for groups that were males, females and the two combined. Each station was considered independently within the results along with a final collective team measurement results table based on all stations combined.

The independent variable for this type of work was timing for effective caffeine supplementation, relative to body mass for the subjects. The dependent variables for this research were the participants' ability to perform in their chosen sport. This research was a double blind, randomized, crossover study and the population for this study was the Women's and Men's Club Rugby Team at Eastern Kentucky University.

CHAPTER IV

RESULTS

The participants included for this study (Tables 1 – 29) involved the use of twenty-two, club level rugby athletes who were recruited from Eastern Kentucky University. Due to injuries, occurring independent to the study, along with university class conflicts, five participants were unable to complete all trials required for testing. The subject characteristics were (mean ± SD, N = 17, 8 males, 9 females): age, 20.1 ± 1.3 yrs; body mass, 78.2 ± 17.4 kg; height, 171.6 ±10.2 cm; and body fat percentage, 24.9 ± 9.2 %. Subjects were completing pre-season training at the start of the study, with their training sessions being conducted Tuesday and Thursday evenings. Participants were involved with approximately 4 hours of inter-squad training on the rugby pitch with 2-3 hours independent training in the gym with resistance based training and incorporating aerobic activity.

Table 1. Performance Measures
Performance measure Means ± S.D. are based on all four trials that were conducted.

Performance Measure	**Combined**	**Male**	**Female**
20-Meter Sprint *(seconds)*	4.22 ± 0.58	3.88 ± 0.03	4.52 ± 0.61
15-Meter Sled Push *(seconds)*	6.02 ± 1.04	6.62 ± 1.17	5.48 ± 0.47
Pushups *(repetitions)*	10.58 ± 2.83	11.5 ± 3.41	9.67 ± 1.83
Passing Accuracy *(target hits)*	3.27 ± 0.94	3.74 ± 0.76	2.84 ± 0.89
Offensive Sprint *(seconds)*	8.99 ± 1.2	8.5 ± 1.13	9.42 ± 1.10
Medicine Ball Toss *(wall hits)*	4.12 ± 0.66	4.33 ± 0.54	3.93 ± 0.7
Rugby Specific Sprint *(seconds)*	9.87 ± 1.38	9.28 ± 1.03	10.4 ± 1.45
RPE *(1-10)*	6.04 ± 1.27	6.4 ± 1.30	5.72 ± 1.18

Table 2. Demographics
Demographic measures Means ± S.D.

Demographics						
Group	**N**	**Age (Years)**	**Weight (kg)**	**Height (cm)**	**Body Fat (%)**	**Lean Body Mass (kg)**
M/F	17	20.1 ± 1.3	78.2 ± 17.4	171.6 ± 10.2	24.9 ± 9.2	58.7 ± 15
M	8	20.3 ± 1.3	90.4 ± 17.8	178.1 ± 10.6	20.2 ± 9.5	71.4 ± 12.6
F	9	19.9 ± 1.4	67.3 ± 6.7	165.8 ± 5.7	29.2 ± 7.1	47.3 ± 1.6

Long Timing

Table 3. Supplementation Long Timing – 20-Meter Sprint
There were no significant differences in 20-meter sprint performance across all of the trials and groups.

20-Meter Sprint				
Group	**Placebo 30mins**	**Caffeine 30mins**	**Placebo 60mins**	**Caffeine 60mins**
Combined	1 ± 0	.9783 ± 0.06	.9946 ± 0.05	.9725 ± 0.04
Male	1 ± 0	.9767 ± 0.05	1.0039 ± 0.04	.9838 ± 0.03
Female	1 ± 0	.9798 ± 0.07	.9864 ± 0.05	.9624 ± 0.05

Table 4. Supplementation Long Timing – Sled Push 15-Meter
There were no significant differences in sled push 15-meter performance across all of the trials and groups.

Sled Push 15-Meter				
Group	**Placebo 30mins**	**Caffeine 30mins**	**Placebo 60mins**	**Caffeine 60mins**
Combined	1 ± 0	.9913 ± 0.6	.9902 ± 0.07	.9873 ± 0.05
Male	1 ± 0	1.0083 ± 0.07	.9782 ± 0.9	.9908 ± 0.04
Female	1 ± 0	.9761 ± 0.06	1.0008 ± 0.05	.9841 ± 0.05

Table 5. Supplementation Long Timing – Pushups
There were no significant differences in pushup performance across all of the trials and groups.

