The effects of a low dose of caffeine on bat swing performance in fatigued and non-fatigued female softball athletes

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The effects of a low dose of caffeine on bat swing performance in fatigued and non-fatigued female softball athletes

by

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ABSTRACT

**Objective:** The purpose of this study was to determine if caffeine ingestion decreased time to contact (TTC), and increased peak hand speed (HS), peak bat barrel speed (BS), and power (P) during a softball bat swing by fatigued and non-fatigued female athletes from an NCAA Division III varsity softball team. **Methods:** A randomized, single blind counterbalanced design was used to determine if 200 mg of caffeinated gum produced an ergogenic effect on nine female softball players (mean ± SD; age: 19.4 ± 0.7 yrs; height: 169 ± 6 cm; weight: 76.85 ± 10.82 kg) during a softball swing after chewing caffeinated gum for 10 minutes. In the non-fatigued condition the participants received two pieces of caffeinated gum (100 mg each) or a placebo after their warm-up. In the fatigued condition, participants’ received the gum after the completion of a 20 minute high-intensity exercise circuit. The gum was chewed for 10 minutes before being discarded. Once the gum was discarded each participant hit ten softballs off of a tee into fair territory. A Blast Motion Sensor attached to the knob of the bat measured the BS, HS, TTC, and P for each hit. Pre- and post-hitting questionnaires were used to determine fatigue before and after the hitting test using an 11-point fatigue scale. **Results:** A paired samples t-test was used to determine the change in perceived fatigue within groups. No statistically significant differences were found in pre-hitting test fatigue and post-hitting test fatigue during the non-fatigued placebo condition, \( t(8) = -.707, p = .500 \) and non-fatigued caffeinated condition, \( t(8) = 1.155, p = .282 \). There were statistically significant differences in the pre-hitting test fatigue and post-hitting test fatigue during the fatigued placebo condition, \( t(8) = 5.000, p = .001 \) as well as the fatigued caffeinated condition, \( t(8) = 4.603, p = .002 \). A two-way repeated measures analysis of variance (ANOVA) was used to test the differences in BS, HS, TTC and P between the
caffeine and placebo trails within the fatigued and non-fatigued conditions. There were no statistically significant interactions between fatigue status and supplementation on BS, HS, TTC, and P, so main effects were analyzed. Main effects indicated statistically significant differences in mean BS and P between the placebo (BS = 53.9 mph; P = 1.75 kW) and caffeinated conditions (BS = 55.0 mph; P = 1.83 kW), $F(1,8) = 8.651, p = .019$; $F(1,8) = 6.375, p = .036$. *Conclusion:* Based on these results, it is suggested that caffeinated gum can be beneficial to bat swing performance and perceived fatigue in female softball players.
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CHAPTER 1

INTRODUCTION

Fastpitch softball is a sport played by men and women worldwide. This sport is popular with female and male athletes of all ages. There are hundreds of colleges in the United States that have varsity women’s softball teams in the National Collegiate Athletic Association (NCAA). There are 277 NCAA Division I softball teams alone (Milanovich & Nesbit, 2014). Women’s fastpitch softball was part of the Summer Olympic Games from 1996 until 2008 and will once again be part of the Summer Olympic Games in 2020.

To produce runs in softball, batters must hit the ball to get on base. Other players must hit the ball to move the runner around the bases to score a run at home. More hits produce more runs. Power and velocity of a bat swing is generated through a kinetic chain in the body. During a softball bat swing, force is transferred from the feet, through the legs, torso, arms, wrist and finally to the hands which propel the bat through the air to make contact with the ball (Szymanski, David, & Derenne, 2010). Increased bat speed and power will lead to faster exit velocity of the ball from the bat and increase the distance the ball travels. Bat speed and power may be affected by caffeine supplementation.

Caffeine acts as an adenosine blocker causing enhanced mental alertness, attentiveness, decreased reaction time and decreased perception of fatigue (Crowe, Leicht, & Spinks, 2006; Chen, Wang, Tung, & Chao, 2015). Caffeine also releases calcium in the sarcoplasmic reticulum leading to an increase in power production (Hoffman et al., 2007). Caffeine is the perfect substance to add to food and drinks due to
its water-soluble properties. There is a substantial evidence that caffeine ingestion enhances endurance performance by 3-5% (Kalaja, Deda, & Kraja, 2015). The effect caffeine has on anaerobic sports performance is still unclear. Dragoo, Silvers, Johnson, and Gonzalez (2011) found that caffeine ingestion did not affect mean power, peak power, or fatigue index during a Wingate test. Woolf, Bidwell, and Carlson (2009) found no significant difference between caffeine and a placebo during a 40-yard dash, 20-yard shuttle run, and bench press in football athletes. These studies did not show significant effects of caffeine ingestion on performance, but other studies have shown that caffeine ingestion affects anaerobic performance. Lee et al., (2012) found significant increases in peak power, mean power, total work and fatigue index during an intermittent sprint cycling test when supplementing with caffeine. Supplementing with caffeine also increased shot put distance and alertness during early morning practices (Bellar et al., 2012). The mixed research results have not clearly shown if caffeine ingestion improves anaerobic performances.

The NCAA does not ban the use of caffeine by its athletes, but it does restrict its dose. An athlete will fail an NCAA drug test if the athlete’s urine contains more than 15ug/ml of caffeine. This could occur if one drinks 8-10 cups of coffee 1-2 hours prior to testing (Woolf, Bidwell, & Carlson, 2008). Caffeine supplements are affordable and widely available. Most caffeine supplementation is done through pills and beverages. With these forms of supplementation, the caffeine is absorbed through the stomach and small intestines and it takes about 45 minutes to an hour before any effects of the caffeine are noticeable (Astorino & Roberson, 2009). Caffeine can also be consumed through chewing gum. Caffeine is absorbed into the body through the buccal mucosa when
administered through chewing gum instead of through the stomach and small intestines. The buccal mucosa has an abundance of vesicles, which leads to an increased absorption rate of caffeine (Kamimori et al., 2002). Caffeinated gum decreases the absorption time from 45 minutes to 5 minutes. Within 5 minutes of chewing caffeinated gum, the body will absorb 85% of the caffeine, and within 10 minutes, 99% of the caffeine will be absorbed (Kamimori et al., 2002). This is a reasonable wait time for athletes. More testing is needed to determine if caffeine produces an ergogenic effect on anaerobic sports performance.

Studies involving caffeine have usually involved only male participants. Doherty and Smith (2004) completed a meta-analysis of caffeine studies and found that out of 414 subjects used in caffeine studies, only ten percent were women. More research is needed to determine if caffeine can be used as an ergogenic aid for women in short-term, high-intensity sports with minimal side effects.

**Statement of the Problem**

Athletes are always trying to gain a competitive edge. It is known that caffeine can improve endurance performance but it is unclear if caffeine ingestion affects ballistic, anaerobic movements of women in sports. The author knows of no studies that have tested the effects of caffeine ingestion on women’s softball batting performance. Is caffeine ingestion beneficial to the performance of explosive, anaerobic based movements such as a softball bat swing?

**Purpose of the Study**

The purpose of this study was to determine if caffeine ingestion decreased time to contact, and increased peak hand speed, peak bat barrel speed, and power during a
softball bat swing by fatigued and non-fatigued female athletes from an NCAA Division III varsity softball team.

**Hypotheses**

1. Ingesting 200mg of caffeine 10 minutes before batting would cause a decrease in time to contact, and an increase in peak hand speed, peak bat barrel speed, and power during softball bat swing in non-fatigued athletes.

2. Ingesting 200mg of caffeine 10 minutes before batting would cause a decrease in time to contact, and an increase in peak hand speed, peak bat barrel speed, and (d) power during a softball bat swing in fatigued athletes.

3. The fatigued athletes would have a decreased score on the 11-point rating of fatigue scale after participants supplement with caffeine.

**Delimitations**

The following were delimitations of the study:

1. A Blast Motion sensor was used to measure time to contact, peak hand speed, peak bat barrel speed, and power of the softball swing in this study. The sensor attaches to the knob of a softball bat and sends data to the app on an IOS or Android device in real time through a Bluetooth connection.

2. The participant pool for this study was limited to SUNY Cortland NCAA Division III female softball athletes who still have eligibility.

3. All participants were undergraduate students 18 years or older who attended SUNY Cortland.

4. The participants were varsity softball players who had a minimum of four years of experience playing fastpitch softball.
5. The participants had no health issues as determined by the Physical Activity Readiness Questionnaire (PAR-Q).

6. Participants were not taking prescription medication for ADD, ADHD, anxiety, depression, hypertension or seizures.

Limitations

The following were limitations of the current study:

1. The questionnaires were passed out and taken in a large group, which may have caused participants to rush or become distracted.

2. Participants may not have answered the questions on the questionnaires honestly.

3. Participants were asked to avoid caffeine consumption 48 hours before testing, as well as avoid vigorous exercise and the consumption of alcohol 24 hours before testing. There was no way to determine if they followed these instructions given by the researcher.

4. Accuracy of the Blast Motion sensor may have been a limitation. A comparison of the Blast Motion measurements to the measurements obtained from high speed video analysis produced the following correlation coefficients between the video swing measurements and those of the blast motion sensor: 0.928 for hand speed, 0.957 for bat speed, 0.930 for time to contact, and 0.858 for power. These strong correlations indicated that the measures produced by the Blast Motion sensor are accurate. There was a possibility that the sensor may have provided erroneous data, however.

Assumptions

The following assumptions were made:
1. All participants chewed the gum for the directed period of time and followed all instructions throughout the testing periods.

2. All participants had the proper attire to perform the given task and showed up on time for each testing period.

3. Participants were tested while in season so it was assumed that the participants were in similar physical shape.

**Definition of Terms**

*Anaerobic Performance*- The performance that occurs during short-term, high-intensity exercise.

*Athlete*- an individual who has eligibly to compete, and is currently a member of a sports team.

*ATP-PCr Energy System*- instant energy source used for short-term, high intensity exercise. Used for exercise that lasts around 3-5 seconds. The ATP is stored in the skeletal muscle.

*Ballistic Movement*- a quick explosive movement that requires quick activation of type II muscle fibers.

*Bat Acceleration*- the rate of change in bat velocity during a softball swing

*Bat Power*- the amount of power applied to the bat by the hands during a softball swing, measured in kilowatts.

*Blast Motion Sensor*- a sensor that attaches to the knob of a softball bat and sends data to your phone through a Bluetooth connection. The sensor is made up of an accelerometer and gyroscope.

*Caffeine*- a central nervous system stimulant.
**Ergogenic Aid**- any type of substance, training, or therapy that will enhance an athlete’s ability to train or perform better giving them a competitive edge during competition.

**Fastpitch Softball**- a form of softball that uses an underhand pitch known as a windmill. This is a full circular motion and the pitch is released next to the pitcher’s hip. Fastpitch also allows players to steal bases, bunt and splat hit.

**Fatigue**- The feeling of tiredness or exhaustion.

**Fatigued Condition**- this condition requires all participants to run through a fifteen minutes of high intensity exercise circuit prior to testing. Each member of the fatigued group will receive both caffeine and placebo gum throughout the course of the study.

**Motor Unit Recruitment**- the activation of additional motor units to make a stronger muscle contraction.

**NCAA**- National Collegiate Athletic Association. This association governs sport competitions on the collegiate level in the United States. There are three NCAA divisions and represent three different levels of competition.

**Neurotransmitter**- a chemical that transmits messages to other cells throughout the body.

**Non-Fatigued Condition**- the experimental condition that did not have to perform any exercise before testing. This condition required participants to come in and test right away while they were fresh. All participants received both caffeine and placebo gum during the non-fatigued condition.

