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Effects of Caffeine Gum on Muscular Strength and Power in Recreationally Active Females

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EFFECTS OF CAFFEINE GUM ON MUSCULAR STRENGTH AND POWER IN RECREATIONALLY ACTIVE FEMALES

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ABSTRACT

Research indicates that a moderate dose of caffeine may enhance muscular strength and power, particularly in males. Less is known on caffeine's impact on muscular performance in females. The purpose of this study was to determine the effects of a 200 mg dose caffeine gum on muscular strength and muscular power in recreationally active females. Nineteen women participated in 3 laboratory sessions, the first being the familiarization trial. During the next two visits, the participants were given either 200 mg of caffeine gum or a placebo gum, rested for 15 minutes, completed a 10 minute warm-up, then performed performance testing consisting of maximal jump height testing on a force plate, followed by one repetition maximum testing for the bench press and leg press. While the caffeine resulted in higher mean differences for all tests, there were no significant differences between caffeine or placebo trials ($p > 0.05$) for any performance measures except the maximal squat jump ($p = 0.04$). In conclusion, a 200 mg dose of caffeine is not sufficient to improve muscular strength and some instances of muscular power. This is a novel finding, and future studies should look at altering time to absorption or higher dosing of caffeine gum.

INDEX WORDS: Caffeine gum, Muscular strength, Muscular power, Females

DEDICATION

I would like to dedicate this thesis to my parents for their unconditional support and love along the way.

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First, I would like to thank Dr. Nicks, for he has made this entire process possible. Without his support, guidance, and feedback, I would not have been able to complete this thesis. He has put forth much time, effort, and patience throughout the process, and I really appreciate it.

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Introduction

Overview of Caffeine

Caffeine is a commonly used ergogenic aid in athletes, especially after its removal from the banned substance list published by the World Anti-Doping Agency according to Del Coso, Muñoz, and Muñoz-Guerra (2011). Caffeine is a popular ergogenic aid due to the beneficial effects including but not limited to an increase of alertness, concentration, and energy (Nehlig, 2018). The International Society of Sports Nutrition stance on caffeine dosage to enhance exercise and sports performance is consuming it in low to moderate doses of 3-6 $mg \cdot kg^{-1}$, but doses 9 $mg \cdot kg^{-1}$ or greater have been seen to have no added benefit (E. R. Goldstein et al., 2010). Caffeine has been shown to provide ergogenic benefits for aerobic endurance, muscular strength, muscular endurance, and anaerobic power, but the aerobic endurance studies hold a higher effect size (Grgic et al., 2019). The best dosage of caffeine to increase muscular strength and anaerobic performance is yet to be determined.

While the effects of caffeine on aerobic endurance have been well documented, there are fewer studies related to its impact on anaerobic performance, such as muscular strength and power. Suchomel, Nimphius, & Stone, 2016, who conducted a meta-analysis on muscular strength in athletic performance, found that in athletes with more muscular strength, there was an association with higher rate of force development, external mechanical power, and specific sport skill performance, as well as there being a reduced risk of injury. A proposed mechanism by which caffeine enhances muscular performance is the increase of calcium release from the ryanodine receptor of the sarcoplasmic reticulum in the muscle cell, which could create more force being generated by the muscle (Penner, Neher, Takeshima, Nishimura, & Numa, 1989).

Duncan, Stanley, Parkhouse, Cook, & Smith Duncan, Stanley, Parkhouse, Cook, and Smith (2013) found that a 5 $mg \cdot kg^{-1}$ dose of caffeine reduced pain perception and rate of perceived exertion (RPE) during the bench press, prone row, back squat, and deadlift for experienced lifters. The reduction of pain perception could be caused by caffeine's ability to block the adenosine receptors that control pain (Sawynok, 1998). The reduction of RPE could be caused by several factors, with the lowered pain perception being one of them (Doherty & Smith, 2005). However, in a meta-analysis done by Grgic et al. (2019) the results are inconclusive due to methodological differences in measuring RPE and pain perception during exercise after caffeine ingestion. While the exact mechanisms are not fully understood, evidence suggests that caffeine has the potential to improve muscular strength and power.

Caffeine and Muscular Strength

In the area of muscular strength, results on if caffeine impacts upper and lower body strength are conflicting, especially with different exercises. Grgic and Mikulic (2017) found no significant increases for upper body strength during the bench press in resistance trained men with 6 $mg \cdot kg^{-1}$ of caffeine, but they found a 2.8% increase in lower body strength during the back squat, suggesting it was due to decreases in RPE. Another study that used the barbell back squat found a 3.46% increase in performance when trained males ingested 75 mg of caffeine gel (Martin, 2015). Arazi, Dehlavinejad, and Gholizadeh (2016) found an increase in both upper and lower body strength for male novice body builders with 6 $mg \cdot kg^{-1}$ of caffeine during the bench press and leg press. However, Astorino, Rohmann, and Firth (2008) did not find any significant differences between the 6 $mg \cdot kg^{-1}$ caffeine dose and placebo during either lower or upper body strength for the bench press and leg press in resistance trained men. In their meta-analysis, Warren, Park, Maresca, McKibans, and Millard-Stafford (2010), reported that caffeine enhances lower body maximal voluntary contraction (MVC) strength for the knee extensors but not in other muscle groups. The results from the Grgic, Trexler, Lazinica, and Pedisic (2018) meta-analysis are contrasting to the Warren et al. (2010) meta-analysis because they found that caffeine increases upper body strength, not lower body strength. While the effects of caffeine on muscular strength are still not clear between upper and lower body exercises, most of the research done with muscular power saw improvements with caffeine supplementation.