Pushups				
Group	**Placebo 30mins**	**Caffeine 30mins**	**Placebo 60mins**	**Caffeine 60mins**
Combined	1 ± 0	1.0521 ± 0.09	1.0114 ± 0.12	1.0551 ± 0.1
Male	1 ± 0	1.0547 ± 0.09	1.0540 ± 0.09	1.0611 ± 0.12
Female	1 ± 0	1.0497 ± 0.09	.9736 ± 0.14	1.0498 ± 0.09

Table 6. Supplementation Long Timing – Passing Accuracy
There were statistically significant improvements for passing accuracy for the combined group and for females at 60 minutes pre exercise caffeine consumption ($P < 0.05$) compared to placebo at 30 minutes. There were also statistically significant improvements in female placebo consumption at 60 minutes pre exercise ($P < 0.05$) compared to placebo at 30 minutes.

Passing Accuracy				
Group	**Placebo 30mins**	**Caffeine 30mins**	**Placebo 60mins**	**Caffeine 60mins**
Combined	1 ± 0	1.0942 ± 0.16	1.1216 ± 0.24	1.2289 ± 0.34*
Male	1 ± 0	1.1642 ± 0.16	1.0959 ± 0.13	1.1010 ± 0.16
Female	1 ± 0	1.0319 ± 0.15	1.1444 ± 0.32*	1.3426 ± 0.42*

Table 7. Supplementation Long Timing – Offensive Sprint
There were no significant differences in offensive sprint performance across all of the trials and groups.

Offensive Sprint				
Group	**Placebo 30mins**	**Caffeine 30mins**	**Placebo 60mins**	**Caffeine 60mins**
Combined	1 ± 0	1.0164 ± 0.04	.9928 ± 0.05	.9832 ± 0.05
Male	1 ± 0	1.0065 ± 0.06	.9847 ± 0.05	.9801 ± 0.04
Female	1 ± 0	1.0253 ± 0.02	1 ± 0.05	.9859 ± 0.06

Table 8. Supplementation Long Timing – Medicine Ball Toss
There were no significant differences in medicine ball toss performance across all of the trials and groups.

Medicine Ball Toss				
Group	**Placebo 30mins**	**Caffeine 30mins**	**Placebo 60mins**	**Caffeine 60mins**
Combined	1 ± 0	.9988 ± 0.11	1.0282 ± 0.13	1.0167 ± 0.12
Male	1 ± 0	1.0004 ± 0.07	1.0421 ± 0.09	.9915 ± 0.10
Female	1 ± 0	.9975 ± 0.13	1.0157 ± 0.16	1.0392 ± 0.13

Table 9. Supplementation Long Timing – Rugby Specific Sprint
There were statistically significant improvements for rugby specific sprint for the combined group at 60 minutes pre exercise caffeine consumption ($P < 0.01$) along with the 30 minutes pre exercise caffeine consumption ($P < 0.05$) and 60 minutes pre exercise placebo consumption ($P < 0.05$) when compared to 30 minutes pre exercise placebo consumption. There were statistically significant improvements for the male group at 60 minutes pre exercise caffeine consumption ($P < 0.05$) and for the female group at 60 minutes pre exercise caffeine consumption ($P < 0.01$) compared to 30 minutes pre exercise placebo consumption. There were statistically significant improvements for the female group at 60 minutes pre exercise placebo consumption ($P < 0.01$) compared to 30 minutes pre exercise placebo consumption.

Rugby Specific Sprint				
Group	**Placebo 30mins**	**Caffeine 30mins**	**Placebo 60mins**	**Caffeine 60mins**
Combined	1 ± 0	.9559 ± 0.06*	.9488 ± 0.04*	.9300 ± 0.04†
Male	1 ± 0	.9398 ± 0.07	.9521 ± 0.05	.9251 ± 0.04*
Female	1 ± 0	.9702 ± 0.05	.9459 ± 0.03†	.9343 ± 0.03†

Table 10. Supplementation Long Timing – RPE
There were no significant differences in ratings of perceived exertion across all of the trials and groups.

RPE				
Group	**Placebo 30mins**	**Caffeine 30mins**	**Placebo 60mins**	**Caffeine 60mins**
Combined	1 ± 0	.9224 ± 0.20	.9463 ± 0.18	.9637 ± 0.18
Male	1 ± 0	.8536 ± 0.18	.9657 ± 0.19	.9431 ± 0.17
Female	1 ± 0	.9836 ± 0.22	.9290 ± 0.17	.9819 ± 0.19

Table 11. Supplementation Long Timing – Collective Team Measures
There were statistically significant improvements in collective team measurements for the combined group at 60 minutes pre exercise caffeine consumption ($P < 0.05$) along with the female group 60 minutes pre exercise caffeine consumption ($P < 0.05$) when compared to 30 minutes pre exercise placebo consumption.