**Peak Bat Barrel Speed**- the maximum speed the bat achieves starting when the bat begins its forward motion until the bat makes contact with the softball.
**Peak Hand Speed**- the maximum speed the hands achieve during a softball swing.

**Placebo**- is used in studies to look and taste like a certain substance with no physiological effects on the body.

**Physical Readiness Questionnaire** - a questionnaire that screens for health problems that might present a risk when participating in physical activity.

**Time to Contact**- the time it takes for the bat to move from initial forward motion to ball contact. The bat swings starts when the bat begins to move forward and ends when the bat makes contact with the softball. This is timed in seconds.

**Varsity Softball**- is a softball team that represents their school during competition. The NCAA regulates varsity sports and players must have eligibility to play. The players are also required to follow the rules placed by the NCAA.

**Significance of the Study**

There is uncertainty about the effects of caffeine ingestion on anaerobic performance in sport. The goal of this study was to determine if caffeine produced an ergogenic effect on female athletes during a softball swing. If caffeine improved ballistic movements such as a softball swing during competition, athletes could have a legal ergogenic aid to help them gain a competitive edge. This could lead to harder hit balls and increase the distance the ball will move through the air. Caffeine could potentially help to improve the offensive game of any softball team by increasing on base percentage, hits, and runs scored. Caffeinated gum could be a practical way to administer caffeine before or during a game. An athlete could easily put two pieces of caffeinated gum in their mouths and chew it while on defense. Once the inning ends, the athlete could enter in dugout, spit the gum out and go up to bat.
CHAPTER 2
REVIEW OF LITERATURE

Softball is a worldwide competitive and recreational sport that has been growing in popularity for the last few years. Fastpitch softball recently gained enough popularity to be a part of the 2020 Olympic summer games. Softball was originally designed as an indoor version of baseball in the 1880s. Softball was recognized as its own sport in the 1930s and is now played outside (Flyger, Button, & Rishiraj, 2006). The rules of softball are similar to baseball in that there are two teams and each team has to get three outs to end the half inning. An inning consists of both teams playing both offense and defense. On offense, batters each have three strikes before they are out or four balls until they walk to first base. A softball field’s dimensions are smaller than a baseball field with a minimum of 190 feet in right and left fields and a no more than 220 feet in center field according to NCAA guidelines (Van Kleeck, 2017, pg. 18). The base paths are 60 feet instead of 90 feet and the pitcher is 43 feet from home plate. A softball field has a full dirt infield. There are seven innings in a complete game. The softball weighs seven ounces instead of five ounces for a baseball. In fastpitch softball the pitcher performs a windmill pitch, which consists of a full arm circle before releasing the ball at the hip. Other than pitching, batting is one of the most important aspects of softball. A player needs to hit the ball to get on base and to ultimately score runs.

Successful hitting in softball requires a fast bat. An average softball bat swing is completed within 0.200-0.300 seconds, so batters need to produce a high bat velocity in a short period of time (Flyger et al., 2006). Hitting is a ballistic movement, which means the bat achieves high velocities in a very short period of time. Resistance training and
plyometric training can increase bat velocity and power but this training effect takes time to achieve (Ebben, 2006). Some athletes use ergogenic aids to help them during training and competition to boost their performance. Ergogenic aids are any type of substance, training, or therapy that will help an athlete perform better in practice and competition. One of the most widely used legal ergogenic aids is caffeine. Ninety percent of adults in the United States consume caffeine daily (Astorino & Roberson, 2009). Caffeine can be found in different kinds of affordable foods and beverages, including energy drinks. One of the main reasons energy drinks are consumed is to help improve sports and workout performance (Campbell, Richmond, & Dawes, 2016). Caffeine is known to enhance aerobic performance, but researchers are still unsure of the effects caffeine has on anaerobic performance, such as a bat swing. To provide better understanding of the research on this topic, this chapter reviews the research in the following categories:

1. Kinematics of a softball swing
2. How to improve bat speed and power
3. Caffeine’s effect on anaerobic performance
4. Anaerobic performance with low doses of caffeine
5. Caffeine and fatigue
6. Ways to ingest caffeine
7. Habitual caffeine users versus non-habitual caffeine users

**Kinematics of a Softball Swing**

Softball is a popular sport in the United States and there are currently 277 NCAA Division I colleges with softball programs (Milanovich & Nesbit, 2014). Batting is one of the key components of softball and is needed to produce runs within the game. A bat
swing is a full body movement that takes about 0.200-0.300 to complete (Flyger et al., 2006). Batters differ in form, speed, and force of their swings but there are similarities across swings that should be addressed.

When a batter steps into the batter’s box the batter takes an open stance (body towards the pitcher) or a closed stance (side towards the pitcher). The batter’s dominant eye determines the batter’s stance in the box. A player who swings from the same side as their dominant eye would benefit more from an open stance, while someone who swings from the opposite side of their dominant eye should swing with a closed stance (Flyger et al., 2006). As the swing progresses the weight shifts from the back foot to the front foot (Flyger et al., 2006). Milanovich and Nesbit (2014) found that the center of rotation of the bat stays inside of the path of the hands at the beginning of the swing, and, at 39 degrees before impact, the hand path and center of rotation of the bat are on the same plane. The center of rotation of the bat then moves back inside the hand path until ball contact (Milanovich & Nesbit, 2014).

One of the most important aspects of batting is linear velocity. Increased bat velocity will lead to an increase in force between the bat and the ball at the moment of impact, resulting in a increased exit velocity of the ball after the completion of the swing (Szymanski, David et al., 2012). Starting from the beginning of the swing through 135 degrees of rotation, linear velocities of the grip point, bat center of percussion, and bat center of gravity are all equal to one another (Milanovich & Nesbit, 2014). After 135 degrees of rotation, linear velocity of the center of percussion and center of gravity increase as the bat moves away from the body. Maximum grip velocity occurs at 90 degrees of rotation from impact with the ball, and peak linear velocity is reached right
before impact (Milanovich & Nesbit, 2014). Angular pitch velocity of the bat occurs around 120 degrees before impact. Finally, the wrists begin to roll at 65-70 degrees before impact, and then reach maximum velocity at 20 degrees before impact when the wrists line up with one another (Milanovich & Nesbit, 2014). Knowing the kinematics of a softball swing can be beneficial to coaches to help improve the form of their players. Improving form will help to increase overall offensive performance.

**How to Improve Bat Speed and Power**

The ability to hit a softball with a bat is an important aspect in the game of softball. During offense, a player must hit the softball and run around the bases in order to produce runs. Batting is an explosive ballistic movement that requires quick activation of type IIa muscle fibers (Ebben, 2006). Increasing a bat’s linear velocity increases bat momentum, some of which is transferred to the ball during contact and it ultimately increases the ball’s exit velocity (Szymanski, David et al., 2007). Increased exit velocity allows the ball to travel farther into the field of play. The power and velocity of a bat swing is generated from through a kinetic chain starting at the feet. Power is then transferred to the legs, hips, torso, arms and hands (Szymanski, David & Derenne, 2010). Researchers have sought to determine what kind of training can increase bat swing velocity and power.

Resistance training can increase muscle mass, strength, motor unit recruitment and motor unit firing rate. Resistance training can be used to improve bat velocity for baseball and softball players. The lower body and torso produce 50 percent of the total power of a baseball/softball swing (Ebben, 2006). Due to the transfer of energy that occurs throughout the course of a softball swing, whole body resistance training is
beneficial to increasing bat velocity. Olympic lifts and upper body movements such as bench press can be useful to increase bat velocity (Ebben, 2006). Hand grip and forearm strengthening programs do not seem to change bat velocity (Szymanski, David & Derenne, 2010).

Plyometric medicine ball training is a form of resistance training that can incorporate more sports specific movements. Medicine ball training can stimulate the stretch-shortening cycle which could improve batting performance (Ebben, 2006). During a swing, the body produces an explosive rotational force that projects the bat through the transverse plane. The bat itself does not slow down until it makes contact with the ball. Medicine ball training is more sports specific compared to traditional resistance training because the athlete is able to throw the medicine ball through space without deceleration (Ebben, 2006). A group of baseball players who completed 100 dry swings 3 days a week was compared with another group that completed dry swings with medicine ball training 3 days a week. Both groups increased linear bat end velocity, angular hip velocity, angular hip velocity and torso rotational strength (Szymanski, David et al., 2007). The medicine ball group saw greater increases in these categories compared to the dry swings. So it is possible that medicine ball plyometric training can lead to improvements in bat velocity during a baseball or softball swing.

The last type of resistance training that can help to improve bat velocity is ballistic implemented training. Ballistic training is throwing some form of resistance into free space (Ebben, 2006). Swinging a bat in baseball or softball is a type of ballistic movement because the player is swinging the bat through the air to try to make contact with the ball. Swinging a bat without making contact with a ball, also know as dry swings
could potentially improve batting velocity. In the previously mentioned study by Szymanski et al. (2007) one group of players who did dry swings 100 times a day 3 days a week was compared to another group that did medicine ball throws and dry swings. The medicine ball group had greater improvement in bat velocity (Szymanski et al., 2007), but the group that just did dry swings also improved bat velocity. So dry swings can be a type of ballistic training that can improve bat swing velocity. Szymanski et al. (2012) also looked at different warm-up devices to see if they had any effect on bat velocity. The items included an aluminum softball bat, six overweight devices and one underweight device. The results showed that was no difference in bat velocity after using the eight different warm-up devices (Szymanski et al., 2012). More research needs to be completed to see ballistic training can improve bat velocity in baseball and softball.

**Caffeine’s Effect on Anaerobic Performance**

Caffeine is known to improve endurance, but the effect of caffeine on anaerobic performance is still unclear. Caffeine affects both peripheral and central mechanisms of the body. So caffeine can increase force production, and also have the ability to decrease fatigue and pain. The effect caffeine has on anaerobic power is unclear. Researchers have not determined if caffeine use benefits anaerobic exercise.

Caffeine increases the release of calcium in the sarcoplasmic reticulum (Beck et al., 2006; Lee, Cheng, Lin, & Huang, 2012; Hoffman et al., 2007). Releasing more calcium in the sarcoplasmic reticulum will lead to an enhanced excitation-contraction coupling causing an increase in power production (Hoffman et al., 2007). This could lead to more forceful muscle contractions and increased power production during exercise. Woolf, Bidwell, and Carlson (2008) found that caffeine significantly increased the total
amount of weight lifted during a bench press and increased peak power during a Wingate test. Lee et al. (2012) found that caffeine significantly improved mean power, peak power and total work produced during an intermittent sprint cycling test with 12 x 4 second sprints with 90 seconds of active recovery at 60-70 rpm. Hoffman et al. (2007) found no significant difference between caffeine and placebo during a Wingate anaerobic power test. While some researchers agree that caffeine increases power production, others have found no significant increases compared to a placebo.

Caffeine can also act as an adenosine blocker, which is a central mechanism. Caffeine hinders the effects of adenosine in the central nervous system which leads to an increase in plasma epinephrine, reaction time, focus and memory, while decreasing perceived exertion during exercise, and perception of fatigue, (Crowe, Leicht, & Spinks, 2006; Chen, Wang, Tung, & Chao, 2015). It is theorized that adenosine increases pain perception, and pain affects the rate of motor unit recruitment. An increase in pain produced by adenosine results in a decrease in motor unit recruitment in skeletal muscle leading to a decrease in power output (Davis & Green, 2009). Caffeine blocks the release of adenosine, essentially decreasing the perception of pain which leads to increased motor unit firing to ultimately increase force production. Del Coso et al. (2016) found that distance covered during high intensity running significantly increased with caffeine compared to a placebo. Pereira et al. (2010) found significant differences in power or fatigue index during Wingate test for anaerobic power. Jordan, Farley, and Caputo (2012) found that caffeine improved best sprint performance time and increased rating of perceived exertion (RPE) compared to a placebo. Even though caffeine improved performance, RPE stayed the same or increased compared to the placebo trial. Caffeine
produced a larger power output, possibly leading to a higher RPE because more work was done during the exercise. More research needs to be done on caffeine’s effect on fatigue and pain perception during exercise.