Caffeine and Muscular Power

In terms of muscular power, caffeine has ergogenic effect on improving performance on countermovement jump (CMJ) in various types of athletes with caffeine doses ranging from 3-6 $mg \cdot kg^{-1}$ of body weight (Bloms, Fitzgerald, Short, & Whitehead, 2016; Diaz-Lara et al., 2016; Foskett, Ali, & Gant, 2009; Gant, Ali, & Foskett, 2010). Bloms et al. (2016) was the only author who investigated squat jump (SJ), found an increase in jump height in both CMJ and SJ with the 5 $mg \cdot kg^{-1}$ caffeine pill for both male and female athletes. They determined that time to half-peak force was improved for squat jump (SJ), while peak force was improved for the countermovement jump. In addition, Bloms et al. (2016) reported that caffeine improved results for 44% of women, and 56% of men for the SJ. For the countermovement jump, caffeine improved results for 68% of men and 33% of women. Based on their data, more men were responders to caffeine than women (Bloms et al., 2016).

Taken together, caffeine is seen as an effective ergogenic aid for measures of muscular performance. However, much of the research either solely uses males (Arazi et al., 2016; Astorino et al., 2008; Grgic & Mikulic, 2017) or mixes the gender sample (Bloms et al., 2016;

Duncan et al., 2013; Sabblah, Dixon, & Bottoms, 2015). As such, there is limited evidence for caffeine's effects on muscular strength and power in females.

Effects of Caffeine on Females

Only two known studies have been conducted solely using females in the area of muscular strength, endurance, and power. Ali, O'Donnell, Foskett, and Rutherfurd-Markwick (2016) examined muscular strength and power for knee flexors and extensors as well as a countermovement jump in females who played team sports. An isokinetic dynamometer was used for participants to perform five concentric and eccentric contractions of the knee flexors and extensors at 30° per second as well as isometric contractions at 75°, all with little to not rest in order to determine leg strength and power. For the countermovement jump, a jump mat was used to get the participant's jump height, which was later put into a power equation to estimate leg power. The authors found that a dose of 6 $mg \cdot kg^{-1}$ of caffeine increased muscular strength for the knee flexors, but it had no effect on muscular strength for the knee extensors (Ali et al., 2016). When they examined muscular power, there was a significant effect of caffeine on eccentric knee flexor and extensor contractions, but it had no effect on concentric contractions. In addition, there was no effect of caffeine on countermovement jump height (Ali et al., 2016). Goldstein, Jacobs, Whitehurst, Penhollow, and Antonio (2010) used resistance trained females that could bench press 70% of their body weight, and they looked at muscular strength and endurance using a bench press test. After ingesting 6 $mg \cdot kg^{-1}$ of caffeine, the participants had an increase from 52.1 ± 11.7 kg with the placebo to 52.9 ± 11.1 kg with the caffeine supplement in 1-RM bench press (~1.5%), but there were no significant effects of caffeine on muscular endurance. More studies need to be conducted to determine how caffeine may affect resistance exercises for females. In addition, more research is needed to determine how alternate forms of caffeine, besides relative doses of anhydrous caffeine, can affects females.

Administration of Caffeine

Much research relating to the ergogenic benefits of caffeine has been done in the form of anhydrous caffeine through relative dosing based on body weight (Ali et al., 2016; Arazi et al., 2016; Astorino et al., 2008; Bloms et al., 2016; Diaz-Lara et al., 2016; Duncan et al., 2013; E. R. Goldstein et al., 2010; Grgic & Mikulic, 2017). However, methods of administering caffeine, such as coffee, energy drinks, caffeine rinses, energy bars, caffeine gels, and gum, have limited evidence supporting their value to enhance performance. These alternate forms of caffeine have not been widely studied when looking at measures of muscular strength and power. Alternate forms of caffeine with absolute doses compared to relative doses can be more reflective of real-world situations, making them more practical. Using an absolute dose of caffeine would be more convenient to use, rather than having to measure out a dose that is relative to body weight in situations like sporting events or before the gym. Caffeine gum is an alternate form that provides a low dose of caffeine, which can be useful to even the average person to remedy sleep deprivation and fatigue. The caffeine from the gum is absorbed by the buccal cavity, as opposed to absorption in the gut, which means there is an immediate effect, opposed to caffeine pills that take about an hour to take effect (Kamimori et al., 2002). After 5 minutes of chewing, approximately 85% of the caffeine is released (Novum, 1997). The caffeine level in the blood begins to show a significant increase at about 15 minutes after administration compared to the caffeine pill, which does not begin to show a large increase in levels until about 45 minutes after administration (Kamimori et al., 2002). Doses of 100 mg or 200 mg of caffeine gum, which is either 1 or 2 pieces for Stay Alert® gum (Amurol Confectioners ,Yorkville, IL), can sustain caffeine levels in the blood as long as it is administered every two hours, which means that exercise performance could be sustained (Syed, Kamimori, Kelly, & Eddington, 2005).

