The Effect of Caffeine Supplementation on Figure Skating Jump Height

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Abstract

The consumption of caffeine has many physiological effects beneficial to athletic performance and has great potential as an ergogenic aid. Significant studies support the idea that caffeine supplementation enhances muscular endurance, muscular strength, and muscle power output, all important components to a technically advanced figure skating jump. A single-blind within-subjects study in which participants from the Liberty University Figure Skating Team tested their off-ice loop jump height over two trials (caffeine and placebo), investigated the relationship between caffeine and figure skating jump height. The results of the study suggest that caffeine supplementation increases off-ice loop jump height.

The Effect of Caffeine Supplementation on Figure Skating Jump Height

Caffeine, a crystalline compound, is a widely known substance often found in coffee or tea that acts as a stimulant for the brain and central nervous system. Consumption of caffeine can lead to feelings of being more awake or alert with its peak effectiveness being around 60 minutes after consumption. According to the Food and Drug Administration (FDA), up to 400 milligrams (mg) is considered a safe amount of caffeine for healthy adults to consume daily. In addition to this, caffeine has great potential as an ergogenic aid. An ergogenic aid can be defined as any substance that promotes an enhanced energy production or recovery in an athlete that provides them with a competitive advantage. Some of the physiological effects of caffeine that affect the body include antagonism of adenosine receptors and increased calcium mobilization on a musculoskeletal level which increases muscle function overall. The substance's ergogenic effects have been studied extensively in the field of exercise science, and it is suggested that caffeine may boost the number of active motor units recruited and the rate at which they fire, or rate coding. Contreras-Barraza et al. (2021) showed that studies have focused primarily on testing muscular endurance, muscular strength, and muscle power output as well as various specific athletic movements. This empirical overview presents findings supporting idea that caffeine does enhance various athletic performances. However, there is gap in the literature in regards to practical application of the potential ergogenic effects of caffeine within the specific sport of figure skating.

As a sport that requires muscular strength, muscular endurance, and power, figure skating performance is likely to be influenced by caffeine supplementation. Figure skating is a sport known for the performance of various jumps, spins, and footwork on the ice, usually in a

choreographed program. There are 6 different jumps identified in the sport of figure skating: the toe loop, salchow, loop, flip, lutz, and axel, all of which can be divided in two classifications: edge jumps, and toe jumps. Edge jumps are identified by the skater taking off on one side of the blade, as opposed to the toepick or the entire bottom of the blade. For the purpose of this study, edge jumps, as they can be most accurately simulated off-ice, are the focus of this study (more specifically the loop jump). The loop jump takes off backwards on the outside edge of the skater's dominant skating foot, rotates the required number of revolutions, and then lands on the same outside edge of the skater's dominant skating foot.

Participants from the Liberty University Figure Skating Team tested their off-ice loop jump height over two trials (caffeine and placebo) in a single-blind, within-subjects study that investigated the relationship between caffeine and figure skating jump height. The purpose of this study is to investigate the practical application of the potential ergogenic effects of caffeine supplementation within the sport of figure skating, or more specifically, to determine the effect caffeine supplementation has on figure skating jump height. It is important to bridge the gap between research on caffeine supplementation and sport specific application. Knowledge of the potential ergogenic effect caffeine has on figure skating would be beneficial to coaches and figure skaters training competitively in the sport. When judged in a competitive figure skating program, skaters receive a base value for execution of a jump, but they can earn more points for a jump that presents a delay in rotation and great height and/or distance. Precision in figure skating is vital as jumps are completed in fractions of seconds. It would be beneficial for a competitive figure skater to improve jump height even slightly as even the smallest improvement in height could allow a skater to fully rotate a jump during their airtime. Additionally, integrating

caffeine supplementation into the diet of a competitive figure skater could significantly impact the training regime of said figure skater by allowing the skater to experience repeated exposure to the higher jumps. This would allow for the skater to build the muscle memory necessary to repeat the higher jumps in competition. Applying previous research conducted to the specific sport of figure skating, it was hypothesized that figure skating jump height would increase with caffeine supplementation.

Caffeine and Muscular Strength, Muscular Endurance, and Power Output

Abian et al. (2015) aimed to investigate the effect caffeinated energy drinks has on jump performance within elite badminton players. This was a double-blind, placebo-controlled, and randomized study in which 16 male badminton players consumed 3 mg of caffeine per kilogram (kg) of body weight in energy drink form or the same energy drink without caffeine. This study had 2 trials in which each badminton player participated in the experimental and placebo trial. 60 minutes after caffeine or placebo consumption, participants performed a squat jump and a countermovement jump in which jump heights were recorded to compare data between caffeine and placebo trials. Results showed that squat jump height was greater with caffeine (36.04±4.3 cm) compared to squat jump height with placebo (34.5±4.7 cm). Additionally, countermovement jump height was greater with caffeine (37.7±4.5 cm) compared to countermovement jump height with placebo (36.04±4.3 cm). Results indicate a greater jump height with caffeine supplementation, but further testing with a jump protocol more similar to an on-ice figure skating jump would be needed to determine if caffeine supplementation increases figure skating jump height.