Researchers believe that caffeine can enhance anaerobic performance through the Na⁺/K⁺ ATPase activity (Chen et al., 2015). Enhancing the Na⁺/K⁺ ATPase activity could lead to increased excitation-contraction coupling which leads to an increase in power production (Davis & Green, 2009). Contractions produced by increased exercise lead to depolarization in the skeletal muscle, which releases K⁺ into extracellular fluid (Davis & Green, 2009). Caffeine inhibits the release of K⁺ into the extracellular fluid stabilizing the Na⁺ and K⁺ gradient, improving the Na⁺/K⁺ ATPase activity (Davis & Green, 2009). Improving the Na⁺/K⁺ ATPase activity results in an improved environment for excitation-contraction leading to a decreased perception of fatigue (Davis & Green, 2009). Crowe et al., (2006) found no significant differences in peak power, work output, RPE, and peak heart rate between caffeine and placebo groups during two 60 second cycling bouts. While Rouhola et al. (2010) found that caffeine significantly increased average power, minimum power and fatigue index compared to placebo during a running based anaerobic sprint test (RAST) test. Researchers are still unclear if caffeine does in fact enhance anaerobic performance. More research needs to be done on this subject.

**Anaerobic Performance with Low Doses of Caffeine**

Caffeine is one of the most widely used drugs in the world today. People consume caffeine daily through coffee, tea, soda, and energy drinks. Caffeine can be used as an ergogenic aid to enhance athletic performance. The International Society of Sports Nutrition believes that a caffeine dose of 3-6 mg/kg of body weight will produce
Ergogenic effects (Campbell et al., 2016). However, the sides effects of caffeine such as disturbed sleep, nervousness, nausea and confusion are more present in higher doses of caffeine compared to lower doses (Spriet, 2014). A low dose of caffeine is less than 3mg/kg of body mass, and can produce an ergogenic effect with little to no side effects (Spriet, 2014). Using low doses of caffeine can provide an increase in performance without exceeding the limits set by the National Collegiate Athletic Association (NCAA) or World Anti-Doping Agency (WADA).

Athletes should however, monitor their consumption of caffeine. Even though caffeine was removed from the WADA banned substance list, caffeine is still monitored regularly (McCormack & Hoffman, 2012). The NCAA does not ban the use of caffeine, but a urine sample containing more than 12µg/ml of caffeine will result in a failed drug test (Spriet, 2014). This is equivalent 13mg of caffeine per kg of body mass, or to 8-10 cups of coffee (Woolf et al., 2008). Ingesting such a high amount of caffeine can produce negative side effects such as anxiety, restlessness, headaches and shakiness (Astorino & Roberson, 2009). Individuals can notice these side effects with moderate doses as well. Low doses of caffeine (≈ 200mg) are well under the illegal dose, so athletes can receive the ergogenic effect of caffeine well under the dose restricted by the NCAA.

Research studies on the effects of caffeine on performance have typically used caffeine doses within the suggested range on 3-6mg/kg of body weight (Woolf et al., 2008; Turley, R. et al., 2012; Lee et al., 2012; Pettersen, Krstrup, & Bendiksen, 2014). Unlike moderate to high doses of caffeine, doses less than 3mg/kg of body provide enhanced performance without changing exercise heart rate, lactate, or glycerol (Spriet, 2014). Beck et al. (2006) reported a significant increase in one-repetition maximum
bench press in a caffeine group compared to a placebo group after ingesting only 201mg of caffeine. Kruk, Pekkarinen, and Hanninen (1999) found that a 200mg dose of caffeine compared to a placebo significantly increased average power output in a 60 second jumping test. Mean power also increased in the caffeine group but the results were not significant. Finally Bellar et al. (2012) found that only 100mg of caffeine significantly increased the first throw of five attempts in a shot put. The distances of throws two and three increased with caffeine, but the differences were not significant. These three studies are examples of how low doses of caffeine can be beneficial to anaerobic performance.

**Caffeine and Fatigue**

Fatigue can be described as a sense of tiredness or exhaustion. Fatigue can occur after a hard workout or an intense sports competition. Fatigue can reduce performance rate, causing athletes to perform below average. There are multiple ways individuals can become fatigued in sport. Some argue that fatigue can occur due to impaired neurotransmitters such as noradrenaline and dopamine (Connell, Thompson, Kuhn, & Gant, 2016). Caffeine supplementation may help fatigued athletes because caffeine enhances neuromuscular transmission and increases concentration of dopamine, serotonin, and GABA to increase alertness and decrease fatigue (Pereira et al., 2010). Connell et al., (2016) found that caffeine decreased reaction time and perceived exertion in cyclists riding over 180 minutes. Caffeine inhibits the effects of exercise fatigue and may help athletes to work at a higher rate for longer periods of time.

Another way fatigue can occur is through muscle glycogen depletion. Glycogen is stored in the liver and skeletal muscle. When this glycogen within the muscle runs out, it can cause the athlete to feel fatigued. Caffeine can be useful in this situation, because
caffeine can delay the muscle glycogen depletion, causing a delay in fatigue (Pettersen, Krustrup, & Bendiksen, 2014). By delaying fatigue, athletes are able to work hard for a longer period of time. Petersen et al., (2014) found that caffeine did not produce an ergogenic effect for young football players. But Rouhola et al. (2010) found that caffeine did improve average and maximum power and decreased the fatigue index during the running based anaerobic sprinting test (RAST) (Rouhola et al., 2010). The subjects that ran the RAST test felt less fatigued and produced more power during the test with caffeine.

All of these studies examined rate of perceived exertion (RPE) to determine perceived fatigue. RPE is a scale that is used to determine the intensity of physical activity. What RPE determines is how hard a person feels like they are working as opposed to how fatigued a individual feels after a workout. A recent study developed a rating of fatigue scale to determine perceived fatigue (Micklewright et al., 2017). In this study, there were four different experiments. The first experiment provided the basis to construct the rating of fatigue scale (ROF). The second experiment tested the face validity of the ROF, and the third experiment tested the ROF scale during a cycling to exhaustion, and 30-minute recovery trial. Finally the last experiment tested the convergent validity of the ROF with physical activity (Micklewright et al., 2017). The results indicated that there was a high level of face validity got the ROF (Micklewright et al., 2017). In experiment 3, ROF and RPE had a high correlation but not during recovery. This means fatigue was reported rather than exertion (Micklewright et al., 2017). This study showed that the ROF has a high face validity and can be used to measure fatigue. This scale could be applied to determine perceived fatigue during anaerobic exercise.
Finally, the last way caffeine can benefit fatigued athletes is through central mechanisms. Caffeine affects the basal ganglia, which is located in the thalamus within the temporal lobes of the brain. The absorption of caffeine causes a chemical reaction which causes an increase in motivation, memory, reaction time, and decrease in perception of fatigue (Bottoms, Greenhalgh, & Gregory, 2013). Caffeine is one of the most commonly used drugs in today’s society and caffeine can do more than increase alertness and keep individuals awake. Many studies have shown that caffeine decreases perceived fatigue (Bottoms et al., 2013; Connell et al., 2016; Duncan, Taylor, & Lyons, 2012; Rouhola et al., 2010). Caffeine may be beneficial to athletes midway through a competition as opposed to the beginning of competition due to reduced effects of perceived exertion. By reducing these effect athletes may be able to push themselves harder than they normally would when fatigued.

**Ways to Ingest Caffeine**

Caffeine can be consumed in many different forms. Caffeinated beverages seem to be a popular beverage among the population with energy drinks, soda, and coffee. In the reviewed research studies, the three most popular ways to ingest caffeine are through beverages (energy drink or coffee), pills, or gum. Some studies did not reveal how caffeine was ingested; the only information provided was how much caffeine was administered to each participant. Taking caffeine orally can lead to more side effects such as stomach distress and nausea (Dragoo, Silvers, Johnson, & Gonzalez, 2011). By taking caffeine orally the stomach and small intestine absorb caffeine within 45 minutes of ingestion (Astorino & Roberson, 2009). The majority of the studies in this review
involved waits of approximately 60 minutes after ingestion of caffeine to start exercise testing.

Caffeinated pills and caffeinated drinks are the most common way to administer caffeine during research. Caffeine pills are an effective way to administer more caffeine without much fluid leading to a decrease stomach distress. The caffeine is then absorbed in the stomach and small intestines and is fully absorbed by the body within 45 minutes (Antonio, Victor, & Oliveira, 2014). Caffeine has a half life of 4-6 hours and then is broken down by the P450 system in the liver (Jordan, Farley, & Caputo, 2012). Beck et al. (2006) and Andre et al. (2015) found that caffeine pills increased upper body strength and power. While Gonçalves et al. (2010) found that caffeine increased anaerobic work capacity of males in their mid twenties. Caffeinated pills seem to be a way to store caffeine for athletes. Caffeinated pills are easily accessible to the public and can potentially help to enhance athletic performance.

Using energy drinks as a source of caffeine can make a participant or athlete feel more full and create discomfort in the stomach during exercise due the amount of fluid that was ingested. Furthermore, caffeine is not the only ingredient in energy drinks. A popular ingredient in energy drinks is taurine. Taurine is an amino acid found in muscle and may enhance muscle contractile function to produce a more forceful contraction (Gwacham & Wagner, 2012). Taurine may improve the release of calcium in the sarcolemma which can enhance power production (Gwacham & Wagner, 2012). Energy drinks also contain a lot of sugar, which can lead to more distress in the stomach if too much is consumed. Many studies used energy drinks as a source of caffeine (Campbell et al., 2016; Gwacham & Wagner, 2012; Forbes et al., 2007; Woolf et al., 2008). Forbes et
al., (2007) found a significant increase in total bench press repetitions over three sets. Woolf et al., (2008) found that a caffeine shake improved total weight lifted during chest press and increased peak power during a Wingate test. Although there are ways to make drinks that contain only caffeine, most beverages available have additional ingredients. If researchers want to study the effects of caffeine alone, energy drinks may not be the best choice.

Oral ingestion of caffeine through products such as pills, tablets or drinks are absorbed through the stomach and gastrointestinal track which may take may take up to an hour before the subject feels any affects. Caffeinated gum is a substance improves the absorption rate of caffeine in the body. Unlike like caffeine pills and energy drinks, caffeinated gum is absorbed into the body through buccal mucosa. Substances that are absorbed by the buccal mucosa skip over the intestinal and hepatic and go right into metabolism (Kamimori et al., 2002). The interlining of the cheeks have an abundant amount of vesicles, which aid in the speedy absorption of caffeine (Kamimori et al., 2002). Kamimori et al., (2002) found that caffeine was absorbed into the body significantly faster by gum than pills. One study saw an increase in distance with shot put after chewing caffeinated gum for five minutes (Bellar et al., 2012). Another study saw an increase in time trials for cyclists lasting more than 50 minutes after chewing the caffeinated gum 10 minutes prior to the start of testing (Lane et al., 2014). Using caffeinated gum can decrease the absorption time of caffeine, which will decrease the wait time before testing.

Caffeinated drinks and caffeine pills are absorbed through the stomach and gastrointestinal track. Both products take around 60 minutes to fully absorb before testing.
can occur. Caffeinated pills only contain caffeine, where energy drinks include other ingredients that aid in athletic performance. Some of those ingredients may be banned from NCAA and could lead to a positive test. If researchers want to examine only the effects of caffeine, then caffeinated pills or caffeinated gum are a better options than energy drinks. The caffeine in caffeinated gum can be absorbed by the body faster than the caffeine in caffeine pills. Use of caffeinated gum can speed up the time it takes to achieve the ergogenic effects of caffeine. More research needs to be conducted to find the best way for caffeine to be absorbed into the body.