Many of the studies that have been done with caffeine gum look at its effects on endurance and power. Lane et al. (2013) used male and female cyclists and triathletes to test time trial performance on a cycle ergometer, meant to simulate the London Olympic Games course. After they were given a dose of Stay Alert® gum (Amurol Confectioners ,Yorkville, IL) that was equal to about 3 $mg \cdot kg^{-1}$ of body weight, mean power output and completion time was improved for both sexes (Lane et al., 2013). Evans et al., 2018 examined repeated sprint performance during a 40-meter shuttle run test in male team sport players, where sprints were repeated 10 times, giving only a 30 second interval between each sprint. The authors found that only the low caffeine consumers (<40 mg/day) had a reduction in fatigue after chewing 200 mg of Military Energy Gum® (MarketRight Inc.; Plano, Illinois) (Evans et al., 2018). C. D. Paton, Lowe, and Irvine (2010) also looked at the effect of caffeine gum on fatigue as well as hormone response in male cyclists. Participants did high intensity interval training sessions on a cycle ergometer, where they completed 4 sets of 30-second-long sprints (repeated 5 times each set), separated by 30 second rest periods. The authors found that after ingesting 6 pieces of Jolt® caffeine energy gum (Gum Runners; Hackensack, NJ, USA), equal to 240 mg of caffeine, the participants had reduced fatigue, which was associated with an increase in testosterone (C. D. Paton et al., 2010). Paton, Costa, & Guglielmo (2015) investigated time trial performance in male and female cyclists during 30-kilometer sprints, including sprinting at maximal effort for 0.2 kilometers every 10 kilometers. They found that with a moderate dose of caffeine, 3-4 $mg \cdot kg^{-1}$ of body weight or 2-3 pieces of Stay Alert® gum, mean and sprint power during the last 10 kilometers was improved, which was most likely due to the increase in heart rate and blood lactate, meaning that the nervous system was activated. They also found a time difference above 5 minutes for endurance performance between placebo and caffeine trials (C. Paton, Costa, & Guglielmo, 2015). Ryan et al. (2013) found improvements in time to completion during a time trial in male cyclists after administering 300 mg of Stay Alert® caffeine gum 5 minutes before performance. In contrast, Ryan et al. (2012) reported that after physically active men were given caffeine, a 200 mg dose did not improve performance in a time to exhaustion cycling protocol. Dittrich, Serpa, Lemos, De, & Guglielmo, 2019 examined exercise tolerance and neuromuscular responses in the knee extensors specifically. The authors used well-trained runners, testing their time to exhaustion at submaximal intensity on a treadmill after ingesting 300 mg of Stay Alert® caffeine gum. They assessed neuromuscular fatigue of the knee extensors before and after the time to exhaustion test (Dittrich et al., 2019). The authors found that the caffeine gum enhanced exercise tolerance by 18%, but this was not due to different neuromuscular responses between caffeine and placebo trials (Dittrich et al., 2019). Countermovement jump performance was enhanced in male athletes after a small dose 200 mg of the caffeine gum (Ranchordas et al., 2019; Ranchordas, King, Russell, Lynn, & Russell, 2018). Ranchordas et al. (2019) used male rugby players and had them perform 3 countermovement jumps, the Illinois agility test, and the Yo-Yo IR-2 test. Countermovement jump was enhanced by 3.6%, performance on the Yo-Yo IR-2 test was improved by 14.5%, and fatigue index was lower during the Illinois agility test for the caffeine gum (Superfast Energy Gum™; Rotherham, UK) trial (Ranchordas et al., 2019). Ranchordas et al. (2018) investigated the effects of caffeine gum on male soccer players and had them perform similar tests (the countermovement jump, 20-meter sprint, and the Yo-Yo IR-1 test). After chewing caffeine gum (Military Energy Gum-Stay Alert; Chicago, Illinois) countermovement jump height was improved by 2.2%, 2.0% more distance was covered on the

Yo-Yo IR-1 test, but sprint performance was not improved. When 100 mg of Stay Alert® caffeine gum was given to male and female collegiate track and field athletes during a morning performance, distance for the shot-put throws were improved during the first 3 attempts out 6 only, with a mean difference of 4.7% between caffeine and placebo trials (Bellar et al., 2012). Taken together there is a scarcity of data on caffeine gum and how it affects muscular power. There are no known studies on the effects of caffeine gum on muscular strength specifically. More importantly, there is no research on how caffeine gum may affect muscle strength and power in female participants

Purpose

There are conflicting results in the scientific literature on how muscular strength and power is affected by caffeine, with a clear lack of data on its efficacy on females. In terms of using an alternative absolute dose of caffeine gum, few studies have done this, and none of them looked at any aspects of muscular strength. Therefore, the purpose of this study was to determine the effects of a 200 mg dose caffeine gum on muscular strength and muscular power in active females. Based on previous research, it was hypothesized that caffeine gum would increase performance on the 1-RM bench press and leg press tests as well as the countermovement and squat jump height tests.

Methods

Subjects

Nineteen recreationally active females, 18-40 years old, from a southeastern university were recruited for the study. The women participated in a minimum of 150 minutes of moderate intensity activity or 75 minutes of vigorous intensity activity per week. Participants were excluded if they had any upper or lower body musculoskeletal injuries, or if they were pregnant. Participants were also excluded if they had any known caffeine sensitivities. Prior to data collection, this study was approved by the Institutional Review Board (IRB). Participants completed an informed consent before beginning the study.

Study Design

The study was a double-blind, randomized, crossover design to investigate the effects of caffeine gum ingestion on jump height and bench and leg press 1-RM testing. Participants attended 3 sessions held at least 72 hours apart. The first trial was familiarization session, and the other 2 trials were the experimental trials with the administration of caffeine gum and placebo gum in a randomized order. Sessions were the same time of day for each participant. Participants were instructed not to consume food or beverages other than water 3 hours before testing during the 2 experimental trial days. The participants chose the time of day for both experimental trial days based on their availability and preference. Participants abstained from caffeinated food and beverages after 6 pm the day before testing to reduce withdrawal symptoms during the 2 experimental trials (Duncan et al., 2013). Strenuous exercise was avoided 24 hours before each trial. The participants were asked to keep a dietary log, including all food and drinks, using the MyFitnessPal app (MyFitnessPal, 2015) 24 hours before each experimental trial to make sure they kept track of caffeine intake.

Procedures

Treatment order was randomly assigned. Participants received the placebo gum during one experimental trial and caffeine gum (Military Energy Gum©, cinnamon flavor, Market

Right, Inc.; Plano, Illinois, United States of America) for the other trial. Military Energy Gum© was originally made for the military to use readily in the field to reduce fatigue. Two pieces containing 100 mg of caffeine each for the caffeine trial or 2 pieces of similar shape and color placebo gum (Epic©, cinnamon flavor, Epic Dental LLC; Murray, Utah) were chewed for 5 minutes, expectorated, then participants sat for 10 minutes before the warm-up. Each trial was separated by at least 72 hours, making sure the participant did not have muscle soreness the day of each trial (Spanidis et al., 2018).

First Visit.