Furthermore, Merino Fernández et al. (2021) researched the effect 3 mg of caffeine per kg of body weight has on vertical jump height in elite traditional jiu-jitsu athletes. This was a double-blind, placebo-controlled, crossover design study in which 16 participants tested bilateral countermovement jump height 60-minute post caffeine or placebo consumption. Using the flight time method, caffeine proved to significantly increase bilateral countermovement jump height compared to placebo. Results from this study indicate that caffeine does improve jump performance, but it would be beneficial to expand upon this research by investigating the practicality of the ergogenic effects of caffeine in the sport of figure skating.

Abien-Vincen et al. (2014) researched the effect caffeinated energy drinks had on jump performance within adolescent basketball players. This study contained many of the same characteristics of the above studies involving badminton players and jiu-jitsu athletes. For this study, 16 basketball players ingested either an energy drink containing 3 mg of caffeine per kg of body weight or a placebo version of the energy drink that contained no caffeine. After waiting 60 minutes to allow for maximum caffeine absorption, a countermovement jump and a repeated maximal jump test for 15 seconds were performed. Results indicate that caffeine improves jump performance as the maximal countermovement jump height was greater with caffeine (38.3±4.4 cm) than with placebo (37.5±4.4 cm), and the average jump height during the repeated maximal jump test was greater with caffeine (30.2±3.6 cm) than with placebo (28.8±3.4 cm). These results support caffeine supplementation improving power output abilities within athletes. Given these results and implications, caffeine supplementation is likely to improve jump height within figure skaters as well.

Additionally, Guerra et al. (2018) researched the effect of caffeine on countermovement jump height within male professional soccer players. This was a randomized, counterbalanced, and double-blind study in which 12 participants consumed either 5 mg of caffeine per kg of body weight or placebo, waited 60 minutes for maximal caffeine absorption, and then tested countermovement jump height. Results show a significant improvement in countermovement jump height compared to that with placebo. The trend of jump performance improving with caffeine consumption should follow suit within the sport of figure skating, but it is important to investigate caffeine's effects with the specific biomechanical principals of figure skating jumps.

In Bloms et al. (2016), researchers investigated the effects of caffeine on vertical jump height within the population of collegiate athletes. This study is a single-blind, randomized, crossover design study in which 25 athletes consumed either 5 mg of caffeine per kg of body weight or placebo. Upon completion of a 60-minute waiting period, athletes performed 3 countermovement jumps and 3 squat jumps on a force platform. Results indicated that squat jump height with caffeine (34.5±6.7 cm) was greater than squat jump height with placebo (32.8±6.2 cm), and countermovement jump height with caffeine (37.9±7.4 cm) was greater than countermovement jump height with placebo (36.4±6.9 cm). This is indicative of caffeine improving jump height, and researchers note that the results suggest that the ergogenic effects of caffeine may transfer to other ballistic movements of the lower body. As a figure skating jump is a ballistic task similar to the countermovement jump performed in this study, it would be advantageous to further investigate the ergogenic effects of caffeine on figure skating jumps.

Burke et al. (2021) researches the effects of caffeine on jumping performance within female college athletes. 11 athletes participated in 2 trials separated by 1 week where they were

given either 6 mg of caffeine per kg of body weight or placebo, using a double-blind approach. Following a 60-minute waiting period, unweighted and weighted squat jump height and countermovement jump height were tested. The study concluded that caffeine does improve jump height as unweighted and weighted squat jump height and countermovement jump height all increased with caffeine versus with placebo. Each improvement with caffeine was small but a significant difference compared to jump height with placebo. This research could be expanded upon by applying similar methods to a study with competitive figure skaters.

Degrance et al. (2019) aimed to investigate the effect of caffeine supplementation on power output during back squats. In this blind crossover study, 12 males consumed either 6 mg of caffeine per kg of body weight or placebo 60 minutes prior to completing 3 maximal back squats with 2 minutes rest between each movement. A linear transducer was used to measure power with each movement, and results suggested that lower body power output was greater with caffeine than with placebo. In a figure skating jump, athletes need to be able to propel themselves and overcome gravity to attain height in their jump. This increased height comes with increased lower body power output.

Garner et al. (2021) researched the effect of caffeine on vertical jump performance in anaerobically trained individuals. For this study, 11 anaerobically trained athletes participated in 2 trials (1 with 6 mg of caffeine per kg of body mass and 1 with placebo) where static jump height and countermovement jump height were tested. A repeated-measures ANOVA statistical analysis test revealed that there was no significant improvement in static jump height or countermovement jump height with caffeine. Significant other studies indicate improvement in vertical jump height with caffeine and improvements in many athletic abilities like muscular

strength, muscular endurance, and power output. It is important to note that figure skating uses several and/or a combination of energy systems. While figure skating is an aerobic effort when put into the context of a competitive routine, figure skating is anaerobic in nature when put into the context of training skills like jumps and spins. The results from this study are characteristic of anaerobic athletes, but it is important to evaluate the effects of caffeine supplementation in the context of figure skating due to the complex energy system usage within the sport.