**Habitual Caffeine Users versus Non-habitual Caffeine Users**

Caffeine is one of the most popular drugs in the world and is present in foods, drinks, and some medications. Caffeine has minimal health risks, but with too much consumption one can experience stomach discomfort, anxiety, restlessness, headaches and shakiness (Astorino & Roberson, 2009). Some people are more sensitive to caffeine than others, while others can build up a caffeine tolerance with habitual use of caffeine (Jordan, Farley, & Caputo, 2012). Some researchers believe that habitual caffeine use can lead to decreased effects or inability to receive the effects of caffeine during exercise.

Caffeine is a central nervous system stimulant that affects the release of adenosine. Caffeine blocks the adenosine receptors throughout the CNS and brain which leads to increased alertness, decreased fatigue, and increased motor unit recruitment in the skeletal muscle (Pereira et al., 2010). With long term, habitual consumption of caffeine, one can increase the number of adenosine receptors in the body (Jordan et al., 2012). This could lead to a different number of receptors between habitual and non-
habitual caffeine drinkers. So non-habitual caffeine drinkers could potentially receive an ergogenic effect at a lower dose than habitual drinkers.

Jordan et al. (2012) tested habitual and non-habitual caffeine users to see if caffeine ingestion produced a difference in exercise performances compared to a placebo. The subjects completed 12 x 30m sprint test. Caffeine ingestion significantly increased sprint time compared to placebo in both habitual and non-habitual groups. But there was no difference between the habitual and non-habitual caffeine group, which means non-habitual users, did not perform better than the habitual group. Both groups improved the same amount with the same dose of caffeine (Jordan et al., 2012). Bell and Mclellan, (2002) did however find that non-habitual caffeine users received the effects of caffeine longer than habitual users. Subjects completed six exercise rides to exhaustion on an ergometer at 80 percent of the subjects’ VO$_2$ max. The non-habitual caffeine users increased their exercise time one, three and six hours after the consumption of caffeine. While habitual caffeine users increased their exercise time one and three hours after the consumption of caffeine (Bell & Mclellan, 2002). So caffeine improved the time to exhaustion in both groups, but the effect of caffeine was longer in duration in the non-habitual group.

The effects of caffeine on performance in habitual and non-habitual caffeine drinkers are still unclear. Jordan et al. (2012) found increases in sprint performance with caffeine, but there were no significant differences between habitual and non-habitual drinkers. Bell and Mclellan (2002) found that caffeine improves performance in both habitual and non-habitual groups, but the effects of caffeine last longer in non-habitual users compared to habitual users. But some studies show no performance improvement in
non-habitual caffeine drinkers (Woolf, Bidwell, & Carlson, 2009). More research need to be done on this topic to figure out if caffeine enhances performance in non-habitual users or if caffeine affects both groups equality.

**Conclusion**

There is much uncertainty about caffeine’s effect on anaerobic performance. Research has not produced consistent results and it is unclear whether caffeine affects habitual and non-habitual caffeine drinkers differently. In a meta-analysis of research regarding the effect of caffeine, out of 414 subjects, only ten percent of the subjects were women (Doherty & Smith, 2004). More tests need to be completed on effects of caffeine on women. To our knowledge, no studies have examined the effects of caffeine on softball bat swing performance. A softball bat swing is an anaerobic action, which requires motor unit recruitment of type IIa muscles (Ebben, 2006). As mentioned previously caffeine can release more calcium in the sarcoplasmic reticulum which will increase excitation-contraction coupling and improve power production (Hoffman et al., 2007). This could be beneficial to a softball player during competition. More research needs to be conducted to determine if caffeine is beneficial to anaerobic performance.
CHAPTER 3

METHODS

The purpose of this study was to determine if chewing caffeinated gum for 10 minutes produced an ergogenic effect in female athletes during a softball swing. There was uncertainty about the effects caffeine ingestion had on anaerobic performance in sport. If caffeine ingestion produces an ergogenic effect during a softball swing, this could lead to an increase in bat velocity, which would produce an increase in power. An increase in power could lead to an increase in the softball’s exit velocity, thus increasing the total distance the ball travels.

Experimental Approach to the Problem

This study used a randomized, single-blind counterbalanced design. There were two independent variables: supplementation (caffeinated gum or placebo gum) and fatigue condition (fatigued or non-fatigued). There were four dependent variables: time to contact, hand velocity, bat velocity, and power. Participants completed the hitting test during both the fatigued and non-fatigued conditions. The participants came to the test facility on four separate occasions. The non-fatigued (NF) condition was completed during the first and second test sessions, and the fatigued (F) condition was completed during the third and fourth test sessions. On the first visit to the test facility, the researcher recorded the height and weight of each participant. Participants then completed a ten-minute whole body warm-up. Next, the participants received either two pieces of caffeinated gum containing 100mg of caffeine per piece (Military Energy Gum) or two pieces of non-caffeinated gum (placebo) that was identical to the caffeinated gum in color, size and taste. The gum pieces were given to the each participant in a paper cup.
Participants were then instructed to put the pieces of gum into their mouth and chew the gum for 10 minutes before discarding the gum into the trash. While the participants were chewing the gum, each participant filled out a pre-hitting test questionnaire (appendix E). The questionnaire asked if the participants ingested any alcohol or caffeine before testing and also asked the participants to indicate their current fatigue level by circling a number on a fatigue scale that rated fatigue from 0-10. Next, participants completed a hitting test, which required all participants to hit ten softballs off of a softball tee. The softball swing counted if the participant hit the ball into fair territory and both feet stayed inside the batter’s box throughout the course of the swing. Once the participants completed ten hits each, they filled out a post-hitting test questionnaire (appendix F) and were then asked to indicate their current fatigue level, using a fatigue scale located on the back of the questionnaires. On the second visit to the test facility, participants repeated the same protocol except the participants received the opposite supplementation.

On the third visit to the test facility, participants completed the same ten-minute warm-up that was used for the first two test days of testing. Once the warm-up was completed, participants completed a 20 minute high-intensity exercise circuit (appendix F). At the end of the circuit, participants followed the same protocol as the non-fatigued tests for the supplementation, pre-hitting test questionnaire, hitting test, and post-hitting test questionnaire. Finally during the fourth and final visit the participants repeated the same protocol as described above except the supplementation was switched. Participants were instructed to avoid the consumption of caffeine 48 hours before testing as well as the consumption of alcohol and participation in any vigorous exercise 24 hours before the testing session. If a participant did not follow these guidelines or could not make a test
day the participant’s test day was rescheduled or the participant was withdrawn from the study.

Any rescheduled test days were completed within one week of the original test day. The tests were administered during the same time of the day during all four visits. Participants completed the same pre-hitting test and post-hitting test questionnaires at each test session and were unaware of the supplementation they received. Only the researcher knew which participants were associated with swing data, height and weight measurements, and fatigue status from the questionnaires. Following each test session the researcher returned to her office, and all questionnaires were placed inside of a folder located inside a locked desk in the researcher’s office. All electronic data was kept in a password protected flash drive that was locked inside of the researcher’s desk when testing was not in session.

Participants

The researcher met with the varsity softball team at the beginning of the spring semester. During the meeting the researcher explained the study to the team and went over experimental design, inclusion criteria, testing protocol, supplementation, and possible side effects of the supplement. Any player who was interested was asked to fill out a participation questionnaire (Appendix C), PAR-Q (Appendix D), and informed consent (Appendix B) to participate in the study. The participation survey asked participants questions to see if they qualified to be in the study, while the PAR-Q screened for any physical activity health risks.

Ten healthy, physically active female softball players volunteered. The participants were $19.4 \pm 0.7$ years old, were $168.6 \pm 6.1$ cm tall, and weighed $76.9 \pm 10.8$
kg. All participants filled out a participation questionnaire and a physical activity readiness questionnaire (PAR-Q). Of the ten women who filled out the questionnaire, nine were able to complete the study. Volunteers were eligible to participate in the study if they were an undergraduate student age 18 or older, attended SUNY Cortland, played on the varsity softball team at SUNY Cortland, had NCAA eligibility, had a minimum of four years of fastpitch softball experience, and passed the PAR-Q questionnaire. Participants were excluded from the study if they presented any health issues identified by the PAR-Q or if they were taking prescription medication for ADD/AHD, hypertension, anxiety, depression or seizures. Once selected, the participants completed the testing during two separate conditions, F and NF. Baseline characteristics of the participants are described in Table 2 on page 41. The SUNY Cortland Institutional Review Board approved this study (Appendix A), and all participants in the study signed an informed consent before the start of testing. Finally, participants were briefed on risks involved in the participation of the study and possible side effects that could occur due to the ingestion of caffeine.

Protocols

**Anthropometric measures.** Height and weight of the participants were measured and recorded while the participants wore shorts, t-shirt, and socks, but no shoes. Height was measured with a tape measure. The tape measure was attached to the wall and participants had the back of their head, back and heels against the wall. Height was recorded to the nearest millimeter. Weight was measured with a portable digital scale (Health o meter model HDR743DQ3-41, Boca Raton, FL). Weight was recorded to the nearest hundredth of a pound and then converted to kilograms by dividing the weight in
pounds by 2.2 lb/kg. The anthropometric measures of each participant are shown in Table 2, page 41.

**Warm-up.** Before the start of the hitting test, participants ran through a condensed warm-up that would typically be performed by a softball team prior to practice. The warm-up was split up into two, 5-minute sections. The first section consisted of a dynamic warm-up while the second half was a hitting warm-up. During the dynamic warm up, participants performed a series of exercises while moving towards to a designated cone located 9-meters from the start. Participants were instructed to perform a different exercise on the way back to the starting line. Exercises in the dynamic warm-up were: jog down and back, jog while crossing their arms across their body and back, high knees/quadriceps stretch, toe kicks/figure 4 stretch, lunge down/Frankenstein’s back, karaoke down and back, 50% sprint and jog back, 75% sprint and jog back, and 100% sprint and jog back.

Once the dynamic warm-up was completed all participants within the group began the hitting warm-up that was led by the researcher. The purpose of the hitting warm-up was to warm up and stretch the upper body before hitting to prevent injuries. The hitting warm-up included six different exercises, and each exercise was performed for 1 set of 10 repetitions. The warm-up exercises were performed in the following order with a bat: skull crushers, windshield wipers, figure 8’s, trunk twists and dry swings. When the warm-up was completed during the non-fatigued condition, participants were given two pieces of caffeine (CAF) or placebo (PL) gum. During the fatigued condition participants immediately began their 20-minute high intensity exercise circuit. Once the exercise circuit was completed, participants then received their supplementation. While
the participants chewed their gum for 10 minutes they filled out a pre-hitting test questionnaire. Once the questionnaire was completed participants were allowed to free stretch until the 10 minutes were up.

**Fatigued protocol.** During the fatigued condition, once the warm-up was finished, participants then completed a 20-minute high intensity exercise circuit prior to the start of the hitting test. The circuit consisted of three sets of eight exercises, and each exercise lasted thirty seconds with no rest in between each exercise. The participants did have two minutes to rest in between each set. The first set was a circuit of all eight exercises. During the second and third sets, participants were asked to sprint 5 meters, 10 meters, or 15 meters after each exercise. Participants sprinted to the designated cone and then jogged to the starting line and began the next exercise. The exercises within the circuit were high knees, jumping jacks, burpees, body weight squats, pushups, planks, mountain climbers and flutter kicks. The participants were asked to perform as many repetitions as possible within 30 seconds and were asked to put forth their maximal effort. During the two minutes rest in between sets, participants were allowed to consume water as needed.