On the first visit, participants completed the consent form, PAR-Q, and self-made questionnaires about resistance training habits and current caffeine consumption and sensitivities. Participants used an online resource to estimate the amount of caffeine in their specific brands of coffee, coffee drinks or other caffeinated products (caffeineinformer.com). Their height was measured with a Seca stadiometer (Seca®; Hamburg, Germany) to the nearest 0.5 cm, and weight was measured with a Prodoc Detecto scale (Detecto®; Webb City, Missouri) to the nearest 0.5kg.

Participants were then familiarized with how to perform both squat and countermovement jumps on the force plate. For the squat jump (SJ), participants were asked to start in a squatted position, pause for 3 seconds, then jump while keeping hands on the hips; for the countermovement jump (CMJ) participants were asked to jump as high as possible without pause while keeping the hands on the hips (Bloms et al., 2016).

After familiarization of the SJ and CMJ, the subjects received instructions on how to perform a 1-RM test for the bench press and leg press. ACSM procedures were used while administering the 1-RM test (Gibson, Wagner, & Heyward, 2018). First a warm-up was completed with 5 to 10 repetitions at 40-60% of their 1-RM. After they rested for 1 minute, they did 3-5 repetitions at 60-80% of their estimated 1-RM. They then rested for 2 minutes before the 1-RM attempt was made. If the attempt was not their maximum, 2 minutes of rest were given, then weight was increased in increments of 5-10% for the bench press and 10-20% for the leg press.

Second and Third Visits.

During the next 2 visits, participants entered the laboratory and were seated for approximately 5 minutes. Resting heart rate was recorded using a Zephyr Bioharness (Medtronic; Annapolis, MD). Resting blood pressure was taken manually with a palm aneroid sphygmomanometer (American Diagnostic Corporation; Hauppauge, NY). Subjects were then given either the caffeine or placebo gum and instructed to chew it for 5 minutes while sitting. After expectorating the gum, the participants sat for 10 minutes, then heart rate and blood pressure were recorded again with the same instruments used for resting. Next, participants did a dynamic flexibility warm-up before the jumps. The warm-up consisted of a 5-minute brisk walk or light jog on the treadmill at 4.0 mph and dynamic stretching exercises (walking lunges, squats with overhead arm reach, front and back leg swings, and forward and backwards arm circles) for 10 repetitions each. Participants then performed 1 practice jump and 3 measured jumps of the SJ and CMJ with the AMTI Force and Motion force plate (AMTI®; Watertown, Massachusetts). The average (Avg) jump height of the 3 jumps for each technique was recorded. The average of the three jumps as well as the highest (Max) of the three jumps were analyzed due to previous studies that have used both. Rate of perceived exertion (RPE), using the 6-20 scale,(Borg, 1982), and pain perception (PP), using the 0-10 scale, (Cook, O'connor, Oliver, & Lee, 1998) was recorded after the completion of each of the jump techniques within 5 seconds after completion (Grgic & Mikulic, 2017). A prompt of "how do you feel now" was given. However, this prompt seemed to be confusing for many participants. Even though the participants were familiarized with the RPE and PP scales, many of them were unsure on how to answer, and therefore, the data was not used in the final analysis. Heart rate was also recorded after each of the jump techniques. Upon completion of the SJ and CMJ, participants completed 1-RM testing with the Hammer Strength brand leg press machine and bench press (Hammer Strength®; Falmouth, Kentucky). Bench press 1-RM was performed first to allow the lower body to rest after the jump testing. ACSM protocols were followed again for the testing (Gibson et al., 2018). Five minutes of rest was given between 1-RM tests. RPE and PP were recorded within 5 seconds after the completion of the 1-RM bench press and 1-RM leg press. Heart rate and blood pressure were recorded after each of the 1-RM tests.

Statistical Analysis

Data was analyzed using SPSS version 26.0 (IBM, Armonk, NY, USA). Descriptive statistics were expressed as mean values ± SDs. Normality was assessed for the main dependent variables (CMJ, SJ, 1RM BP, and 1RM LP) with the Shapiro-Wilk test. Paired t-tests were used to compare caffeine and placebo gum conditions. In all cases, a p-value less than 0.05 was declared statistically significant. Effect sizes were calculated for all dependent variables using Cohen's d using values of 0.2 as small, 0.5 as moderate, and 0.8 as large effects (Cohen, 1988).

Results

One female was excluded from all analyses due to her daily consumption of coffee being over 600 mg. Two more subjects were excluded from the analysis of CMJ and SJ due to technical errors of the equipment used. The dose of 200 mg of caffeine was equivalent to an average of 3.19 $mg \cdot kg^{-1}$ of participants' body weight of 62.5 kg. Participants characteristics is presented in Table 1. The impact of caffeine on the strength and jump variables is presented in Table 2, with a significant difference between the placebo and caffeine trial observed in the Max SJ ($p < 0.05$). Figures 1-6 show the individual differences versus the average differences between caffeine and placebo trials for the dependent variables (Avg CMJ and SJ, Max CMJ and SJ, 1-RM BP, and 1-RM LP). Max SJ was the only significant difference found between caffeine and placebo trials ($p = 0.04$). 56% of participants were caffeine responders for CMJ, SJ, and Max SJ. 63% of participants were caffeine responders for Max CMJ, 39% for BP, and 50% for LP.