In Sandro et al. (2019), researchers investigated the effects of caffeinated gel ingestion on vertical jump height in the squat jump and countermovement jump. This experiment was a randomized, crossover, double-blind, counterbalanced study in which participants were given either caffeinated gel, containing 300 mg of caffeine, or placebo gel. After consumption of the assigned gel, subjects completed a 10-minute warm up and began testing. Compared to the placebo, caffeine improved vertical jump height by 2.9% in the squat jump and by 3.3% in the countermovement jump. Although this study did not allow as great of a time to allow for maximal blood caffeine levels as other studies, significant results showing improved performance with caffeine occurred. This study was also unique to use caffeinated gel as opposed to caffeinated energy drinks or pills, but for the purpose of researching the effect caffeine has on figure skating jump height, caffeine and placebo pills will be used.

Substantial research has been conducted to suggest a positive relationship between caffeine and increased height in various vertical jump movements. However, it is important apply this research to other athletic disciplines in attempt to investigate the potential of the compound as an ergogenic aid to other sports. For instance, there is a lack of research of the

effects of caffeine on vertical jump movements with the specific biomechanical principles characteristic to figure skating jumps.

Figure Skating and Muscular Strength, Muscular Endurance, and Power Output

Figure skating as a whole effort put into a competitive routine is aerobic in nature as a competitive figure skating routine can range from a minimum of 1 minute and 30 seconds to a maximum of 4 minutes and 10 seconds. However, lower intensity figure skating and the effort towards refining skills and training is primarily an anaerobic effort that relies heavily on the athlete's muscular strength, muscular endurance, and power output. In a literature review by Barcelos et al. (2020), it is noted how "caffeine affects performance via peripheral mechanisms such as effort consciousness, voluntary motor unit activation, contractile muscle function, release and uptake of calcium at sarcoplasmic reticulum, and the activity of sodium/potassium ATPase pumps". With an increase in motor unit activation, there is an increase in contractile strength within a muscle; and with improved sodium/potassium ATPase pump function, muscle contractility is improved. Kalmar (2005) explained how caffeine acts as a central nervous system adenosine receptor antagonist and effects the voluntary muscle activation. Caffeine also contains properties that allow for increased arousal, attention, and overall feeling of wakefulness. This all allows for potential to achieve a greater figure skating jump height with caffeine supplementation as an improved attention may make for a better approach and adherence to optimized technique.

Significant studies support the ergogenic effects of caffeine. Contreras-Barraza et al. (2021), an empirical overview of caffeine studies talks about how effects of caffeine supplementation has been linked to an improvement in muscular endurance, contractile

performance, and time to fatigue. Improvements in muscular endurance and time to fatigue would benefit figure skaters throughout their competitive program, but improved contractile performance would be most beneficial to increasing jump height. Additionally, Gomez-Bruton et al. (2021), a systematic review and meta-analysis, makes note of how caffeine intake has a positive effect of several aspects of athletic performance such as muscle endurance and strength, anaerobic power, and aerobic endurance. Grgic et al. (2018), a systematic review, researched the effects of caffeine on muscle strength and power through 8 databases and drew conclusions that caffeine supplementation improved both strength and power. While each of these general athletic improvements would likely benefit figure skaters, the specific dose most effective to figure skating remains unresearched.

Guest et al, (2021) conducted an in-depth evaluation of the available literature regarding caffeine intake and sports performance to determine the International Society of Sports Nutrition (ISSN) position on caffeine consumption. ISSN concluded that caffeine has shown to improve aspects of exercise performance including muscular endurance, movement velocity, muscular strength, sprinting, jumping, throwing, and a variety of aerobic and anaerobic sport-specific actions. Caffeine supplementation is also linked to improved cognitive function like attention and vigilance. Although the degree to which caffeine benefits each individual varies, studies show that aerobic activities benefit from caffeine intake the most. Moderate doses of caffeine (3-6 mg per kg of body mass) have shown to provide the greatest ergogenic effect, whereas high doses of caffeine (9 or more mg of caffeine per kg of body mass) elicit negative side effects and do not produce an ergogenic effect. Effects of lower doses of caffeine (2 or less mg of caffeine per kg of body mass) on exercise remains unresearched. For the purpose of this study, the effects

of 200 mg of caffeine on figure skating jump height will be researched. Although the amount of time needed to reach optimal caffeine consumption depends on the mode of caffeine intake, 60 minutes pre-exercise appears to be the most commonly used time frame within studies. For the purpose of investigating the effects of caffeine on figure skating jump height, a 60-minute wait time between caffeine ingestion and off-ice loop jump height will take place to allow for maximal blood caffeine levels.