The purpose of this exercise circuit was to produce a level of fatigue in the participants that was similar to the level of fatigue a softball athlete may experience at the end of a competition. When this exercise circuit was completed participants were given caffeine or placebo gum at random to chew for 10 minutes, and the pre-hitting test questionnaires were filled out while the gum was being chewed before the start of the hitting test. Participants also rated their fatigue level before and after the hitting protocol
using an 11-point fatigue scale located on the backside of the pre- and post-hitting test questionnaire.

**Hitting test.** The procedure to find hand speed (HS), bat speed (BS), time to contact (TTC) and power (P) follows. The Blast Motion bat sensor was attached to the knob of the bat that was selected by the researcher. The bat being used during this study was a Louisville Sluggler Xeno-plus with the serial number WTFPXN170. The Louisville Sluggler Xeno-plus was 33 inches long, weighed 23 ounces and had a barrel diameter of 2 ¼ inches. The Xeno-plus was ASA certified and was on the NCAA approved bat list on the date of testing. The bat information was entered into the Blast Motion app. To track swings for each participant, the researcher created a new batting session in the app for each participant.

The hitting test was performed in the Lusk Field House on SUNY Cortland’s campus using a bownet. In front of the bownet were a left and right batter’s boxes and foul lines that extended to the outer edges of the bownet that met the NCAA guidelines. Home plate was a five-sided plate whose dimensions matched those specified in the NCAA rules. The batter’s box also conformed to the NCAA rules. It was 7 feet in length, 3 feet in width including the lines, and 6 inches from home plate. The tee used was a portable versatile tee (PV-tee), (ProMounds Inc., Brockton, MA). The tee was placed in the center of home plate and set at a height of 78 centimeters.

Participants were instructed to hit ten, twelve-inch softballs off of the tee into fair territory. A softball bat swing was considered successful and its swing metrics data were recorded if the batter’s feet stayed inside the batter’s box during contact and if the ball was hit into fair territory. These conditions are identical to the NCAA rules regarding
batting. During an NCAA softball game, if a player makes contact with the ball while any part of her foot is outside of the batter’s box, the ball will be declared dead and the batter will be called out whether the ball was fair or foul (Van Kleeck, 2017, pg. 90). Once 10 successful hits were made by each participant, the HS, BS, TTC, and P data were transferred from the app to an electronic spreadsheet. The same procedure was repeated during the second test day for all test conditions. All data were stored on a password protected flash drive, and the flash drive was locked inside of the researcher’s office between testing sessions to insure privacy of the participants’ data.

**Swing Tracker Validity**

To determine which sensor was more accurate, a separate test was completed. Bat swing data from two popular sensors on the market, Diamond Kinetics (DK) and Blast Motion (BM) were compared to data derived from high-speed video recordings of the swings to determine which sensor was more accurate. A Sony DSC-RX100M5 digital camera operated in high frame rate video mode at 480 frames per second was mounted 3.5 m above the floor so that the optical axis of its lens was aligned vertically directly over a batting tee (PV-tee, ProMounds, Inc., Brockton, MA). One researcher stood on a ladder recording trials with the camera while the other researcher hit lite-flight softballs off of the tee. The PV-tee height was adjusted to place the center of the lite-flight ball 78.6 cm high. A 2.436 m long reference length was held horizontally in the video field of view at the height of the tee and recorded by the video camera. The researcher then took 30 softball bat swings, 15 with each sensor, and the data collected from each sensor was compared to the data derived from the high-speed videos. The bat used for this
The experiment was a Louisville Sluggler Xeno-plus. The bat was 33 inches long, weighed 23 ounces, and had a barrel diameter of 2 ¼ inches.

The videos were uploaded to Tracker Video Analysis and Modeling Tool (version 4.95). The ends of a 2.436 m reference length were digitized to establish the calibration length for a 2-dimensional analysis. In each video, the MP joint of the second finger of the left hand (corresponding to a point 6 inches from the bat knob) and a point on the bat barrel, 6 inches from the bat end, were digitized in each video frame from 20 frames before ball contact to 20 frames after ball contact. These two digitized points corresponded to the locations which the Blast Motion sensor used to compute HS and BS. HS, BS, TTC, and P were then computed from the frame times and coordinates of the two digitized points. Once all trials for both sensors were digitized, those data were entered into a spreadsheet. A Pearson’s correlation was used to compare the sensor data to the video data using SPSS version 24. After computing the correlation matrix, a linear regression was used to see how well the sensor data predicted the video data. The results showed that there was a strong relationship between video HS and BM HS, video BS and BM BS, video TTC and BM TTC, video HS and DK HS, video BS and DK BS, video TTC and finally DK TTC. All of these correlations were high with p < 0.01. The regression equations which used the Blast Motion HS, BS, TTC, and P to predict the same variables computed from the Tracker data were all statistically significant (p < 0.01), and indicated that the Blast Motion sensor could be used to determine swing performance metrics. The bat swing metrics from the Blast Motion sensor accounted for 92.8%, 95.7%, 93.0%, and 85.8% of the variability in HS, BS, TTC, and P respectively as measured by the video analysis. While the bat swing metrics from the Diamond
Kinetics sensor accounted for 85.3%, 90.3%, 66.0%, and 64.9% of the variability in HS, BS, TTC, and P respectively as measured by the video analysis. The bat swing metrics from both sensors were highly correlated to the bat swing metrics derived from video analysis, but the Blast Motion sensor metrics were more strongly correlated across all four bat swing metrics. The Blast Motion sensor was determined to be the more accurate sensor was used during testing.

**Questionnaires**

Before participants were able to participate in this study, they were required to fill out the participation questionnaire. This questionnaire asked participants about their current school status, age, caffeine intake, exercise frequency, softball experience and medications. Participants also filled out a PAR-Q to see if they were able to participate in physical activity. The PAR-Q was used in multiple studies to make sure participants did not present any health problems that could occur with physical activity (Forbes et al., 2007; Jordan et al., 2012). People diagnosed with ADD/AHD, hypertension, anxiety, depression or seizure disorders were excluded from the study because caffeine may lead to unwanted side effects in these individuals.

Participants that met the requirements of the study filled out a written consent form during the interest meeting with the researcher. During the four test days participants came in and filled out a pre-hitting test questionnaire after the completion of the warm-up. This questionnaire asked participants if they consumed any alcohol, caffeine or participated in vigorous exercise before testing. This questionnaire also asked participants to rate their fatigue before the start of the hitting test using an 11-point scale. The post-test questionnaire asked participants if they were experiencing any side effects
of the supplementation they had before the start of testing. The post-test questionnaire also asked participants to rate their fatigue after the hitting test. The pre-hitting test and post-hitting test questionnaires were filled out during all test sessions because participants were unaware of which form of supplementation they were receiving throughout course of the study.

**Supplementation**

Military Energy Gum, also known as Stay Alert Gum (MarketRight, Inc., Chicago, IL), was used as the source of caffeine in this study. Military Energy Gum has been used in multiple studies to test the effects of caffeine on fatigue and sports performance (Bellar et al., 2012; Chiu & Salem, 2006; Kamimori et al., 2015; Newman, Kamimori, Wesensten, Picchioni, & Balkin, Thomas, 2013; Paton, Costa, & Guglielmo, 2015; Kamimori et al., 2002). When chewing caffeinated gum, the caffeine is absorbed through the interlining of the cheeks which contains a rich source vesicles, which leads to the increased absorption rate (Kamimori et al., 2002). Using this method, the time it takes for caffeine to be absorbed can be as fast as ten minutes.

During the testing days, participants were given two pieces of caffeinated gum or placebos that were made and sold by the same company that produces the caffeinated Military Energy Gum (MarketRight, Inc., Chicago, IL). The placebo was also called Military Energy Gum, and was designed to look and taste like the caffeinated Military Energy Gum except it did not contain caffeine. The packaging was identical to the caffeinated Military Energy Gum as well. Nutrition facts for both placebo and caffeinated gum are shown in table 1. To insure that the participants were unaware of which form of supplementation they were receiving, participants received the gum in a plastic cup and
the gum was the same color, shape and taste. The gum was chewed for 10 minutes and then discarded. According Kamimori et al., (2002), 85% of the caffeine inside the Military Energy Gum was absorbed within 5 minutes of chewing and 99% of the caffeine was absorbed after 10 minutes of chewing. On the last testing session participants repeated the same protocol with the opposite supplementation.

Table 1

<table>
<thead>
<tr>
<th>Gum type</th>
<th>Serving size</th>
<th>Calories</th>
<th>Total carbs (g)</th>
<th>Sugars (g)</th>
<th>Sugar Alcohol (g)</th>
<th>Caffeine (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Military Energy Gum (CAF)</td>
<td>1 piece</td>
<td>10</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Military Energy Gum (PL)</td>
<td>1 piece</td>
<td>10</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Notes: CAF = caffeine, PL = placebo, g = grams, mg = milligrams. Percent daily values for both types of gum are based on a 2000-calorie diet.

Statistical Analysis

A two-way repeated measures analysis of variance (ANOVA) was used to test the differences in BS, HS, TTC, and P between the caffeine and placebo trials within the F and NF conditions. A paired samples t-test was used to determine the change in perceived fatigue within the NF and F conditions. The Statistical Package of Social Sciences (SPSS) for Macintosh (SPSS inc., Chicago, IL, Version 24.0) was used to run statistical analyses for this study. Averages of each variable under placebo and caffeine supplementation were used and compared between and within both the F and NF
conditions. Statistical significance for this study was set at an alpha level of 0.05 for all analyses.
CHAPTER 4

RESULTS

Of the original ten participants who volunteered and provided consent to participate, nine completed the study. One participant withdrew from the study because of an injury. Before the start of testing, three participants never drank caffeine, two participants drank caffeine once a week, and four participants drank caffeine one to two times a day. Age, height, and weight for all participants are presented in Table 2 below.

Side effects were recorded for both the placebo and caffeinated gum throughout the course of the testing. During the non-fatigued trials, there were three participants who did not feel any effects while using caffeine. The remaining participants recorded stomach discomfort, increased heart rate, restlessness, shakiness, and increased urinary output. Four participants reported not feeling any effects from the placebo, while the other participants recorded dizziness, shakiness, increased urinary output, headaches, increased heart rate and restlessness.

Table 2

<table>
<thead>
<tr>
<th>Variable</th>
<th>M</th>
<th>SE</th>
<th>SD</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>19.44</td>
<td>0.24</td>
<td>0.73</td>
<td>0.53</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>76.85</td>
<td>3.61</td>
<td>10.82</td>
<td>117.18</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>168.62</td>
<td>2.03</td>
<td>6.09</td>
<td>37.20</td>
</tr>
</tbody>
</table>

Note: M=mean. SE=mean standard error. SD=standard deviation. yr=years. kg=kilograms. cm=centimeters.

During the fatigued conditions, six people felt no effects from the caffeine. The remaining participants recorded stomach discomfort, nausea, increased heart rate,
anxiety, dizziness, and restlessness. Finally, during the fatigued placebo condition, six participants recorded no side effects from the placebo, while three participants recorded headaches, increased heart rate, and shakiness. A nocebo effect may be contributing to the amount of side effects sent during the placebo trials.