Collective Team Measures				
Group	**Placebo 30mins**	**Caffeine 30mins**	**Placebo 60mins**	**Caffeine 60mins**
Combined	1 ± 0	1.0936 ± 0.02	1.0961 ± 0.17	1.1547 ± 0.20*
Male	1 ± 0	1.1448 ± 0.15	1.1025 ± 0.18	1.1102 ± 0.15
Female	1 ± 0	1.0481 ± 0.14	1.0905 ± 0.16	1.1943 ± 0.23*

Chronological Effects Results

Table 12. Chronological Effects Results – 20-Meter Sprint
There were no significant differences in 20-meter sprint performance across all of the trials and groups.

20-Meter Sprint				
Group	**Visit 1**	**Visit 2**	**Visit 3**	**Visit 4**
Combined	.9865 ± 0.03	.9918 ± 0.05	.9946 ± 0.05	.9725 ± 0.04
Males	.9832 ± 0.04	.9935 ± 0.03	1.0039 ± 0.04	.9838 ± 0.03
Females	.9895 ± 0.03	.9903 ± 0.07	.9864 ± 0.05	.9624 ± 0.05

Table 13. Chronological Effects Results – Sled Push 15-Meter
There were no significant differences in sled push 15-meter performance across all of the trials and groups.

Sled Push 15-Meter				
Group	**Visit 1**	**Visit 2**	**Visit 3**	**Visit 4**
Combined	.9898 ± 0.03	1.0014 ± 0.06	.9902 ± 0.07	.9873 ± 0.05
Males	.9927 ± 0.02	1.0156 ± 0.06	.9782 ± 0.09	.9908 ± 0.04
Females	.9872 ± 0.04	.9888 ± 0.5	1.0008 ± 0.05	.9841 ± 0.05

Table 14. Chronological Effects Results – Pushups
There were no significant differences in pushup performance across all of the trials and groups.

Pushups				
Group	**Visit 1**	**Visit 2**	**Visit 3**	**Visit 4**
Combined	1.0276 ± 0.07	1.0244 ± 0.07	1.0114 ± 0.12	1.0551 ± 0.10
Males	1.0181 ± 0.05	1.0366 ± 0.09	1.0540 ± 0.09	1.0611 ± 0.11
Females	1.0361 ± 0.09	1.0136 ± 0.06	.9736 ± 0.14	1.0498 ± 0.09

Table 15. Chronological Effects Results – Passing Accuracy
There were no significant differences in passing accuracy performance across all of the visits and groups.

Passing Accuracy				
Group	**Visit 1**	**Visit 2**	**Visit 3**	**Visit 4**
Combined	1.0664 ± 0.16	1.0278 ± 0.07	1.1216 ± 0.24	1.2289 ± 0.34
Males	1.1248 ± 0.17	1.0394 ± 0.10	1.0959 0.13	1.1010 ± 0.16
Females	1.0144 ± 0.14	1.0176 ± 0.03	1.1444 ± 0.32	1.3426 ± 0.42

Table 16. Chronological Effects Results – Offensive Sprint
There were no significant differences in offensive sprint performance across all of the visits and groups.

Offensive Sprint				
Group	**Visit 1**	**Visit 2**	**Visit 3**	**Visit 4**
Combined	1.0114 ± 0.03	1.0050 ± 0.03	.9928 ± 0.05	.9832 ± 0.05
Males	1.0130 ± 0.05	.9935 ± 0.03	.9847 ± 0.05	.9801 ± 0.04
Females	1.0099 ± 0.01	1.0153 ± 0.03	1 ± 0.05	.9859 ± 0.06

Table 17. Chronological Effects Results – Medicine Ball Toss
There were no significant differences in medicine ball toss performance across all of the visits and groups.

Medicine Ball Toss				
Group	**Visit 1**	**Visit 2**	**Visit 3**	**Visit 4**
Combined	.9929 ± 0.08	1.0059 ± 0.07	1.0282 ± 0.13	1.0167 ± 0.12
Males	1.0153 ± 0.04	.9851 ± 0.05	1.0421 ± 0.09	.9915 ± .10
Females	.9731 ± 0.10	1.0244 ± 0.08	1.0157 ± 0.16	1.0392 ± 0.13

Table 18. Chronological Effects Results – Rugby Specific Sprint
There were statistically significant improvements for rugby specific sprint performance for the combined group on Visit 4 ($P < 0.05$) and for the female group on Visit 4 ($P < 0.01$) when compared to 30 minutes pre exercise placebo consumption.

Rugby Specific Sprint				
Group	**Visit 1**	**Visit 2**	**Visit 3**	**Visit 4**
Combined	.9765 ± 0,05	.9794 ± 0.05	.9488 ± 0.04	.9300 ± 0.04*
Males	.9582 ± 0.05	.9816 ± 0.06	.9521 ± 0.05	.9251 ± 0.04
Females	.9928 ± 0.04	.9775 ± 0.03	.9459 ± 0.03	.9343 ± 0.03†

Table 19. Chronological Effects Results – RPE
There were no significant differences in ratings of perceived exertion across all of the visits and groups.