In addition to all of this, Jiménez et al. (2021) conducted a systematic review on the effect of caffeinated drinks on physical performance. Within the review, 6 studies involving cycling, an endurance-based sport, were included. Of these, 5 of the cycling studies concluded that caffeine intake positively correlates to an improved performance. 2 of 2 studies reviewed regarding the effect of caffeine on power-based sports reported an increase in reaction performance post caffeine consumption. Studies drawn from various other sports disciplines were used in this review as well. In total, 37 studies were included in this systematic review, of which, the ergogenic role of caffeine was supported within studies involving endurance-based sports, power-based sports, individual and team sports, and skill-based sports. It is important to apply this knowledge of the ergogenic effects of caffeine gathered within the sport of figure skating.

While caffeine supplementation has shown to be very beneficial within various athletic disciplines, Pickering et al. (2019) notes that it is important to keep in mind the adverse effects of caffeine while attempting to use caffeine for its ergogenic effects. For example, caffeine has the potential to elevate feelings of anxiety and cause jitters or shakiness. If an athlete does experience these adverse side effects, then caffeine consumption would actually have the

potential to hinder sports performance rather than improve it. For example, in the setting of a figure skating competition, a figure skater is likely to already be feeling performance anxiety or the normal pressures of competing, and the addition of caffeine may increase these feelings. It is critical that the effects of caffeine, both negative and positive, are further evaluated within the realm of figure skating.

While the effect of caffeine on various jump performances have been investigated in general, the greatest gap in the literature is the application of the ergogenic effects of caffeine to the sport of figure skating, and more specifically, the effect of caffeine on figure skating jump height. Given the positive relationship between caffeine supplementation and jump height within various other vertical jump movements shown throughout an abundance of studies, caffeine has the potential to be a turning point within the sport of figure skating. Caffeine has been widely used as an ergogenic aid in numerous other sports, however, remains unresearched within the sport of figure skating.

Method

Experimental Approach to the Problem

This study is a single-blind, placebo controlled, within-subjects design study. For the first testing session (trial 1), each participant was assigned either placebo or caffeine via counterbalanced assignment; a crossover trial (trial 2) occurred after trial 1. Participants did not know in either trial whether they received placebo or caffeine to control for participant's subconscious additional exertion during a trial they favored. Participant number corresponds to the order in which the participant signed up for a testing time slot. Participants were only given access to sign up for a testing time slot upon signing an informed consent document and physical

activity readiness questionnaire. Testing for trial 2 was repeated the same way as trial 1, where participants were given the opposite treatment that they received for the first testing session (either placebo or caffeine). Participants' jump height with and without caffeine were compared.

The materials necessary for this empirical research study include a laptop computer that contained the data collection sheet used in this study and linking list. Off-ice loop jump height was tested using a vertical jump contact mat and handheld computer (Just Jump System, Probotics Inc., Huntsville, AL, USA). The pills assigned to participants were Nutricost Caffeine Pills (200mg per serving) (Nutricost, Vineyard, UT, USA) and Capsuline size 00 – colored white empty gelatin capsules (Capsuline, Dania Beach, FL, USA). Pills were given to participants in a Ziploc sandwich sized plastic bag (SC Johnson, Racine, WI, USA) with printed instructions for their testing day. SignUpGenius (SignUpGenius, Charlotte, NC, USA) was used to organize testing sessions between participants. All statistics were calculated using SPSS 19.0 statistical analysis software (IBM, Armonk, NY, USA).

For the purpose of this study, an off-ice loop jump was used to measure the effect caffeine supplementation has on figure skating jump height. A loop jump in figure skating, being an edge jump that takes off from a backwards outside edge of the skating foot and rotates for the designated number of rotations (1 full rotation for a single jump, etc.) and lands on a backwards outside edge of the same skating foot used for take-off, is often used as an off-ice measure within figure skating. This off-ice jump is completed by having the skater prep for the jump by standing with their body weight on their dominant leg, knees bent, and non-dominant leg in front of their dominant. Included in this position, the skater's arms would be up at shoulder height in an L-formation (dominant arm to the side of the body, and non-dominant arm in front of the body).

Then, the skater bends their knees and jumps up, completing a rotation by crossing their non-dominant foot over their dominant foot, and lands on their dominant foot. The skater's arms are pulled in to the center of the body for the duration of the jump. All participants received the same instruction during testing sessions to ensure reliable results.