**Fatigue Status**

The paired samples t-test showed no statistically significant differences in pre-hitting test fatigue and post-hitting test fatigue during the non-fatigue placebo condition, \( t(8) = -0.707, p = .500 \) and non-fatigued caffeinated condition, \( t(8) = 1.155, p = .282 \). Even though there were no significant differences, mean pre-hitting test fatigue during the non-fatigue placebo condition (3.11) was lower than post-hitting test fatigue during the non-fatigue placebo condition (3.44). But the mean pre-hitting test fatigue during the non-fatigue caffeine condition (3.00) was higher than post-hitting test fatigue during the non-fatigue caffeine condition (2.33). Overall there were no statically significant differences when comparing the NF pre and post-trials during the caffeine and placebo trials. Results from the paired samples t-test are shown in table 3.
There were statistically significant differences in pre-hitting test fatigue and post-hitting test fatigue during the fatigued placebo condition, $t(8) = 5.000, p = .001$ and fatigued caffeinated condition, $t(8) = 4.603, p = .002$. The mean pre-hitting test fatigue for the fatigued placebo condition (6.55) and fatigued caffeinated condition (4.88) was significantly higher than the mean post-hitting test fatigue for the fatigued placebo condition (5.66) and fatigued caffeinated condition (4.11).

### Table 3

*Paired Samples T-Test for Fatigue*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SE</th>
<th>SD</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>NF-PL-F&lt;sub&gt;b&lt;/sub&gt;</td>
<td>3.11</td>
<td>0.789</td>
<td>2.37</td>
<td>0.500</td>
</tr>
<tr>
<td>NF-PL-F&lt;sub&gt;a&lt;/sub&gt;</td>
<td>3.44</td>
<td>0.728</td>
<td>2.18</td>
<td></td>
</tr>
<tr>
<td>NF-CAF-F&lt;sub&gt;b&lt;/sub&gt;</td>
<td>3.00</td>
<td>0.408</td>
<td>1.22</td>
<td>0.282</td>
</tr>
<tr>
<td>NF-CAF-F&lt;sub&gt;a&lt;/sub&gt;</td>
<td>2.33</td>
<td>0.373</td>
<td>1.12</td>
<td></td>
</tr>
<tr>
<td>F-PL-F&lt;sub&gt;b&lt;/sub&gt;</td>
<td>6.55</td>
<td>0.580</td>
<td>1.74</td>
<td>0.001*</td>
</tr>
<tr>
<td>F-PL-F&lt;sub&gt;a&lt;/sub&gt;</td>
<td>4.88</td>
<td>0.538</td>
<td>1.61</td>
<td></td>
</tr>
<tr>
<td>F-CAF-F&lt;sub&gt;b&lt;/sub&gt;</td>
<td>5.66</td>
<td>0.707</td>
<td>2.12</td>
<td>0.002*</td>
</tr>
<tr>
<td>F-CAF-F&lt;sub&gt;a&lt;/sub&gt;</td>
<td>4.11</td>
<td>0.564</td>
<td>1.69</td>
<td></td>
</tr>
</tbody>
</table>

Note. SE=mean standard error. SD=standard deviation. NF-PL-F<sub>b</sub>=fatigue status for non-fatigue, placebo conditions before testing. NF-PL-F<sub>a</sub>=fatigue status for non-fatigue, placebo conditions after testing. NF-CAF-F<sub>b</sub>=fatigue status for non-fatigue, caffeine conditions before testing. NF-CAF-F<sub>a</sub>=fatigue status for non-fatigue, caffeine conditions after testing. F-PL-F<sub>b</sub>=fatigue status for fatigued, placebo conditions before testing. F-PL-F<sub>a</sub>=fatigue status for fatigued, placebo conditions after testing. F-CAF-F<sub>b</sub>=fatigue status for fatigued, caffeine conditions before testing. F-CAF-F<sub>a</sub>=fatigue status for fatigued, caffeine conditions after testing.
Bat Speed (BS)

A series of two-way ANOVAs with repeated measures were run to determine the effect of fatigue status and supplementation on BS, HS, TTC, and P. Results of the two-way repeated measures ANOVA are presented in Table 4. There were no statistically significant interactions between fatigue status and supplementation on BS, $F(1,8) = .027$, $p = .873$, partial $\eta^2 = .003$. Therefore, main effects were analyzed. The main effects for fatigued conditions are presented in Table 5. The analyses indicated no statistically significant difference in mean bat speed within the fatigued conditions, $F(1,8) = 3.734$, $p = .089$. However, there was a statistically significant difference in mean bat speed between the placebo (53.928 mph) and caffeinated conditions (55.026 mph), $F(1,8) = 8.651$, $p = .019$. Pairwise comparisons for the significant main effect were reported with a 95% confidence interval.

Table 4

Two-Way Analysis of Variance of Fatigue Status and Supplementation

<table>
<thead>
<tr>
<th>Variable</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>$\eta^2$</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>BS (mph)</td>
<td>1,8</td>
<td>1</td>
<td>0.153</td>
<td>0.027</td>
<td>0.003</td>
<td>0.873</td>
</tr>
<tr>
<td>HS (mph)</td>
<td>1,8</td>
<td>1</td>
<td>0.027</td>
<td>0.074</td>
<td>0.009</td>
<td>0.792</td>
</tr>
<tr>
<td>TTC (s)</td>
<td>1,8</td>
<td>1</td>
<td>1.878E-5</td>
<td>2.052</td>
<td>0.204</td>
<td>0.190</td>
</tr>
<tr>
<td>P (kW)</td>
<td>1,8</td>
<td>1</td>
<td>0.001</td>
<td>0.020</td>
<td>0.002</td>
<td>0.891</td>
</tr>
</tbody>
</table>

Notes: df=degrees of freedom. SS=sum of squares. MS=mean square. F=total variance. $\eta^2$=partial eta. squared. Sig=significance. BS=bat speed. HS=hand speed. TTC=time to contact. P=power.
Table 5

**Main Effects: Supplementation**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>MD</th>
<th>SE</th>
<th>sig</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>BS-PL (mph)</td>
<td>53.93</td>
<td>-1.097*</td>
<td>3.73</td>
<td>0.019</td>
<td>[-1.957, -0.237]</td>
</tr>
<tr>
<td>BS-CAF (mph)</td>
<td>55.03</td>
<td>1.097*</td>
<td>3.73</td>
<td>0.019</td>
<td>[0.237, 1.957]</td>
</tr>
<tr>
<td>HS-PL (mph)</td>
<td>16.52</td>
<td>-0.411</td>
<td>0.193</td>
<td>0.066</td>
<td>[-0.856, 0.035]</td>
</tr>
<tr>
<td>HS-CAF (mph)</td>
<td>16.93</td>
<td>0.411</td>
<td>0.193</td>
<td>0.066</td>
<td>[-0.035, 0.856]</td>
</tr>
<tr>
<td>TTC-PL (s)</td>
<td>0.166</td>
<td>0.000</td>
<td>0.001</td>
<td>0.922</td>
<td>[-0.002, 0.003]</td>
</tr>
<tr>
<td>TTC-CAF (s)</td>
<td>0.166</td>
<td>0.000</td>
<td>0.001</td>
<td>0.922</td>
<td>[-0.003, 0.002]</td>
</tr>
<tr>
<td>P-PL (kW)</td>
<td>1.75</td>
<td>-0.079*</td>
<td>0.031</td>
<td>0.036</td>
<td>[-0.150, -0.007]</td>
</tr>
<tr>
<td>P-CAF (kW)</td>
<td>1.82</td>
<td>0.079*</td>
<td>0.031</td>
<td>0.036</td>
<td>[0.007, 0.150]</td>
</tr>
</tbody>
</table>

Note. n=number of participants. SE=mean standard error. CI=confidence interval. mph=miles per hour. s=seconds. kW=Kilowatts. BS-PL=bat speed, placebo. BS-CAF=bat speed, caffeine. HS-PL=hand speed, placebo. HS-CAF=hand speed, caffeine. TTC-PL=time to contact, placebo. TTC-CAF=time to contact, caffeine. P-PL=power, placebo. P-CAF=power, caffeine.

**Hand Speed (HS)**

There were no statistically significant interactions between the fatigue status and caffeine supplementation on HS, $F(1,8) = .074$, $p = .792$, partial $\eta^2 = .009$. Due to non-significant interactions main effects were analyzed. The main effects indicated no statistically significant difference in mean hand speed within the fatigued condition, $F(1,8) = 3.073$, $p = .118$, or supplementation conditions $F(1,8) = 4.509$, $p = .066$. As mentioned previously, there were no statistically significant differences in hand speed within the supplementation or fatigued conditions.
Time to Contact (TTC)

No statistically significant interactions were found between the fatigue status and caffeine supplementation on TTC, $F(1,8) = 2.052, p = .190$, partial $\eta^2 = .204$. Since no significant interactions were found between fatigue status and supplementation, main effects were analyzed. The main effects showed no statistically significant differences in mean time to contact within the fatigued conditions, $F(1,8) = .241, p = .637$. No statistically significant differences were found when comparing mean time to contact within the supplementation conditions $F(1,8) = .010, p = .922$. The findings showed that caffeine did not improve time to contact during fatigued and non-fatigued conditions.

Power (P)

A series of two-way ANOVAs reported no statistically significant interactions between fatigue status and supplementation on P, $F(1,8) = .020, p = .891$, partial $\eta^2 = .002$. Since no statistically significant interactions were found, so main effects were run. The main effects for fatigued conditions are presented first and the analyses indicated that there were no statistically significant difference in mean power within the fatigued conditions, $F(1,8) = 2.449, p = .156$. However, a statistically significant interaction was found when comparing the two forms of supplementation. The mean power for the placebo condition (1.746 kW) was significantly lower when compared to the caffeinated condition (1.825 kW), $F(1,8) = 6.375, p = .036$. Pairwise comparisons for the significant main effect were reported with a 95% confidence interval. The results showed that caffeine did increase power compared to the placebo trail.
CHAPTER 5
DISCUSSION

The results of this study showed that there were significant increases in BS and P when comparing supplementation in main effects. Bat power is defined by the amount of power that is applied to the bat by the hands and body during a softball swing. To find power you multiply the BS squared, by the mass of the bat and divide by TTC. Even though TTC did not change, the significant increase in BS caused a significant increase in P. The placebo trail had a mean BS of 53.93mph and a power of 1.746kW, while caffeine trail had a mean bat speed of 55.03mph and a power of 1.825kW. This study supports findings by (Lee, Cheng, Lin, & Huang, 2012; Woolf, Bidwell, & Carlson, 2008) that caffeine increases anaerobic power. During exercise, caffeine increases the release of calcium in the sarcoplasmic reticulum that causes a more forceful muscle contraction, leading to an increase in power (Beck et al., 2006). So caffeine has the potential to increase anaerobic power during a softball swing.

Hand speed and time to contact had no significant difference when compared to the supplementation or fatigued conditions. One of the reasons TTC and HS did not see significant increases might be due to the amount of caffeine that was given. The mean TTC stayed the same when compared to supplementation (0.166 sec) when main effects were run. But mean HS did see a very slight increase when comparing placebo (16.52mph) to caffeine (16.93mph) when main effects were run. But once again this slight increase was not significant. For this study, 200mg of caffeine was used, which amounted to an average dose of slightly less than 3mg/kg of body weight for the participants. This is the lowest amount that can be used and still have ergogenic effects.
The International Society of Sports Nutrition believes that 3-6mg/kg of body weight will produce ergogenic effects (Campbell, Richmond, & Dawes, 2016). Using a higher dose could potentially cause an ergogenic effect, but a higher dose produces more side effects.

When comparing the participants there were three participants who did not normally drink caffeinated beverages, two participants drank caffeinated beverages once a week, and the remaining four participants drank caffeinated beverages one to two times a day. So overall, five participants were non-habitual and four participants were habitual caffeine users. Since significant increases in BS and P were found, this study found similar results to Jordan Farley, and Caputo (2012). Jordan et al. (2012) found that both habitual and non-habitual caffeine users found significant increases in sprint performance when compared to a placebo. Participants saw increases in BS and P when supplementing with the same dose of caffeine, regardless of whether they were habitual or non-habitual users prior to the study.