RPE				
Group	**Visit 1**	**Visit 2**	**Visit 3**	**Visit 4**
Combined	.9617 ± 0.17	.9607 ± 0.13	.9463 ± 0.18	.9637 ± 0.18
Males	.8667 ± .17	.9869 ± 0.08	.9657 ± 0.19	.9431 ± 0.17
Females	1.0462 ± 0.12	.9374 ± 0.16	.9290 ± 0.17	.9819 ± 0.19

Table 20. Chronological Effects Results – Collective Team Measures
There were statistically significant improvements in collective team measurements for the combined group on Visit 3 ($P < 0.05$) and for the female group on Visit 3 ($P < 0.05$) compared to 30 minutes pre exercise placebo consumption.

Collective Team Measures				
Group	**Visit 1**	**Visit 2**	**Visit 3**	**Visit 4**
Combined	1.0537 ± 0.11	1.0399 ± 0.12	1.1547 ± 0.20*	1.0961 ± 0.17
Male	1.1148 ± 0.12	1.0300 ± 0.13	1.1102 ± 0.15	1.1025 ± 0.18
Females	.9993 ± 0.07	1.0488 ± 0.12	1.1943 ± 0.23*	1.0905 ± 0.16

Supplementation

Table 21. Supplementation – 20-Meter Sprint
There were no significant differences in 20-meter sprint performance across all of the trials and groups.

20-Meter Sprint			
Group	**Placebo**	**Caffeine 30mins**	**Caffeine 60mins**
Combined	.9973 ± 0.03	.9783 ± 0.06	.9725 ± 0.04
Males	1.0020 ± 0.03	.9767 ± 0.05	.9838 ± 0.03
Females	.9932 ± 0.04	.9798 ± 0.07	.9624 ± 0.05

Table 22. Supplementation – Sled Push 15-Meter
There were no significant differences in sled push 15-meter performance across all of the trials and groups.

Sled-Push 15 Meter			
Group	**Placebo**	**Caffeine 30mins**	**Caffeine 60mins**
Combined	.9951 ± 0.05	.9913 ± 0.06	.9873 ± 0.05
Males	.9891 ± 0.06	1.0083 ± 0.07	.9908 ± 0.04
Females	1.0004 ± 0.03	.9761 ± 0.06	.9841 ± 0.05

Table 23. Supplementation – Pushups
There were no significant differences in pushup performance across all of the trials and groups.

Pushups			
Group	**Placebo**	**Caffeine 30mins**	**Caffeine 60mins**
Combined	1.0057 ± 0.08	1.0521 ± 0.09	1.0551 ± 0.10
Males	1.0270 ± 0.07	1.0547 ± 0.09	1.0611 ± 0.11
Females	.9868 ± 0.10	1.0497 ± 0.10	1.0498 ± 0.09

Table 24. Supplementation – Passing Accuracy
There were statistically significant improvements for passing accuracy performance for the combined group at 60 minutes pre exercise caffeine consumption ($P < 0.05$).

Passing Accuracy			
Group	**Placebo**	**Caffeine 30mins**	**Caffeine 60mins**
Combined	1.0608 ± 0.18	1.0942 ± 0.16	1.2289 ± 0.34*
Males	1.0480 ± 0.10	1.1642 ± 0.16	1.1010 ± 0.16
Females	1.0722 ± 0.23	1.0319 ± 0.15	1.3426 ± 0.42

Table 25. Supplementation – Offensive Sprint
There were no significant differences in offensive sprint performance across all of the trials and groups.

Offensive Sprint			
Group	**Placebo**	**Caffeine 30mins**	**Caffeine 60mins**
Combined	.9964 ± 0.04	1.0164 ± 0.04	.9832 ± 0.05
Males	.9924 ± 0.03	1.0065 ± 0.06	.9801 ± 0.04
Females	1 ± 0.04	1.0253 ± 0.02	.9859 ± 0.06

Table 26. Supplementation – Medicine Ball Toss
There were no significant differences in medicine ball toss performance across all of the trials and groups.

Medicine Ball Toss			
Group	**Placebo**	**Caffeine 30mins**	**Caffeine 60mins**
Combined	1.0141 ± 0.09	.9988 ± 0.11	1.0167 ± 0.12
Males	1.0211 ± 0.07	1.0004 ± 0.07	.9915 ± 0.10
Females	1.0079 ± 0.11	.9975 ± 0.13	1.0392 ± 0.13

Table 27. Supplementation – Rugby Specific Sprint
There were statistically significant improvements for rugby specific sprint performance for the combined group at 60 minutes pre exercise caffeine consumption ($P < 0.01$) and for the female group at 60 minutes pre exercise caffeine consumption ($P < 0.05$).