Table 1

Descriptive Characteristics of Participants (N = 18)

Variable	Mean ± SD
Age (y)	23.7 ± 4.2
Height (cm)	161.6 ± 6.8
Weight (kg)	62.5 ± 10.8
BMI (kg/m^2)	23.9 ± 3.3
Caffeine Consumption per Day (mg)	187.7 ± 129.2
Days per Week Consumed	4.4 ± 3.0

Table 2

Differences in Placebo vs. Caffeine Conditions in Measures of Performance Responses

Measure	Placebo (mean ± SD)	Caffeine (mean ± SD)	Change from Placebo (95% CI)	*P*-Value	ES
Avg CMJ (cm)	19.53 ± 2.92	20.66 ± 3.62	1.12 (-0.13, 2.39)	0.07	0.47
Avg SJ (cm)	18.67 ± 2.90	19.70 ± 4.00	1.02 (-0.10, 2.15)	0.07	0.48
Max CMJ (cm)	20.64 ± 3.17	21.58 ± 3.77	0.93 (-0.15, 2.03)	0.08	0.45
Max SJ (cm)	20.31 ± 3.04	21.40 ± 4.00	1.09 (-0.006, 2.18)	0.04*	0.53
1RM BP (kg)	41.32 ± 14.10	42.08 ± 13.70	0.75 (-6.62, 20.23)	0.08	0.43
1RM LP (kg)	208.24 ± 79.13	215.05 ± 75.15	6.80 (-0.10, 1.62)	0.30	0.25

Note: CMJ: countermovement jump; SJ: squat jump; 1RM: one-repetition maximum; BP: bench press; LP: leg press; Avg: average of 3 jumps; Max: highest of 3 jumps; n=16 for Avg CMJ, Avg SJ, Max CMJ and Max SJ; N=18 for 1RM bench press and 1RM leg press

**Statistically significant difference between conditions.*

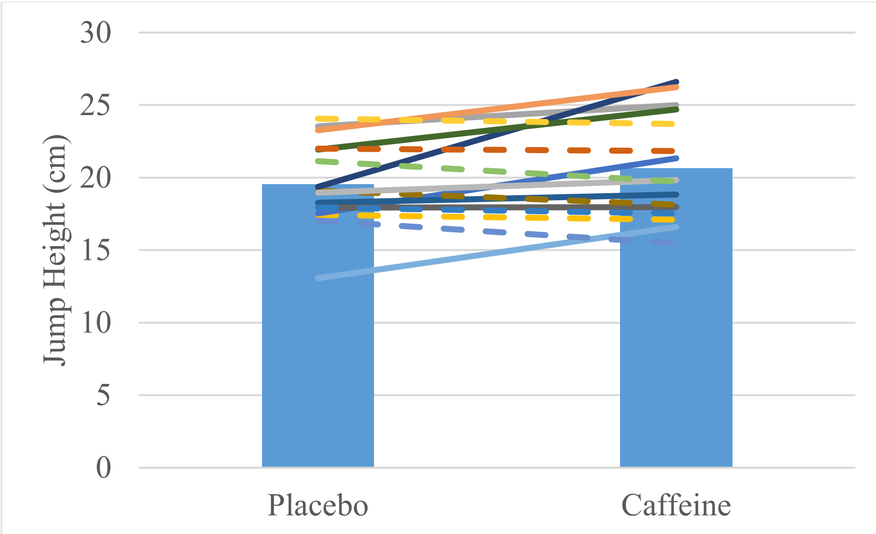

Figure 1

Countermovement Jump Height for Individuals and Average Between Caffeine and Placebo trials

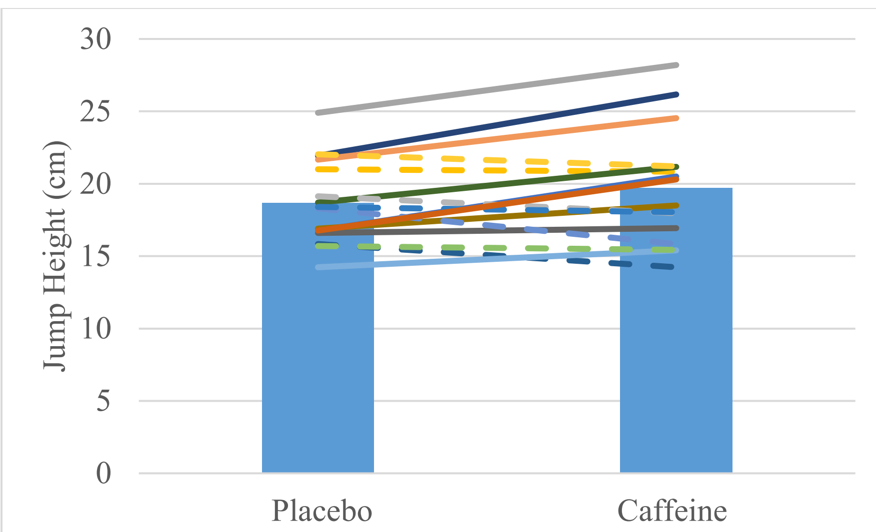

Figure 2

Squat Jump Height for Individuals and Average Between Caffeine and Placebo Trials

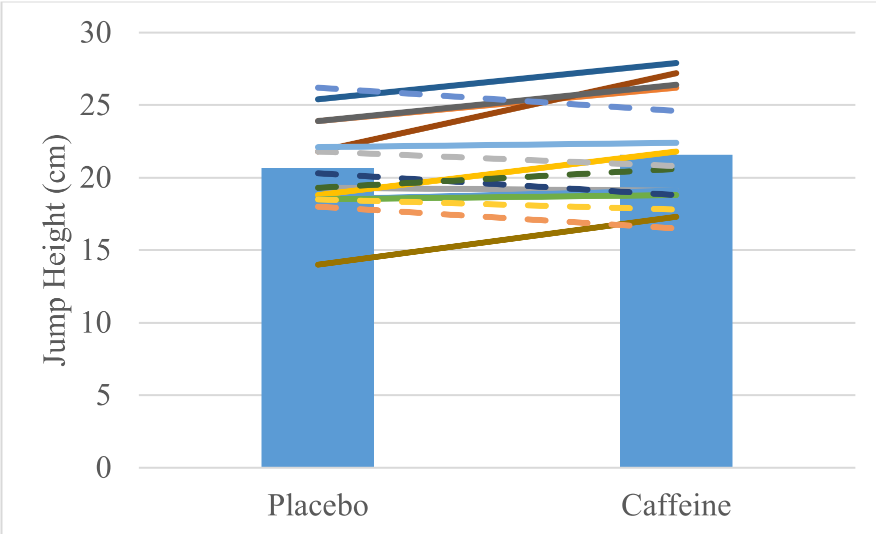

Figure 3

Maximum Countermovement Jump Height for Individuals and Average Between Caffeine and Placebo Trials