Extraneous variables that were controlled for include; the temperature of the Human Performance Lab, as it was kept at a constant temperature throughout all testing days; skater's attire, as participants were instructed to wear their normal figure skating practice attire on testing days; and skater's diet/water consumption and amount of sleep, as participants were instructed to continue normal eating and water consumption habits on testing days as well as continue normal sleeping habits the nights before testing. Participants were also instructed to abstain from caffeine intake outside of the study on testing days as well as avoid strenuous training 24 hours before testing. Participants potential to exert themselves more during their trial with caffeine was controlled for by the addition of a placebo pill during the control trial. The caffeine pill and gelatin placebo pill looked very similar as they were relatively the same size capsule and both colored white.

Subjects

Subjects consisted of 15 figure skaters, varying in age from 18-23 years; all members of the Liberty University Figure Skating Team (female=15). All subjects were female and over the age of 18. Participants varied in level from high-beginner to senior level free-skate. Approval for this study was obtained through the local institutional review board, and all subjects completed an informed consent before participation. A physical activity readiness questionnaire was used to

screen individuals who may be placed at increased risk during strenuous exercise. Those found at an increased risk were excluded from the study.

Subjects reported to the Human Performance Lab with normal figure skating practice attire, having taken their assigned pill (either caffeine or placebo) 40 minutes prior to arrival to the lab. Previous research conducted instructed participants to take their assigned treatment 60 minutes prior to testing; however, a 40-minute prior to arrival timeframe was used for this protocol to allow for the addition of a guided 15-minute warm up before testing. Participants were instructed to abstain from caffeine intake outside of the study on testing days. Additionally, the participants were instructed to continue their typical eating and drinking habits on testing days. To produce the most accurate results, subjects were instructed to abstain from strenuous training at least 24 hours before testing sessions.

Procedure

Subjects participated in 2 testing sessions total. Upon completion of the informed consent document and activity readiness questionnaire, subjects were given access to a SignUpGenius created to pick a time slot to test their off-ice loop jump. Participants signed up using their participant number. Subjects were then given their assigned pill, either 200mg of caffeine or placebo. Athletes consumed either caffeine or placebo in the form of a pill 60 minutes before testing to allow for the caffeine to reach its peak effect (this time frame was determined through accumulation of the participants taking their assigned pill 40 minutes prior to arrival to the Human Performance Lab and the guided 15 minute warm up). Participants did not know whether they received placebo or caffeine.

Upon arrival to the Human Performance Lab, participants were lead through a 15-minute warm up. The warm up consisted of 10 body weight squats; a series of dynamic stretches including quad, glute, and hamstring stretches moving and walking kicks; and a static deep squat stretch. Participants were then instructed to practice 3 off-ice loop jumps on their own to aid in post activation potentiation of their off-ice loop jump. After, subjects practiced 3 off-ice loop jumps on the jump mat to get the feeling of completing the off-ice loop jump both starting and finishing on the jump mat. The jump mat was not collecting data during this time. Following warm up, the jump mat was turned on and participants' jump height was tested by completion of 2 off-ice loop jumps on the vertical jump contact mat. Participants were instructed to stick the landing to provide the most accurate data from the jump mat. Completion of the first off-ice loop jump was used as a practice for data collection, and data was only recorded and kept from the second off-ice loop jump. Jump height (in inches) was recorded to allow for comparison after the second testing session. After participants' completion of trial 1, participants were given access to a SignUpGenius to register for a second testing session. Participants' trial 1 and trial 2 were separated by about a week. Testing was repeated the same way for the second testing session where participants were given the opposite treatment they received for the first testing session (either placebo or caffeine).

Results

After 2 weeks of data collection, (2 trials about a week apart) the researcher reviewed the quantitative data, taking note of the difference between each participant's off-ice loop jump height with caffeine and with placebo. Participants' jump height with and without caffeine was

compared. See Table 1 for off-ice loop jump height values with caffeine and with placebo, organized by participant number.

Table 1

Jump Height (inches) with Caffeine and with Placebo

Participant Number	Jump Height with Caffeine	Jump Height with Placebo
1	**15.9 in**	**14.5 in**
2	**17.5 in**	**18.2 in**
3	**15.9 in**	**15.8 in**
4	**16.1 in**	**15.8 in**
5	**10.5 in**	**8.6 in**
6	**13.1 in**	**12.9 in**
7	**8.2 in**	**7.4 in**
8	**8.9 in**	**8.3 in**
9	**10.9 in**	**11.0 in**
10	**12.5 in**	**11.4 in**
11	**16.3 in**	**16.5 in**
12	**7.4 in**	**7.1 in**
13	**12.2 in**	**12.4 in**
14	**9.7 in**	**8.4 in**
15	**11.3 in**	**10.8 in**

For most participants, their off-ice loop jump height with caffeine was greater than their off-ice loop jump height with placebo. The participant's jump height with caffeine and with placebo are compared via a scatter plot below. See Figure 1. The blue data plots represent jump height (in inches) with caffeine, and the orange data plots represent jump height (in inches) with placebo. Data is organized by participant number.