Rugby Specific Sprint			
Group	**Placebo**	**Caffeine 30mins**	**Caffeine 60mins**
Combined	.9744 ± 0.04	.9559 ± 0.06	.9300 ± 0.04†
Males	.9760 ± 0.04	.9398 ± 0.07	.9251 ± 0.04
Females	.9729 ± 0.04	.9702 ± 0.05	.9343 ± 0.03*

Table 28. Supplementation – RPE
There were no significant differences in ratings of perceived exertion across all of the trials and groups.

RPE			
Group	**Placebo**	**Caffeine 30mins**	**Caffeine 60mins**
Combined	.9731 ± 0.12	.9224 ± 0.20	.9637 ± 0.18
Males	.9829 ± 0.13	.8536 ± 0.18	0.9431 ± 0.17
Females	.9645 ± 0.12	.9836 + 0.22	.9819 ± 0.19

Table 29.) Supplementation – Collective Team Measures
There were statistically significant improvements for collective team measurements for the combined group at 60 minutes pre exercise caffeine consumption ($P < 0.05$) and for the female group at 60 minutes pre exercise caffeine consumption ($P < 0.01$) compared to 30 minutes pre exercise placebo consumption.

Collective Team Measures			
Group	**Placebo**	**Caffeine 30mins**	**Caffeine 60mins**
Combined	1.0481 ± 0.13	1.0936 ± 0.15	1.1547 ± 0.20*
Males	1.0512 ± 0.14	1.1448 ± 0.15	1.1102 ± 0.15
Females	1.0453 ± 0.12	1.0481 ± 0.14	1.1943 ± 0.23†

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CHAPTER V

DISCUSSION

Study Purpose

The objectives and goals for this study were looking into the effectiveness of caffeine, enhancing performance in simulated rugby specific activity based on pre exercise ingestion. Primarily, the focus was to narrow the window of time for when caffeine should be ingested, prior to activity, in order to elicit a performance enhancing effect. The researchers had participants ingesting caffeine ($3mg*kg^{-1}$) either 30 or 60 minutes, before they began the trial on test days. This was to allow time for the body to metabolize the supplement within the beverage. For the researchers who were involved with this study, the gap in the knowledge from the reviewing the literature, looking into the effectiveness of caffeine on sports performance (Doherty & Smith, 2005), was determining what stage caffeine should be ingested to aid sport specific performance for the individual. The effectiveness of caffeine on performance is transparent; caffeine will allow the participant to work for longer periods of time, improve alertness and overall cognitive functioning. This allows for more specific performance improvements such as enhanced decision making abilities, alleviating the stress put on the body thus delaying onset fatigue, and therefore more refined skill execution throughout match play. (Doherty & Smith, 2005). What was noted in various research studies reviewed for this work is that in order to optimize performance for the athlete, the window of time for ingestion be approximately 60 minutes prior to engaging in activity (Bonati et al., 1982; Fredholm, Bättig, Holmén, Nehlig, & Zvartau, 1999). In contrast, other studies were reviewed and it was recognized that although caffeine is considered to be most effective when ingested 60 minutes prior to activity, other time frames had been governed within these studies. The times that were used ranged from 30 minutes to 90 minutes pre exercise caffeine consumption (Campbell, Richmond, & Dawes, 2016; Ivy et al, 2009; Beck et al., 2008; Stuart et al., 2005; Bell et al., 2001). Experimental designs varied between sports and also between physical parameters that were being measured. The dosage of caffeine within these trials varied in how it was administered and would range between 2.5-6mg*kg^{-1}.

With this lack of clarity within the literature, the researchers were intrigued and therefore created a study in which this concept for time manipulation with caffeine ingestion may be explored in more depth. A simulated rugby union circuit, involving eight separate stations, completed ten consecutive times, that would mimic the types of movements, along with the energy systems that would be targeted on a rugby pitch, along with the duration for a trial matching one half of a match (40 minutes), was designed that would help the researchers to effectively test what the effects might be when altering the times for ingestion, prior to activity.

Interpreting the Data

Three separate measures for the data analysis were considered for understanding the effect of caffeine when manipulating time for ingestion prior to simulated rugby union activity. This involved running ANOVA tests for long timing (comparing all trials), chronological (based on visitation), and supplementation (combined placebo trials against 30 minutes and 60 minutes pre exercise caffeine consumption). Data was normalized for 30 minutes pre exercise placebo consumption, and then comparisons were made against the change in the mean percent values for 30 minutes pre exercise caffeine consumption, 60 minutes pre exercise placebo consumption and 60 minutes pre exercise caffeine consumption. This was incorporated for each station independently and allowed the researchers to determine how much of an effect there was on the performance based on the caffeine consumption, the time for ingestion, and also based on visitation.