When supplementing with caffeine there were some side effects that were noted during the trials on the post-hitting test survey. During the NF caffeine trial there were three participants who experienced no side effects, while six felt at least one side effect. Four participants felt no side effects during the NF placebo trial, but five felt at least one side effect. Six participants felt no side effects of the caffeine during the F caffeine and placebo trial, and three participants felt at least one side effect. The side effects that were noted included: dizziness, shakiness, increased urinary output, and headache, increased heart rate, restlessness, stomach discomfort, and nausea. Even though side effects were present, they were not unpleasant enough to cause any participant to withdraw from the study. It is interesting that the participants felt side effects during the placebo trial.
Instead of a placebo (positive) effect, the participants actually experienced a nocebo (negative) effect from the placebo trail. A nocebo effect is a psychosomatic effect to a treatment that causes negative health conditions (Klarić, Mandić, Lovrić, Ćorić, & Zovko, 2017). It is possible that the participants believed that they received the caffeinated gum and psychosomatically caused themselves to feel side effects of the caffeine.

The feeling of fatigue was compared pre- and post-hitting test using the pre- and post-hitting test questionnaires during each of the four testing trials. The results of the $t$-test showed that there were no significant differences when comparing pre- and post-scores during the non-fatigued group during both caffeine and placebo conditions. These findings were expected since the participants started the hitting test non-fatigued, their fatigue after hitting ten softballs shouldn’t have significantly changed.

When comparing perceived fatigue during the fatigue conditions there were significant differences in pre- and post-fatigue in both the placebo and caffeine conditions. The significant differences in fatigue during the caffeine conditions agrees with other research that caffeine can be used to decrease fatigue (Bottoms, Greenhalgh, & Gregory, 2013; Connell, Thompson, Kuhn, & Gant, 2016; Duncan, Taylor, & Lyons, 2012; Rouhola et al., 2010). Fatigue tends to occur after a hard workout or towards the end of a sporting event, and is caused by impaired neurotransmitters (Connell et al., 2016). Caffeine enhances neurotransmission that can help to decrease the feeling of fatigue. Caffeine also helps to increase the concentration of dopamine, serotonin and GABA (Pereira et al., 2010).
The significant differences during the pre- and post-fatigue in the non-fatigued, placebo conditions were unexpected. Typically when using a placebo the expectation is that there would be no change in fatigue because there was no ingredient within the placebo gum that should have caused a decrease in fatigue. A possible explanation for the significant decrease in fatigue could be a placebo effect. It was noted previously that the placebo gum caused a nocebo effect, so it could be possible that a placebo effect occurred during testing as well. If the participants thought they received the caffeinated gum this could have caused a psychosomatic nocebo response such as side effects as well as a placebo effect that decreased the feeling of fatigue.

Another possible explanation of what caused a decrease in fatigue pre- and post-testing could be the amount of time it took to chew the gum. After the exercise circuit, participants had to chew gum for ten minutes before they could start the hitting test. This time was to insure that the caffeine within the gum was absorbed. Kamimori et al., (2002) showed that 85% of the caffeine inside the Military Energy Gum was absorbed within five minutes of chewing and 99% of the caffeine was absorbed after ten minutes of chewing. The ten minute wait between the exercise circuits and hitting test was necessary to insure that the caffeine was properly absorbed into the system, but could have caused the participants to recover from the circuit and feel less fatigued during the placebo condition.

In fatigued and non-fatigued conditions it was observed that during the non-fatigue trials all the balls that were hit off of the tee were hard hit line drives into the bownet. When the participants hit during the fatigue condition, their hitting mechanics began to breakdown due to the fatigue. More pop ups and ground balls were hit during
the fatigued condition. The hit counted if the ball was hit off of the tee into fair territory, so the hits counted even though they were not well hit balls. When fatigue begins to set in, the batters begin to drop their hands while they swing the bat, which causes the hitter to hit the bottom of the ball, which results in a pop up. The batter could also chop the ball, which means they swing the bat at a downward angle causing the batter to hit the top of the ball, which results in a ground ball.

**Future research**

This is the first study to our knowledge that looked at the effects of caffeine on bat swing performance in softball players. Future research should study the effects of caffeine on both baseball and softball swings. Baseball and softball are similar, but the swing mechanics for baseball are slightly different from softball. So, research on baseball would be beneficial. As mentioned before, as fatigue began to set in during the fatigued condition, swing mechanics began to break down. Future research should change the methods to only count line drive as opposed to all types of hits into fair territory. This way the researcher is comparing all they same types of hit off of the bat.

It would be interesting to test different doses of caffeine as well. This study could be repeated with different doses within the range that produces ergogenic effects (3-6mg/kg of body weight) to see if a high dose would improve bat performance even more. Studies could also change the amount of time the gum is chewed to see if it affects fatigue status and bat performance as well. Finally future research could look into the effects caffeine has on habitual and non-habitual users. Future studies could see if the effects of caffeine last longer in non-habitual users compared to habitual users.
Conclusion

The ingestion of caffeine did significantly improve bat speed $F(1,8) = 8.651, p = .019$ and power $F(1,8) = 6.375, p = .036$ compared to the placebo regardless of the fatigued/non-fatigued condition. Ingesting caffeine while fatigued caused a significant decrease in perceived fatigue $t(8) = 4.603, p = .002$. There were however no significant differences in time to contact or power. The potential to improve the speed and power of a ballistic movement such as a softball swing is possible using a low dose of caffeine. More research needs to be done on this topic, and different doses should be used to see what dose is most beneficial to improve bat swing performance in softball athletes.

Practical Applications

Chewing caffeinated gum for ten minutes caused a significant increase in bat speed and power, as well as a decrease in fatigue during a hitting test in softball players. A low dose of caffeine (200mg) produced increased bat speed and power while hitting ten softballs off of a tee when compared to a placebo. Due to the significant results, it could be recommended to coaches, and trainers that softball players could benefit from a low dose of caffeine before the start of competition. The amount of caffeine used in this study is low enough to pass an NCAA drug test. Therefore, the amount of caffeine used in this study is a safe for college athletes to consume.
Bibliography


MEMORANDUM

To: Brianna Ferench
   Peter McGinnis

From: Thomas Frank, Reviewer on behalf of
       Institutional Review Board

Date: 12/29/2017

RE: Institutional Review Board Approval

In accordance with SUNY Cortland’s procedures for human research participant protections, the protocol referenced below has been approved for a period of one year:

Title of the study: The effects of a low dose of caffeine on bat swing performance in fatigued and non-fatigued female softball athletes

Level of review: Expedited
Protocol number: 171877
Project start date: Upon IRB approval
Approval expiration date*: 12/28/2018

*Note: Please include the protocol expiration date to the bottom of your consent form and recruitment materials.

For more information about continuation policies and procedures, visit
www.cortland.edu/irb/Applications/continuations.html

The federal Office for Research Protections (OHRP) emphasizes that investigators play a crucial role in protecting the rights and welfare of human subjects and are responsible for carrying out sound ethical research consistent with research plans approved by an IRB. Along with meeting the specific requirements of a particular research study, investigators are responsible for ongoing requirements in the conduct of approved research that include, in summary:

- obtaining and documenting informed consent from the participants and/or from a legally authorized representative prior to the individuals’ participation in the research, unless these requirements have been waived by the IRB;
- obtaining prior approval from the IRB for any modifications of (or additions to) the previously approved research; this includes modifications to advertisements and other recruitment materials, changes to the informed consent or child assent, the study design and procedures, addition of research staff or student assistants, etc. (except those alterations necessary to eliminate apparent immediate hazards to subjects, which are then to be reported by email to irb@cortland.edu within three days);
- providing to the IRB prompt reports of any unanticipated problems involving risks to subjects or others;
- notifying the IRB of continued research under the approved protocol to keep the records active; and,
- maintaining records as required by the HHS regulations and NYS State law, for at least three years after completion of the study.
In the event that questions or concerns arise about research at SUNY Cortland, please contact the IRB by email irb@cortland.edu or by telephone at (607) 753-2511. You may also contact a member of the IRB who possesses expertise in your discipline or methodology, visit http://www.cortland.edu/irb/members.html to obtain a current list of IRB members.

Sincerely,

[Signature]

Thomas Frank, Reviewer on behalf of
Institutional Review Board
SUNY Cortland
Appendix B Informed Consent

INFORMED CONSENT

You are invited to participate in a research project titled “The effects of a low dose of caffeine on bat swing performance in fatigued and non-fatigued female softball athletes.” SUNY Cortland graduate student, Brianna Ferchen, is conducting this research for her master’s thesis. Your informed consent is requested if you wish to participate as a subject in this research project. Before you consent to participate, please read the following regarding the details of the study so that you fully understand what your involvement, as a participant will be and what risks you may experience as a participant. If you have questions about anything related to the study or your involvement in the study, please ask.

Purpose and brief description of the study

The purpose of this study is to determine if caffeine ingestion can decrease (a) time to contact and increase (b) peak hand speed, (c) peak bat barrel speed, and (d) power during a softball swing by fatigued and non-fatigued female athletes from an NCAA Division III varsity or club softball team. Bat swing data will be collected from each subject for four conditions: non-fatigued with caffeine ingestion, non-fatigued without caffeine ingestion, fatigued with caffeine ingestion, and fatigued without caffeine ingestion. The swing data for the four conditions will be compared to determine if caffeine ingestion improves bat swing performance in both fatigued and non-fatigued conditions.

Your involvement as a participant

Should you choose to participate, you will be asked to complete a PAR-Q and another questionnaire to determine if you meet the criteria for the study. If you meet the criteria and still wish to participate, you will be asked to attend four (4) separate test sessions at the SUNY Cortland Lusk Fieldhouse from late January through early March.

During the day of the first test session, you will come to the fieldhouse and your height and weight will be measured. You will then complete a 10-minute warm up similar to what is typically performed by a softball team prior to practice. It includes a 5-minute dynamic warm up and a 5-minute hitting warm up. Following the warm up period, you will be asked to close your eyes and will be given a paper cup with two pieces of gum in it. The two pieces of gum are either caffeinated or non-caffeinated, but you will not know which you receive. You will be asked to put the pieces of gum in your mouth while still keeping your eyes closed. You can open your eyes once the gum is in your mouth. You will then chew the gum for 10 minutes before discarding the gum into the trash. While chewing the gum, you will indicate your fatigue level and complete a pre-test questionnaire. Once the questionnaire is completed you will be allowed to free stretch for the remaining time. Next, you will hit ten softballs off a softball tee. You will use a bat which has a swing sensor attached the knob of the bat. The swing sensor
measures your swing parameters. Your softball swing data will be recorded if you hit the ball into fair territory and both feet stay inside the batter’s box throughout the course of the swing. After you complete ten successful hits, you will be asked to fill out a post-hitting test questionnaire and you will rate your current fatigue, using the fatigue scale located on the backside of the post-hitting test questionnaire. On the second test session, you will repeat the same protocol except the caffeinated and non-caffeinated gum will be switched.

The third and fourth test session are identical to the first two test sessions except that the 10 minute warm up will be followed by a 20 minute high intensity exercise circuit. The circuit consists of three sets of eight exercises, with each exercise lasting thirty seconds with no rest in between each exercise. You will have two minutes to rest in between each set. The first set will be a circuit of all eight exercises. During the second and third set you will be asked to sprint after each exercise for 5-meters, 10-meters or 15-meters. You will run to a designated cone and then jog to the starting line to begin the next exercise. The exercises within the circuit are high knees, jumping jacks, burpies, body weight squats, pushups, planks, mountain climbers and flutter kicks. You will be asked to perform as many reps as possible within the 30 seconds and to put forth your maximal effort. During your rest in between sets you will be allowed to consume water as needed. After the high intensity exercise, you will follow the same procedure as in the first two tests. You will then be given two pieces of gum to chew for 10 minutes. After discarding the gum at the end of the 10 minutes, you will fill out the pre-hitting questionnaire and indicate your fatigue level on the backside of the questionnaire. Finally, you will complete the hitting tests and then indicate your fatigue and complete the post-hitting test questionnaire. This will complete your involvement as a subject in the study.