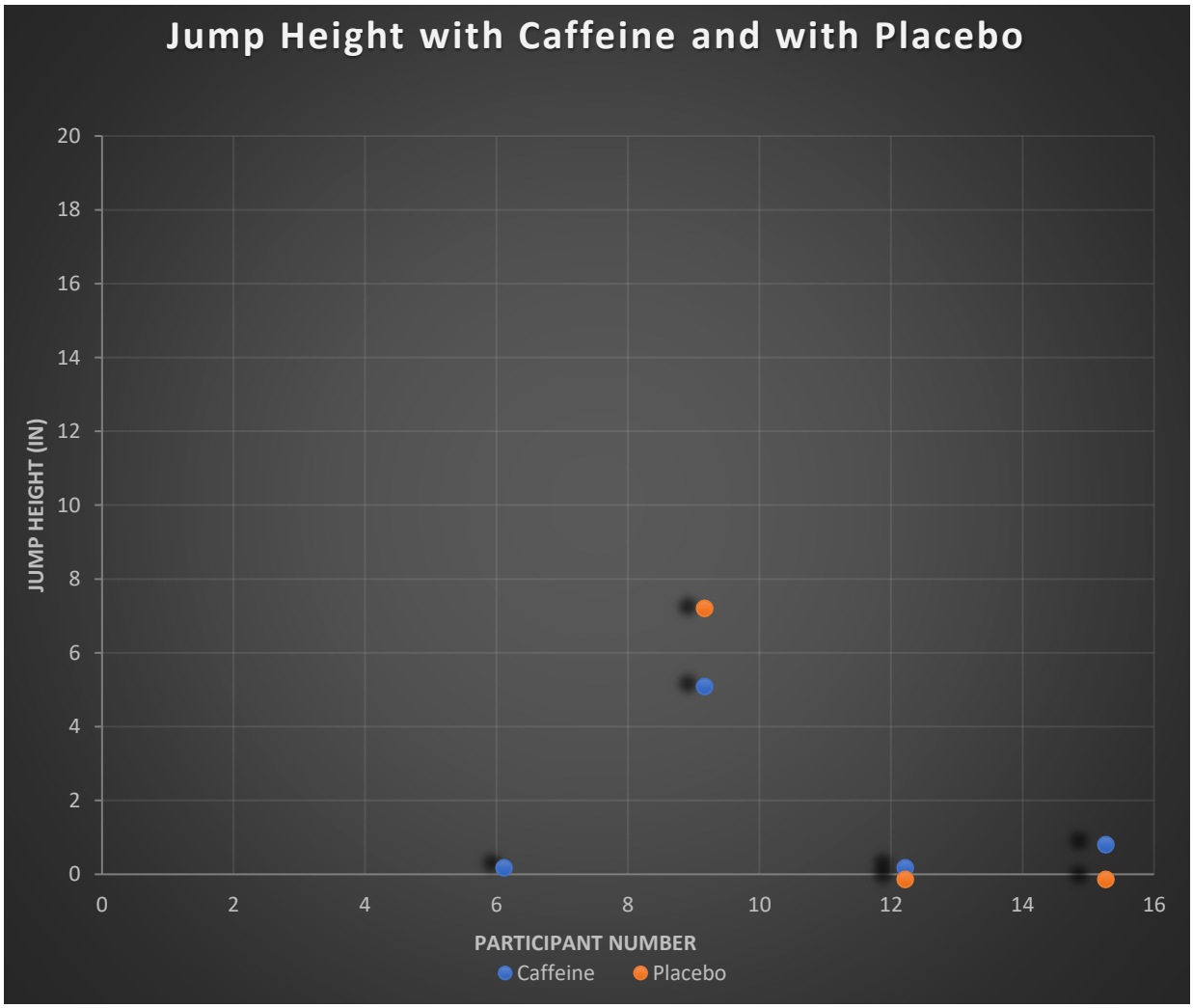

Figure 1

Jump Height (inches) with Caffeine and with Placebo Compared

Statistical Analysis

All statistics were calculated using SPSS 19.0 statistical analysis software (IBM, Armonk, NY, USA). The mean off-ice loop jump height with caffeine was 12.4±3.3 inches, whereas the mean off-ice loop jump height with placebo was 11.9±3.6 inches with a sample size of 15 figure skaters from the Liberty University Figure Skating Team (N=15). Off-ice loop jump height on average was greater with caffeine than it was with placebo, as the mean off-ice loop jump height with caffeine was .5 inches higher than the mean off-ice loop jump height with placebo. These results indicate that caffeine supplementation does increase figure skater jump height. Full dependent statistics can be seen in Figure 2.

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Caffeine	12.4267	15	3.26441	.84287
	Placebo	11.9400	15	3.59480	.92817

Figure 2

Dependent Statistics

Mean values for the dependent measures (jump height for trial 1 and 2) were compared using the paired samples test of variance, and an alpha of .05 was used to determine significance. The results show a significant difference (p=0.018) between off-ice loop jump height with caffeine versus with off-ice loop jump height with placebo, in favor of caffeine supplementation. Full dependent T-test results can be seen in Figure 3.