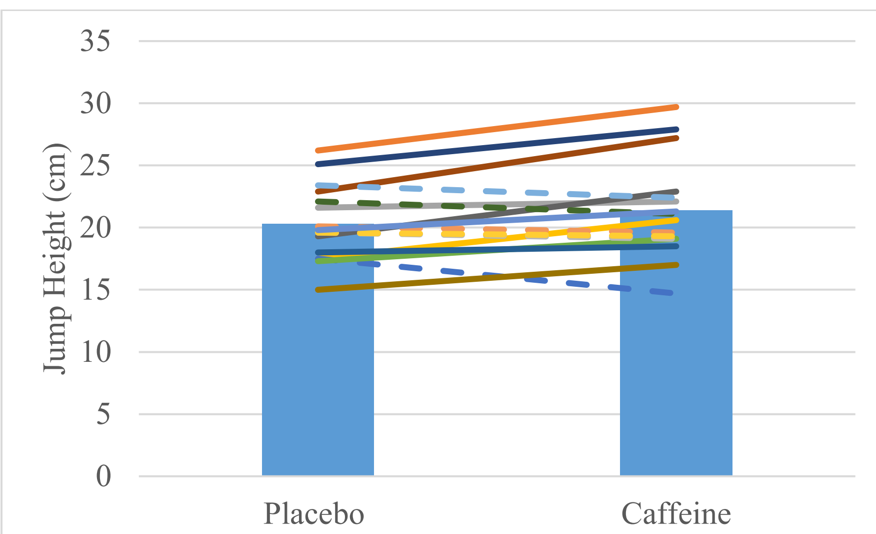

Figure 4

Maximum Squat Jump Height for Individuals and Average Between Caffeine and Placebo Trials

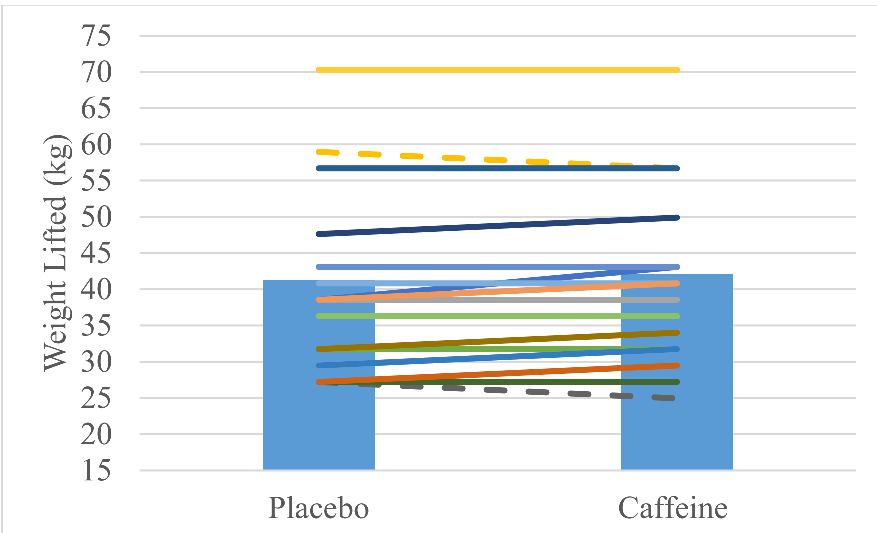

Figure 5

Bench Press Weight Lifted for Individuals and Average Between Caffeine and Placebo Trials

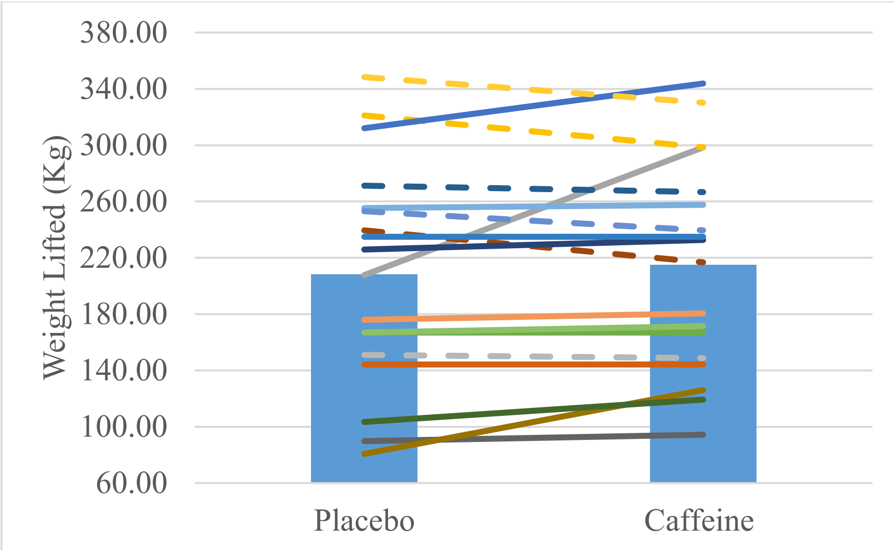

Figure 6

Leg Press Weight Lifted for Individuals and Average Between Caffeine and Placebo Trials

Discussion

The purpose of this study was to determine the effects of a 200 mg dose of caffeine gum on muscular strength and power performance tests in recreationally active females. Caffeine did not significantly affect Avg CMJ, Avg SJ, Max CMJ, 1RM BP, or 1RM LP compared to the placebo trial. The findings disagree with previous studies where different forms of caffeine have been shown to improve muscular strength (Ali et al., 2016; Arazi et al., 2016; E. Goldstein et al., 2010; Grgic & Mikulic, 2017; Martin, 2015) and power (Ali et al., 2016; Bloms et al., 2016; Diaz-Lara et al., 2016; Foskett et al., 2009; Gant et al., 2010). Taken together, these results reject the initial hypothesis that caffeine would improve measures of muscular performance in active females.