What was first noted for these results, was how passing accuracy had improved. More specifically, there was improved passing accuracy for long timing measures among the combined group and within the female group at 60 minutes pre exercise caffeine consumption. Evidence is reported within Table 6. Based on supplement measures, passing accuracy showed statistically significant enhancements for 60 minutes pre exercise caffeine consumption for the combined group. Evidence is reported within Table 23. The passing accuracy drill relied on the participants to demonstrate greater awareness, a higher level of skill, visual acuity and enhanced coordination, if they were to strike the target with each of the seven balls placed 5-meters from the wall. These results support the notion that $3mg*kg^{-1}$ caffeine, ingested 60 minutes pre exercise, may act as an ergogenic aid on passing ability in simulated rugby union activity. The results also provided some evidence, supporting the effectiveness for $3mg*kg^{-1}$ caffeine ingested 30 minutes for enhancing passing ability as these results were trending but not conclusive.

Within long timing measures, there were statistically significant improvements in rugby specific sprints times at 60 minutes pre exercise caffeine consumption among the combined group, the female group and also the male group. What was also seen from these results was that 30 minutes pre exercise caffeine consumption for the combined group, showed performance enhancements. Evidence is reported within Table 9. For chronological measures, it was seen how rugby specific sprint times were significantly improved on Visit 4 for the combined group and for the female group. Evidence is reported within Table 18. For the final measure utilized for data analysis, it was seen within supplement measures how rugby specific sprint times had statistically significant improvements for 60 minutes pre exercise caffeine consumption for the combined group and for the female group. Evidence is reported within Table 27.

For the rugby specific sprint station, a certain amount of coordination, along with skill and timing, was required for the participants to be able to fully exert themselves, and yet maintain composure and skill to effectively complete this portion of the circuit within the quickest possible time. There is limited research on the effects of caffeine enhancing skill performance, within sport specific trials, but such evidence was highlighted within the study completed and mirrored for aspects of this research experimental design (Stuart et al., 2005). The results from the data analysis support the literature stating how caffeine will elicit an effect on performance as an ergogenic aid when ingested 60 minutes pre exercise. There is also evidence from the results from rugby specific sprint data that supports the notion that 30 minutes pre exercise caffeine consumption will allow for performance enhancements. The researchers also noted that by Visit 4, female subjects had a learning effect with the circuit and were completing the stations and the trial as a whole more efficiently. No such evidence was in support for the male group.

A fourth approach alongside measures for long timing, chronological, and supplemental analysis was executed for interpreting the data from an alternative viewpoint. For this metric, all of the stations were combined into one, for each of the participants, and the analysis was viewing the percent change in performance when considering each station collectively, as opposed to independently. The data values that were input for 30 minutes pre exercise placebo consumption were normalized and then comparisons were made against the other trials with the mean percent change for 30 minutes pre exercise caffeine consumption, 60 minutes pre exercise placebo consumption and for 60 minutes pre exercise caffeine consumption.

What the researchers found following this data analysis was how for long time measures; there were statistically significant improvements in collective team performance at 60 minutes pre exercise caffeine consumption for the combined group and for the female group. Evidence is reported within Table 11. Within chronological measures, it was seen how there were statistically significant improvements in collective team performance for Visit 3, for the combined group and for the female group. Evidence is reported within Table 20. For supplemental measures, there were statistically significant improvements in collective team measures at 60 minutes pre exercise caffeine consumption for the combined group. Evidence is reported within Table 29. Data analyzed for collective measures highlights and supports the reviewed literature for how caffeine, when ingested 60 minutes pre exercise will act as an ergogenic aid for enhancing sports specific performance.

Caffeine Dosage

The caffeine dosage for this experimental design was relatively low at $3mg*kg^{-1}$ with most research studies using approximately $6mg*kg^{-1}$ (Jones, 2008). Even though there was a lower dosage, there was still enough of an effect to enhance performance for specific parameters within the simulated rugby circuit e.g. passing accuracy and rugby specific sprint. Stuart et al. (2005) measured the effects on high intensity simulated rugby activity and the results from this work had some crossover to the results gained from this study. Between the two, it was noted how the effects of caffeine were prominent within that station that simulated the rugby specific sprint. There were also improvements in passing accuracy for the caffeine trials versus the placebo visits for the participants between the two studies. A major contrast between these two works is the dosage of caffeine, with the work for Stuart et al. (2005) having participants ingest $6mg*kg^{-1}$ prior to activity and this study incorporating the use of $3mg*kg^{-1}$. This supports the literature for administering caffeine as an ergogenic aid to improve performance for skill based components.