Paired Samples Test

		Paired Differences					t	df	Significance	
					95% Confidence Interval of the Difference					
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			One-Sided p	Two-Sided p
Pair 1	Caffeine - Placebo	.48667	.70596	.18228	.09572	.87761	2.670	14	.009	.018

Figure 3

Dependent T-test

Results from this study indicate the hypothesis that caffeine supplementation will increase figure skating jump height is true. The mean off-ice loop jump height with caffeine (12.4±3.3 inches) was .5 inches higher than the mean off-ice loop jump height with placebo (11.9±3.6 inches). Results are significant between the two conditions (p=0.018), in favor of caffeine supplementation.

Discussion

All participants from this study participated in 2 trials, 1 trial with caffeine and 1 trial with placebo. Participants did not know which trial they had been given caffeine and which trial they had been given placebo. The researcher analyzed the quantitative data from participant's off-ice loop jump height with caffeine compared to participant's off-ice loop jump height with placebo.

The findings of this study conclude that, on average, off-ice loop jump height is increased with caffeine compared to placebo. The mean off-ice loop jump height amongst participants with placebo was 11.9±3.6 inches which increased by an average of .5 inches to 12.4±3.3 inches with caffeine. Although not every participant's off-ice loop jump height increased with caffeine supplementation, most participant's off-ice loop jump height increased with caffeine. This

implies a positive correlation between off-ice loop jump height and caffeine, which is indicative of caffeine supplementation increasing figure skating jump height.

This study attempted to bridge the gap in literature in regards to sport specific, practical application of the potential ergogenic effects of caffeine within the sport of figure skating, or more specifically, to determine the effect caffeine supplementation has on figure skating jump height. From the results of this study, it can be gathered that caffeine supplementation increases off-ice loop jump height in figure skaters. The biomechanics of an off-ice loop jump are very comparable to that of an on-ice loop jump. The preparation stance of an off-ice loop jump (skater standing with their body weight on their dominant leg, knees bent, and non-dominant leg in front of their dominant) simulates the preparation stance of an on-ice loop jump as well as the required outside edge of the dominant skating foot that is characteristic of an on-ice loop jump. Included in this off-ice loop jump preparation position, the skater's arms would be up at shoulder height in an L-formation (dominant arm to the side of the body, and non-dominant arm in front of the body), which is identical to the arm positions that would be used for execution of an on-ice loop jump. During an off-ice loop jump, the skater bends their knees and jumps up, completing a rotation by crossing their non-dominant foot over their dominant foot, and lands on their dominant foot, which is extremely comparable to the method of execution for an on-ice loop jump and simulates the appropriate edges that make up a loop jump. The skater's arms are pulled in to the center of the body for the duration of the jump both off-ice and on-ice. Seeing as the biomechanics of an off-ice loop jump are a very appropriate simulation of an on-ice loop jump, the results of this study imply that caffeine supplementation does increase figure skating jump height.

Knowledge of this could significantly impact the training regimens of athletes in the competitive figure skating world. When a figure skater attempts a jump in their competitive figure skating program, the skater receives a base value for the execution of the jump, but they are able to earn more points if their jump presents a delay in rotation and great height and/or distance. Each of these aspects that make a figure skating jump more competitively advantageous would benefit from an increased jump height. In the elite levels of figure skating, increasing a figure skater's jump height even slightly would be extremely beneficial. Implementing caffeine supplementation into the lives of competitive figure skaters would be relatively simple and easy. Additionally, often times recreational figure skaters lack the jump height necessary to master a new jump. The small boost in jump height that caffeine supplementation provides could be the key to figure skaters mastering new skills. Caffeine's ergogenic effects useful to the sport of figure skating could provide a range of benefits from improving a recreational figure skater with the increase in jump height necessary to land a new jump to providing the competitive edge necessary to put elite Team USA figure skaters above competitors in high level competitions like the Olympics.

Limitations

It is important to note that the increase in off-ice loop jump height between trials, for some participants, may have been influenced by increased comfortability with the testing procedures as time progressed. Although the off-ice loop jump is a fairly accurate simulation of an on-ice loop jump, it is not specifically how figure skaters are used to training. Most members of the Liberty University Figure Skating Team incorporate on-ice loop jumps into their daily training, whereas off-ice loop jumps are not practiced as often. It is possible that if a participant

received placebo as their first treatment and caffeine as their second treatment that the participant's off-ice loop jump height increase from trial 1 to trial 2 was due to increased comfortability with the testing procedures rather than from caffeine supplementation. Inversely, if a participant received caffeine for their first treatment and placebo for their second treatment and their off-ice loop jump height increased from trial 1 to trial 2, it is likely that the increase in jump height was due to increased comfortability with the testing procedures rather than the placebo treatment. However, the counterbalanced design was necessary to create the randomized, single-blind effects of the study.