Muscular Power

Caffeine did not significantly improve Avg CMJ, Avg SJ, and Max CMJ. However, Max SJ was significantly different between placebo and caffeine conditions where caffeine enhanced the Max SJ 5.36% with a moderate effect size ($d = 0.53$). A possible reason for the significant improvement in Max SJ compared to the other jumps could relate to the participants familiarity to the squat jump. However, Avg SJ was not significantly changed so it remains speculative as to why Max SJ improved. Norm-referenced values for jump data in athletes typically use the Vertec™, which is different from the methods used in our study, so the present study cannot compare with those norms. Contrary to the present study, Bloms et al. (2016) found a significant difference in jump height for SJ (5.4 ± 6.5%) and CMJ (4.3 ± 4.6%) in Division 1 collegiate athletes, consisting of 9 females and 16 males, after consuming 5 $mg \cdot kg^{-1}$ of caffeine in pill form. Sixteen of the 25 participants were reported to not regularly consume caffeine, unlike the present study where only 3 participants were not regular consumers. Even though the authors used a force plate, the jump height was calculated with an equation using the vertical velocity of center of mass at takeoff squared divided by 2 times gravity, which is different from the methods in the present study. Therefore, we cannot compare the data accurately. However, while there was not a significant difference observed in most CMJ or SJ jumps in the current study, the percentage of improvement was comparable to Bloms et al. (2016) with a range of 4.5 to 5.3% improvement across all jumps. The present study was the first known study to test SJ height difference using caffeine gum, so there are no known studies to compare to using those same methods. Although, the CMJ height values were not significantly affected by the caffeine gum, there were larger improvements between the two conditions than in previous literature. Ranchordas et al. (2018) found that the caffeine gum significantly improved the CMJ height by 2.2% ($d = 0.30$) for male soccer players, and in a later study, Ranchordas et al. (2019) had a similar finding in male rugby players with an improved CMJ height of 3.6% ($d = 0.22$). Both studies took the highest of the jumps and recorded it, so in the present study, the Max CMJ would compare. Although our results were not significant like theirs, Max CMJ was improved by 4.5% ($d = 0.45$), which is a higher effect size than Ranchordas et al. (2019); (Ranchordas et al., 2018). The difference between their results and the present study could be due to the difference in gender, training status and sample size. The current study used females (N = 18) while Ranchordas et al. (2019); Ranchordas et al. (2018) used all males (N = 10; N = 17). The difference on whether or not gender effects caffeine erogenicity is still unclear as some studies have suggested that caffeine metabolizing speeds are different for females (Pickering & Grgic, 2019; Skinner et al., 2019). The slower metabolizing speed for caffeine consumption for females could mean that more wait time between caffeine administration and the start of exercise could benefit females. Another difference between the present study and Ranchordas et al., 2019 and Ranchordas et al. 2018 is the training status of their participants being athletes in soccer and rugby, while in the present study, the participants were recreationally active. Previous studies with endurance athletes have suggested that training status plays a factor in the ergogenic effects of caffeine; however this is inconclusive for power and strength athletes (Boyett et al., 2016; Grgic et al., 2018).

Muscular Strength

Neither 1RM BP or 1RM LP had significant changes between the placebo and caffeine trials with only a 3.26% change for 1RM LP with a small effect size ($d = 0.25$) and a 1.8% change for 1RM BP with a small effect size ($d = 0.43$). Based on normative data from Brown and Miller (1998), which is used as female ACSM norms, the present study's average 1RM BP and 1RM LP would score "well above average" for both caffeine and placebo trials. This could be because 61% of the women were resistance trained, skewing the Avg BP and Avg LP. When comparing to previous findings, there are no other studies that have looked at the effects of caffeine gum on BP and LP, so comparisons should be made to studies that have used other forms of caffeine. Similarly to the present study, Astorino et al. (2008) found no significant difference in 1RM BP or 1RM LP scores between placebo and caffeine trials after administering 6 $mg \cdot kg^{-1}$ of anhydrous pharmaceutical grade caffeine to resistance trained men. The authors discuss that this could be due to variability in caffeine intake, body mass, and training status, which are the same issues in the present study. While the participants' body mass and training status are not comparable to the present study, we can compare the daily caffeine intake of participants. The average caffeine consumption for our participants was about 187 mg 4 days per week, with a minimum caffeine consumption of 0 mg and a maximum of 470 mg, which fall within the average American adult intake. Astorino et al. (2008) had an average caffeine intake of 110.5 mg 4.4 days per week, with minimum caffeine consumption of 0 mg and a maximum of 600 mg. In the present study, participants could have been habituated based on the proposed habituation thresholds (Filip, Wilk, Krzysztofik, & Del Coso, 2020). The participants in the present study were moderate caffeine consumers, which means an intake between 3 to 5.99 $mg \cdot kg^{-1}$ of caffeine daily, suggesting that they were habituated to the similar dose of caffeine they were given from the 200 mg of gum depending on their body weight (Filip et al., 2020). Although, in the present study, the participant who consumed 600 mg of caffeine daily was excluded, there is similar intake amounts between the two studies. McGuire (2014) with the Institute of Medicine found through a 24-hour recall study that the average daily amount of caffeine consumed by the average adult in America is between 121-215 mg, which is below the limit of 400 mg that is considered safe. The average daily intake of the current study is within this range, so many of our participants seemed to be habituated to caffeine. Pickering and Grgic (2019) suggests that the habituation to caffeine can reduce its ergogenic affects, therefore, a higher dose of caffeine may be needed to see any effects on performance. Contrary to the present study, Arazi et al. (2016) found significant results with the 1RM LP and 1RM BP tests after male novice body builders ingested 6 $mg \cdot kg^{-1}$ of caffeine inside gelatin capsules. The similar training status of the individuals could have been a factor in the results. As mentioned previously, the effect of training status on muscular strength is not well known (Arazi et al., 2016; Boyett et al., 2016; Grgic et al., 2018). In the only study done with females testing muscular strength, E. Goldstein et al. (2010) found that 6 $mg \cdot kg^{-1}$mixed into Propel Fitness Water enhanced strength for the barbell bench press in 15 resistance trained women. The BP score during the caffeine trial was 52.9 ± 11.7 kg versus 52.1 ± 11.7 kg during the placebo trial, which would be a 1.5% change, like the present study with a 1.8% change. These results are over 10 kg higher than the present study for both caffeine (42.08 ± 13.70 kg) and placebo (41.32 ± 14.10 kg), but our participants were not all resistance trained with the added qualification of being able to bench press 70% of their body weight. Again, compared to our study, the training status as well as the caffeine dosage was different because (E. Goldstein et al., 2010) used resistance trained females, and a caffeine dosage considered to be above average compared to the average American daily caffeine intake.