A separate study was created that involved using caffeine as a pre workout supplement, measuring the effects on power, muscular endurance and repeated sprint speed (Campbell et al., 2016). The participants ingested the supplement 30 minutes before they began testing and although performance was not improved across each of the measured activities, there was an improvement in muscular endurance for the caffeine trial. The researchers who were conducting this study used 2.4 $mg*kg^{-1}$ caffeine ($0.6mg*kg^{-1}$ less than what was used for this study protocol). As noted previously, the majority of studies incorporating the use of caffeine as a pre workout supplement to enhance performance, more frequently use $6mg*kg^{-1}$ for the participants. In referencing to this work, not only did the researchers have the participants ingesting the caffeine at 30 minutes prior to activity, but also the dosage was considerably less. Therefore recent studies utilizing caffeine provoke the idea of how modest levels of caffeine dosage might be just as effective as the higher dosage (Jones, 2008). With this information, this suggests the potential for future work where by using a higher dosage might work favorably for subjects who are exposed to caffeine more frequently and therefore have a higher tolerance to the effects listed. Also, higher dosages of caffeine might allow for performance enhancements when ingested 30 minutes pre exercise as the results for rugby specific sprint at 30 minutes pre exercise caffeine consumption were statistically significant and other stations within the circuit were trending. Although, recognizing and understanding that excessive dosages of caffeine ($>9mg*kg^{-1}$) can have side effects that will deteriorate performance by causing the individual to become overly anxious, more jittery, over aroused, dehydrated and thus lowering the level of skill and coordination should be made apparent (Graham & Spriet, 1995).

Sport Specific Performance

The majority of research for caffeine supplementation that has been completed has been used to measure and test the improvements on endurance based activities. More recently, there has been some considerable work completed for measuring the effects of caffeine on resistance based activity and the potential improvements on anaerobic exercise as well as minor enhancements to 1RM ability (Trexler, Smith-Ryan, Roelofs, Hirsch, & Mock, 2016). Based on the results from this study, it was noted that caffeine could have some considerable effects upon skill ability on sport specific performance for rugby activity.

As noted within the previous section, the two stations that showed the participants to have enhanced performance due to the effectiveness of the caffeine supplement were the passing accuracy and the rugby specific sprint. When analyzing the data and making comparisons between the two, the effectiveness of the caffeine supplement was more pronounced and evident for the rugby specific sprint, the final physically demanding station within the circuit. Caffeine enhanced the participants' performance when ingested 60 minutes prior to commencing the trial, but was also effective 30 minutes pre exercise consumption. There are not only considerations for time of consumption, but also how frequently throughout exercise caffeine can be exposed to the participant and what activity is being conducted for testing. More research should be performed on this subject, based on how the effectiveness of caffeine is dependent on dosage, timing for ingestion along with the tolerance of the individual and the design of the experiment.

It was recognized that the participants had a learning effect towards the layout of the circuit and the results from the data analysis supported this concept. Participants acclimated their timing and the types of movements that might be more effective for completing the stations to a more efficient and manageable state. The results showed how the participants had significantly enhanced their performances, specifically for the rugby specific sprint station, on the fourth visit with their testing. This was a noted limitation prior to commencing data collection since the participants are regular players for the university club rugby side and they understand the types of movements of skills required to be effective within this domain. (Collump et al., 1991).

The participants that were selected for this study were regular, starting players within the university team; in reference to the literature, it is understood that incorporating the use of sport specific athletes, as well as using players at the highest level, will allow for more reliable end results because of the understanding of the game along with the competitive nature of the athletes themselves, meaning they will approach each trial date with the same level of heightened play (Mohr, Krustrup, & Bangsbo, 2003). From the data analysis, the improvements in rugby specific sprint performance, passing accuracy, and collective team measures were greater among the female group compared to the male participants. A learning effect was more evident among the female participants by Visit 4 compared to the male participants. Male participants that were selected for this study are part of the men's club rugby squad for their university. What was noted earlier within the study is that this particular team was organized and came together three years ago. Some of the players transitioned from American football and others from soccer and with that knowledge, the team is still in its infancy for development and for effectively understanding the technical side for playing rugby union. Although the players are very strong athletically, they are still learning to play the game. Contrary to the male participants, the female group has been involved with the women's rugby squad for a longer period of time and the team itself was established eight years ago. The squad is involved with a division II league and is also highly decorated with a number of championships and tournament victories. This suggests reasons as to why the female participants were able to stand out for certain stations to a higher degree, compared to the male participants. The two stations that had statistically significant improvements were skill based, and the female subjects had greater success comparatively to their male counterparts.