You must avoid the consumption of caffeine 48 hours before each testing as well as the consumption of alcohol and vigorous exercise 24 hours before each testing session. The tests will be administered at the same time during all four test sessions. If participants fail to abide by these rules they will not be able to participate and must reschedule the missed test day with the researcher at a later date or withdraw from the study.

Before agreeing to participate you should understand the following:

- **Your participation is completely voluntary.** You are free to withdraw from this study at any time without penalty.

- **Confidentiality.** Only the researcher will know which participants are associated with which swing data, height and weight measurements, and personal information from questionnaires. Immediately following each test session the researcher will return to her office in Park Center with the data and completed questionnaires secured in a folder inside of her backpack. The folder will then be put inside a locked desk in the researcher’s office. All electronic data will be kept in a password protected flash drive that will be locked inside of the
researcher’s desk when testing is not in session. The data will be kept for a minimum of three years.

- **Duration of participation.** Participants will be asked to come to the test facility 4 times throughout the course of the study. There will be no more than 2 test sessions per week. The tests will occur from late January through early March.

- **Risks.** The dose of caffeine you ingest from the two sticks of caffeinated gum used in this study is 200 mg and is considered a minimal health risk. This dose is about the same as you would get from 2 cups of brewed coffee or 5 colas. This dose may lead to restlessness, headaches, shakiness, disturbed sleep, nervousness, confusion, anxiety and nausea, especially if you are sensitive to caffeine.

- **Benefits.** The results of this study will provide information about the effects of caffeine on time to contact, hand velocity, bat velocity and power during a softball swing. Knowledge of these results may help you as well as softball coaches and other players if you or they are considering the use of caffeine as an ergogenic aid in softball batting.

- **Contact Information.** If you have any questions concerning the purpose or results of this study, you may contact Brianna Ferchen by phone (607)-437-0202 or by email brianna.ferchen@cortland.edu. For questions or concerns about your rights as a research participant, contact the SUNY Cortland Institutional Review Board by email at irb@cortland.edu, or by phone 607-753-2511.

I _______________________________________ have read the description of the project for which this consent is requested, I understand my rights, and I hereby consent to participate in this study.

_____________________________  ______________________
Signature                      Date

SUNY Cortland IRB
Protocol Approval Date: 12/29/2017
Protocol Expiration Date: 12/28/2018
Appendix C Participation survey

Participation Survey

Name: __________________________  Age: _______________

School email: _____________________________________

1. What is your undergraduate status?
   a. Freshman
   b. Sophomore
   c. Junior
   d. Senior

2. Do you attend SUNY Cortland?
   a. Yes
   b. No

3. Do you play Varsity Softball at SUNY Cortland
   a. Yes, I play varsity softball at SUNY Cortland
   b. No, I do not play on the varsity softball at SUNY Cortland

4. Do you play Club Softball at SUNY Cortland
   a. Yes, I play Club softball at SUNY Cortland
   b. No, I do not play on the Club softball at SUNY Cortland

5. How much experience do you have playing competitive fastpitch softball?
   a. 2 years
   b. 3 years
   c. 4 years
   d. 5 years
   e. greater than 5 years

6. Do you currently have NCAA eligibility?
   a. Yes
   b. No

7. How often do you workout?
   a. I do not workout
   b. 1-2 times a week
   c. 3-4 times a week
   d. 5-6 times a week
   e. I workout everyday of the week

8. How long does your workout last?
a. 30-44 minutes
b. 45-59 minutes
c. 1 hour – 1 hour, 29 minutes
d. 1 hour, 30 minutes - 1 hour, 59 minutes
e. 2 hours or more

9. Do you drink caffeinated beverages (coffee, soda, energy drinks, tea, pre-workout)?
   a. Yes
   b. No

10. What kind of caffeinated beverage do you drink regularly? Circle all that apply.
    a. Coffee
    b. Soda
    c. Energy drinks
    d. Energy shots
    e. Tea
    f. Pre-workout beverage
    g. I do not drink caffeinated beverages
    h. Other: ________________

11. How often do you drink caffeinated beverages?
    a. I do not drink caffeinated beverages
    b. Less than 1 drink a week
    c. 1 drink per week
    d. 1 drink every other day
    e. 1-2 drinks per day
    f. 3 or more drinks a day

12. Do you take any medications for seizures, anxiety, depression, high blood pressures, ADD, or ADHD?
    a. Yes, Please list: ____________________________________________
    b. No
Appendix D  Physical Activity Readiness Questionnaire

Physical Activity Readiness Questionnaire (PAR-Q)

PAR-Q is designed to help you help yourself. Many health benefits are associated with regular exercise, and the completion of PAR-Q is a sensible first step to take if you are planning to increase the amount of physical activity in your life.

For most people, physical activity should not pose any problems or hazard. PAR-Q has been designed to identify the small number of adults for whom physical activity might be inappropriate or those who should have medical advise concerning the type of activity most suitable for them.

Common sense is your best guide in answering these few questions. Please read the carefully and check YES or NO opposite the question if it applies to you. If yes, please explain.

1. Has your doctor ever said you have heart trouble?
   a. Yes
   b. No

2. Do you frequently have pains in your heart and chest?
   a. Yes
   b. No

3. Do you often feel faint or have spells of severe dizziness?
   a. Yes
   b. No

4. Has a doctor ever said your blood pressure was too high?
   a. Yes
   b. No

5. Has your doctor ever told you that you have a bone or joint problem(s), such as arthritis that has been aggravated by exercise, or might be made worse with exercise?
   a. Yes
   b. No

6. Is there a good physical reason, not mentioned here, why you should not follow an activity program even if you wanted to?
   a. Yes
   b. No

7. Are you over age 60 and not accustomed to vigorous exercise?
   a. Yes
   b. No

8. Do you suffer from any problems of the lower back, i.e., chronic pain, or numbness?
   a. Yes
   b. No
9. Are you currently taking any medications? If YES, please specify.
   a. Yes, Please list: ________________________________
   b. No

10. Do you currently have a disability or a communicable disease? If YES, Please specify.
    a. Yes, Please list: ________________________________
    b. No

If you answered **no** to all questions above, it gives a general indication that you may participate in anaerobic testing performed in this study. Answering **no** to the above questions does not guarantee that you will have a normal response to exercise. If you answered **yes** to any of the above questions, then you may need written permission from a physician before participating in anaerobic fitness testing performed in this study.

______________________        _____________________        _____________________
Print Name                        Signature                        Date
Appendix E Pre-Hitting Test Questionnaire

Pre Hitting Test Questionnaire

ID CODE: ___________________________________________ Date: _______________

1. Have you consumed any caffeine in the last 48 hours?
   a. Yes
   b. No

2. Have you consumed any alcohol in the last 24 hours?
   a. Yes
   b. No

3. Were you involved in any high intensity exercise in the last 24 hours, prior to arriving for testing today?
   a. Yes
   b. No
4. How are you feeling right now?
Appendix F Post-Hitting Test Questionnaire

Post Hitting Test Questionnaire

ID CODE: ________________________________ Date: __________

This questionnaire is to be completed directly after the Hitting test. Be sure to answer each question honestly and to the best of your ability. Participants are able to withdraw from the study at any time.

1. Are you experiencing any anxiety?
   a. Yes
   b. No

2. Are you experiencing any dizziness?
   a. Yes
   b. No

3. Are you experiencing any headaches?
   a. Yes
   b. No

4. Are you experiencing increased urinary output?
   a. Yes
   b. No

5. Are you experiencing increased heart rate?
   a. Yes
   b. No

6. Are you experiencing any stomach discomfort?
   a. Yes
   b. No

7. Are you experiencing any nausea?
   a. Yes
   b. No

8. Are you experiencing any restlessness?
   a. Yes
   b. No

9. Are you experiencing any shakiness?
10. How are you feeling right now?

a. Yes
b. No
Appendix G Exercise Circuit for Fatigued Group

Fatigue exercise circuit.

### Exercise circuit for Fatigued group

<table>
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<th>Exercise</th>
<th>Sets</th>
<th>Time (sec)</th>
<th>Sprint distance (m)</th>
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<tbody>
<tr>
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<td>5</td>
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<tr>
<td>Jumping jacks</td>
<td>3</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>Burpies</td>
<td>3</td>
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<td>Body weight squats</td>
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<td>Push ups</td>
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<td>Planks</td>
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<tr>
<td>Mountain climbers</td>
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<tr>
<td>Flutter Kicks</td>
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<td>30</td>
<td>10</td>
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*Note. Participants only sprint on sets two and three. They will complete their exercise and sprint down to the assigned cone and jog back.*
Appendix H Identification/Test Organization Excel Worksheet

Participant Identification Number

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<tr>
<th>ID</th>
<th>Last Name</th>
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<th>Date</th>
<th>F/NF</th>
<th>CAF(1)/PL(2)</th>
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<th>CAF(1)/PL(2)</th>
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Note: ID# = identification number, F = fatigue, NF = non-fatigued, CAF = caffeine, and PL = placebo
### Appendix I Characteristics of Participants Excel Worksheet

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<th>ID#</th>
<th>Age yrs</th>
<th>V/C</th>
<th>Exp yrs</th>
<th>Ex Freq (days)</th>
<th>Workout time (min)</th>
<th>Drink CAF (D/W)</th>
<th>PAR-Q</th>
<th>Informed consent</th>
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*Note: ID# = identification number, yrs = years, V = varsity, C = club, Ex Freq = exercise frequency, min = minutes, CAF = caffeine, D = day, W = week, PAR-Q = physical activity readiness questionnaire.*
Appendix J Height and Weight Table

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### Appendix K Data Collection Non-Fatigue Condition

#### Test Days 1-2: Non-Fatigued Testing

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<th>HS mph</th>
<th>TTC sec</th>
<th>P kW</th>
<th>ID</th>
<th>ID/NF</th>
<th>NF/PL</th>
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<th>BS mph</th>
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**Average**

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**Note:** ID = identification number, NF = non-fatigue condition, F = fatigue condition, PL = placebo, CAF = caffeine, BS = bat speed, HS = hand speed, TTC = time to contact, P = power, mph = mile per hour, sec = seconds, kW = kilowatts, fatigue B = fatigue before, fatigue A = fatigue after.
Appendix L Data Collection Fatigue Condition

Test Days 3-4: Fatigue Testing

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Note: ID = identification number, NF = non-fatigue condition, F = fatigue condition, PL = placebo, CAF = caffeine, BS = bat speed, HS = hand speed, TTC = time to contact, P = power, mph = mile per hour, sec = seconds, kW = kilowatts, fatigue B = fatigue before, fatigue A = fatigue after
### Appendix M Individual Data For Non-Fatigued Condition

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**Note:** ID# = identification number, H = habitual, NH = non-habitual, F<sub>b</sub> = fatigue status before hitting test, F<sub>a</sub> = fatigue status after hitting test, BS = bat speed, mph = miles per hour, HS = hand speed, TTC = time to contact, s = seconds, P = power, kW = kilowatts, PL = placebo, CAF = caffeine
Appendix N Individual Data For Fatigued Condition

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Note: ID# = identification number, H = habitual, NH = non-habitual, F_ b = fatigue status before hitting test, F_ a = fatigue status after hitting test, BS = bat speed, mph = miles per hour, HS = hand speed, TTC = time to contact, sec = seconds, P = power, kW = kilowatts, PL = placebo, CAF = caffeine