Limitations

There were some potentials limitations to the study design that may have impacted the results. The absolute 200 mg dose may have not been enough to enhance muscular performance, particularly for those subjects with higher body weights. Even though it may have been too small of a dose, chewing caffeine gum is more practical than consuming a caffeine pill or a beverage that could take up to an hour to see affects. It is useful in the athletic and exercise community where caffeine is becoming more common to increase performance. The present study may have lacked enough power and could have benefitted from having more participants to see a greater affect. However, the sample size was consistent and even larger than many other studies mentioned previously. Another potential limitation is the training status of all participants not being consistent. While all were active, some only trained aerobically while others were more resistance trained, which could have affected results of the 1RM LP and BP. The caffeine consumption habits of the participants may have also limited results, as most were regular caffeine users. However, given the widespread use of caffeine among the population, it is important to determine whether a specific dose of caffeine will enhance performance in those who regularly use caffeine. Future studies should test with bigger doses of caffeine gum, possibly 300 mg, to help determine its effectiveness.

Conclusion

In conclusion, two pieces (200 mg) of caffeine gum were not enough to produce significant changes in muscular strength and power for active women. This is a novel finding as it is the first known investigation to examine the effects of caffeine gum and muscular strength and power in females. While Max SJ did significantly increase, other measures were not impacted significantly, but the percentage improvements from placebo to caffeine were like previous studies. Many participants responded positively to the treatment so more work is needed in this area. Future studies could examine different doses of caffeine gum or alter the time to absorption to determine any potential effects.

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APPENDIX

APPENDIX A: IRB APPROVAL EMAIL

CSU IRB <irb@columbusstate.edu> Wed, Nov 13, 2019, 9:40 AM

to me, Clayton, CSU, Institutional

Institutional Review Board
Columbus State University

Date: 11/13/2019
Protocol Number: 20-021
Protocol Title: Effect of Caffeine Gum on Muscular Power and Strength
Principal Investigator: Lindsay Montgomery
Co-Principal Investigator: Clayton Nicks

Dear Lindsay Montgomery:

Representatives of the Columbus State University Institutional Review Board have reviewed your research proposal identified above. It has been determined that the research project poses minimal risk to subjects and qualifies for expedited review under 45 CFR 46.110. Approval is granted for the research project.

Please note any changes to the protocol must be submitted in writing to the IRB before implementing the change(s). Any adverse events, unexpected problems, and/or incidents that involve risks to participants and/or others must be reported to the Institutional Review Board at irb@columbusstate.edu or (706) 507-8634.

If you have further questions, please feel free to contact the IRB.

Sincerely,
Manasa Mamidi, Graduate Assistant

Institutional Review Board
Columbus State University

APPENDIX B: CAFFEINE QUESTIONAIRE

Participant # (for researcher): _______________

Date of Birth: _______________________

Caffeine Consumption Questionnaire

Log on to www.caffeineinformer.com and click on "caffeine levels" to search your specific caffeinated beverages. Please answer based on what you eat and drink in the *typical* day. Indicate below the amount of caffeine in 1 serving of the beverage or food, the serving size, and how many

Beverages	Brand/ Drink	Serving Size	# of servings consumed	Total caffeine amount
Coffee				
Decaf Coffee				
Tea				
Caffeinated Soda				

Cocoa				

Edibles	**Brand**	**Serving Size**	**# of servings**	**Total caffeine amount**
Chocolate candy bar				
Chocolate desserts				
Caffeinated Candy/ Gums				
Pre-workout Supplements/ drinks				

Medications	**# of servings consumed**	**Total caffeine amount**
Anacin (32 mg)		
Appetite-control pills (100-200mg)		
Dristan (16mg)		
Excedrin (65mg)		
Midol (120mg)		
NoDoz (200mg)		
Triminicin (30mg)		
Vanquish (33mg)		
Vivarin (200mg)		
Cafergot (100mg)		
Fiorinal (40mg)		
Other		

Total daily caffeine consumption: ________________

APPENDIX C: WEEKLY EXERCISE QUESTIONAIRE

Weekly Exercise Questionnaire

Please answer the following questions about your exercise habits based on your typical week (e.g. excluding holidays). **Exercise** is defined as *planned, structured intentional activity that is intended to improve or maintain physical fitness or general health.*

1. How many days per week do you exercise? ____________

2. How many minutes is each exercise session? ___________

3. What is your total volume you spend exercising per week (days*minutes)? ___________

4. What types of activities do you do for exercise? (Specify the intensity, time and type for each; e.g. walk at 3mph at 10% grade for 30 minutes)

5. How many days per week do you do resistance training? _____________

6. How many minutes do you spend each session? _____________

7. How long have you been resistance training consistently? _____________

8. Please list some of the resistance exercises you perform (body weight, machine or free weight):