This aspect of the study could be regarded as a limitation. Worth noting is how the female subjects had a lower tolerance to caffeine compared to the male participants based on the completed documentation prior to the study commencing. The female participants' naivety to caffeine is another condition to the study that played a factor in how caffeine affected performance. Therefore, female subjects were more skilled individually and also had a lower tolerance to the effects of caffeine. This could potentially explain and clarify why certain results between the two genders appeared as they did.

Future Work

Other stations within the circuit that did not show statistically significant improvements in performance amongst either group were 20-meter sprint, sled push 15-meter, pushups, 25-meter offensive sprint, and medicine ball toss. The participants were also measured for ratings of perceived exertion following the completion of the last physical component station (rugby specific sprint) at the end of each lap. The stations that did show improvements in performance at 30 and 60 minutes pre exercise caffeine consumption were more skill related and required more than just a higher level of sport specific fitness from the participant. More recently, research has been conducted on such examples as improvements in simulated soccer trials (Foskett et al., 2009), and similar to this study, conducts the trials within a closed circuit. This meant extraneous variables were accounted for and would not interfere with the participant’s performance within the trials and stations. Such examples of extraneous variables include other players in the match who might be in the game trying to tackle the participant, the quality of the pitch that is being played on, the climate such as extreme heat, wind or rain, the noise of fans and coaches watching, significance of the match i.e. league game or playoffs, etc. Closed circuit trials also may conceive more limitations such as participants adapting to the trials and thus allowing for a learning effect to occur.

Considerations towards future work involve adjustments to the experimental design in order to accommodate for limitations among subjects in terms of the level of skill for participants individually and collectively, along with naivety towards the effects of caffeine on sports specific performance. The purpose of this study was to narrow the window of time for when caffeine will offer an ergogenic effect on simulated rugby performance. This was apparent for components of testing but not others. This suggests that manipulations should be applied to caffeine dosage ($>3mg*kg^{-1}$) along with refining the stations so participants challenged in a manner that will focus on sports specific performance but will evade possibilities for their to be a learning effect over a number of trials. For the passing accuracy station, it was prompted following data collection that instead of having the one target to aim for, there could be three placed against the wall, and a number assigned to each. A random number generator could be incorporated that will visually present a number on a screen, dictating which target the participant must aim for when performing the pass. This will aid in breaking routine and should prevent participants becoming acclimated to the station as a whole, thus averting a learning effect.

The study began with an n = 22, but due to injuries and time conflicts, the final data had n = 17 (9 females, 8 males). For future work recruiting a larger quantity of participants for the study would potentially yield more clarity within the results. With the nature of rugby union as a sport, the range in physicality and body awareness is fairly wide since players are normally selected on body type and are matched to a position that requires a specific anatomical build and level of fitness. One constant that should remain consistent throughout is the ability of the players. Participants who have played rugby union at a more advanced level will understand the correct movements and technical aspects of the game to be more efficient in their play. Participants act as their own control, but utilizing players who are at a higher standard will offer more reliable results and assist with managing consistency over the various trials that are run compared to players of lower ability that might have fluctuations in skill depending on days of visitation.

Conclusion

Caffeine is an effective supplement that can be used as a means to improve performance, whether that involves enhancing the individual's muscular endurance, the effectiveness with performing resistance based activity, and there is also sound evidence to suggest that caffeine can improve skill based performance when conducted in such a way that all parameters are considered to accommodate for extraneous variables. For future work, and for furthering knowledge around caffeine's effects on exercise and activity, completing research that manipulates the dosage of caffeine that is provided to the participants and also altering times for ingestion (±60minutes) will be useful to understand effective timing and recommended amounts to elicit performance enhancing effects. The results from this study suggest that caffeine, when ingested 30-minutes prior to simulated rugby activity, does have some effect on enhancing performance, but these results were predominantly trending and not definitively significant. Modifications with the study design might allow the results to show more transparency. More skill related components added into the design at different stations could also be an interesting pursuit as there is not as much research for the effects on overall skill ability, compared to the caffeine effects of stamina, delaying onset muscular fatigue and power/force production.

The caffeine dosage that is recommended for trials is approximately 6mg*kg^{-1} (Keisler & Armsey II, 2006) and only 3mg*kg^{-1} was used for this study. There might be an increased response and a significant improvement in all stations if a higher dosage was utilized for the participants. There is also evidence to suggest that creating a study where measuring the effects of caffeine on performance when ingested 90-minutes prior to activity might elicit an ergogenic effect on overall performance. This work is inconclusive and further research should be conducted to properly understand and measure the most effective means for when caffeine should be ingested prior to activity to allow for a performance enhancing effect.

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