It is impossible to completely eliminate extraneous variables, as the researcher is unable to control for the training program that the Liberty University Figure Skating Team participates in regularly. It is important to note that an increase in jump height from trial 1 to trial 2 could be influenced by strength training and/or figure skating practice amongst the participants. Since this study occurred while the team was in season, natural improvements in muscular strength, muscular endurance, and muscle power output will be made due to the team's programming. However, the amount of performance improvement that could occur in a week is unlikely to be substantial enough to influence the results.

Naturally, there are certain extraneous participant variables that are noteworthy as well. Although participants' attire, diet and water consumption, sleep, and abstinence from caffeine intake outside the study and strenuous training 24 hours prior to testing days were controlled for, these variables are subject to participants' level of adherence to the instructions they were given prior to testing. Participants' variance in level of exhaustion and/or muscle soreness between trial 1 and trial 2 could affect off-ice loop jump height differences. Additionally, it should be noted

that variance in the day of the week and time each testing session took place may have contributed to results as participants chose their own testing time on SignUpGenius, for their convenience.

Side effects due to caffeine consumption were unable to be controlled for within this study. Negative side effects from caffeine consumption can include restlessness and shakiness, insomnia, headaches, dizziness, increased heart rate, dehydration, and anxiety. In the event that a subject experienced any or multiple of these adverse side effects during their trial with caffeine, their off-ice loop jump height could have been affected. Additionally, a participant experiencing negative side effects during their trial with caffeine and no side effects during their trial with placebo may have revealed to the participant which pill they had been administered for each trial. This has potential to interfere with the single-blind aspect of the study, potentially allowing participants to subconsciously exert themselves more during the trial with caffeine than during the trial with placebo. However, a relatively low dose of caffeine was used in this intervention, which reduces the likelihood of side effects.

It is also important to note that caffeine affects each person differently. Some people are unaffected by caffeine consumption due to genetics, increased tolerance to the substance, or other neurobehavioral disorders like ADHD. The variability in how caffeine affects each person has the potential to create certain outliers within this study in the case that a participant of this study is unaffected by caffeine consumption or is affected by caffeine consumption to a different degree than other participants. It should also be considered that each participant’s different reaction to the caffeine pill could be due to the same dose of 200 mg being given to every

participant despite their body weight. A person with less body mass may feel greater effects of the 200 mg of caffeine than someone with greater body mass.

Future Research

The results of this study suggest that caffeine supplementation is an effective ergogenic aid and method of increasing jump height in the sport of figure skating as, on average, off-ice loop jump height increased with caffeine supplementation.

If this work were to be expanded upon, it would be beneficial to include additional trials with various amounts of caffeine. Knowing that caffeine supplementation does increase figure skating jump height, it is important to determine the most effective dose of caffeine. It is also important to determine point at which an increased dose of caffeine becomes ineffective. 200 mg of caffeine was the only dosage tested throughout this study, but the effect of smaller and larger doses of caffeine on figure skating jump height remains unresearched. A larger dose of caffeine may increase jump height more than the 200 mg of caffeine did, and results may be more significant. Up to 400 mg of caffeine is considered a safe daily dose of caffeine. In the future, a more in-depth study would be beneficial with several more trials in which participants are administered doses of caffeine ranging from 100 mg to 400 mg, likely in 50 mg increments. It would be beneficial to coaches and competitive figure skaters to understand a determined, precise dose of caffeine that is most effective as an ergogenic aid.

Additionally, in future research it would be beneficial to conduct a control trial with all participants before the experimental trials begin in which participants would not be given caffeine or placebo before testing. This would allow the researcher to collect baseline data of what each participant’s off-ice loop jump height is as well as get participants familiar with the

testing procedures. Addition of this trial would help to control the variability in the data that came with participant's increased comfortability with the testing procedures from trial 1 to trial 2. This would increase the accuracy of the results and confidence of the increased jump height data with caffeine supplementation to not have been influenced by this extraneous variable of comfortability with testing procedures.

For future research, in the presence of additional funding or access to further advanced equipment, it would be extremely beneficial to use an Inertial Measurement Unit (IMU: Opal model, APDM, Inc., Portland, OR, USA) with sensor straps (APDM, Inc., Portland, OR, USA) to collect on-ice jump height data. This piece of equipment would be strapped to the participants' torsos and accurately measure the figure skaters' jump height on the ice. Adjusting this study to include on-ice jump height testing instead of off-ice jump height testing increases the validity of the study and would produce more accurate data. Additionally, use of this more technologically advanced equipment would allow for testing of all figure skating jumps rather than just the loop jump. By incorporating the on-ice testing of loop, flip, lutz, toe-loop, axel, and salchow jump heights into the study, the collected data would better represent the trend of caffeine supplementation increasing figure skating jump height.

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