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Human Kinetics
ORIGINAL INVESTIGATION

Acute Enhancement of Jump Performance, Muscle Strength, and Power in Resistance-Trained Men After Consumption of Caffeinated Chewing Gum

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Purpose: To explore the acute effects of caffeinated chewing gum on vertical-jump performance, isokinetic knee-extension/flexion strength and power, barbell velocity in resistance exercise, and whole-body power. ***Methods:*** Nineteen resistance-trained men consumed, in randomized counterbalanced order, either caffeinated chewing gum (300 mg of caffeine) or placebo and completed exercise testing that included squat jump; countermovement jump; isokinetic knee extension and knee flexion at angular velocities of 60 and $180°\cdot s^{-1}$; bench-press exercise with loads corresponding to 50%, 75%, and 90% of 1-repetition maximum (1RM); and an "all-out" rowing-ergometer test. ***Results:*** Compared with placebo, caffeinated chewing gum enhanced (all $Ps < .05$) (1) vertical-jump height in the squat jump (effect size [ES] = 0.21; +3.7%) and countermovement jump (ES = 0.27; +4.6%); (2) knee-extension peak torque (ES = 0.21; +3.6%) and average power (ES = 0.25; +4.5%) at $60°\cdot s^{-1}$ and knee-extension average power (ES = 0.30; +5.2%) at $180°\cdot s^{-1}$, and knee-flexion peak torque at $60°\cdot s^{-1}$ (ES = 0.22; +4.1%) and $180°\cdot s^{-1}$ (ES = 0.31; +5.9%); (3) barbell velocity at 50% of 1RM (ES = 0.30; +3.2%), 75% of 1RM (ES = 0.44; +5.7%), and 90% of 1RM (ES = 0.43; +9.1%); and (4) whole-body peak power on the rowing-ergometer test (ES = 0.41; +5.0%). Average power of the knee flexors did not change at either angular velocity with caffeine consumption. ***Conclusions:*** Caffeinated chewing gum with a dose of caffeine of 300 mg consumed 10 min preexercise may acutely enhance vertical-jump height, isokinetic strength and power of the lower-body musculature, barbell velocity in the bench-press exercise with moderate to high loads, and whole-body power.

Keywords: caffeine, ergogenic aid, isokinetic testing, resistance training

Caffeine has been used as an athletic performance enhancer for many years.[1] For research purposes, most studies have administered caffeine in the form of a capsule.[2] An example of a study using this form of caffeine is one where the participants ingest a capsule, wait for 60 minutes, and then undergo an exercise protocol.[3] Caffeine is rapidly absorbed, and plasma concentration of caffeine is generally at its maximum level 1 hour postingestion of a caffeine-containing capsule.[3]

Currently, the effects of caffeine ingested in the form of a capsule on exercise performance have been well established, as indicated in several meta-analyses.[4–9] However, one area of caffeine supplementation that has not received sufficient attention in the literature is the effect of the so-called "alternate" forms of caffeine on exercise performance. Alternate forms of caffeine include chewing gums, bars, gels, mouth rinses, energy drinks, and aerosols.[2] Caffeinated chewing gums may be a particularly interesting alternate form of caffeine for athletes given that they provide (as compared with caffeine in capsules) an earlier onset of pharmacological effects of caffeine in the body. Kamimori et al[10] examined the absorption of caffeine in the plasma following the consumption of caffeinated chewing gum and ingestion of a caffeine-containing capsule. With caffeinated chewing gums, the initial increase in plasma caffeine concentration occurred within 5 minutes postingestion. For caffeine-containing capsules, this increase in plasma caffeine concentration was delayed until 25 minutes postingestion.[10] When consuming caffeinated chewing gums, the uptake of caffeine in the buccal cavity may partially explain this fast absorption.[2]

Wickham and Spriet[2] summarized the studies that explored the effects of caffeine administered in alternate forms. The authors have found only 7 studies that examined the effects of caffeinated chewing gum on exercise performance; specifically, these studies examined the effects on aerobic endurance, sprint performance, and shot-put distance.[2] These studies also generally used caffeine doses ranging from 100 to 300 mg, administered 5 to 10 minutes before exercise, while including various populations including physically active males, trained male and female cyclists, and collegiate shot-put athletes.[11–17] Although the findings of the mentioned studies indicated that caffeinated chewing gum may be ergogenic for performance, given the limited number of such studies, this method of caffeine delivery requires further scientific scrutiny.

Several recent reviews and/or meta-analyses on the topic of caffeine ingestion and exercise performance were published.[4,5,18] In one meta-analysis,[4] caffeine ingestion has been reported to increase vertical jump height, whereas in another,[5] caffeine was ergogenic for isokinetic peak torque. However, in both these meta-analyses, all the included studies provided caffeine to the participants in liquid or capsule forms. The authors of these analyses have, therefore, suggested that future work is warranted to explore the effects of alternate forms of caffeine (such as caffeinated chewing gum) on exercise performance. In addition, a recent review[18] of caffeine's effects on resistance exercise performance noted that one area in which future research is warranted pertains to the effects of caffeine provided in alternate forms.

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To address these notable gaps in the literature, this study aimed to explore the effects of caffeinated chewing gum on (1) vertical jump performance, (2) isokinetic knee extension and knee flexion strength and power, (3) barbell velocity in resistance exercise, and (4) whole-body power output. We hypothesized that caffeine in this form would elicit an ergogenic effect in all explored aspects of exercise performance.

Methods

Experimental Design

This study employed a randomized, cross-over, double-blind study design. The participants completed 3 visits to the laboratory. On the first visit, the participants were familiarized with the exercise tests. Following the familiarization visit, the participants were randomized to 2 main conditions (placebo and caffeinated chewing gum) in a counterbalanced fashion. Caffeine was administered in an absolute dose of 300 mg (Military Energy Gum; Ford Gum & Machine Co, Inc, Akron, NY). The placebo was a similar looking and tasting chewing gum that did not contain any caffeine (Spearmint Extra Professional; Wrigley, Chicago, IL). This protocol for the placebo administration was determined based on the study by Paton et al.[16] The participants chewed the gum for 10 minutes and then expectorated it into a container. Immediately after, the exercise session started; this timing of caffeine and placebo administration was previously used in a study by Ryan et al.[12]

Participants were requested to maintain their general sleep and nutritional habits, as well as not to perform any vigorous physical activity 1 day before the visits to the laboratory. All testing sessions were conducted in the morning hours (between 7 and 9 AM), and the participants refrained from caffeine ingestion after 6 PM on the days before these testing sessions. We provided the participants with a list of the most common food and drink products containing caffeine to aid in the process of caffeine restriction. The participants arrived at the laboratory in a fasted state (overnight fast). The placebo and caffeine testing sessions were separated by a minimum of 3 and a maximum of 6 days.

Participants

A priori power analysis that was performed with the expected effect size (*f*) of 0.20 for barbell velocity in the bench press exercise, α of .05, the statistical power of .80, and correlation of .90[19] indicated that minimum sample size for this study was 12 participants. To account for possible dropouts, 19 participants were initially recruited. These participants satisfied the inclusion criteria of being healthy men (aged 18–45 y), without any current muscular injuries or other physical limitations, and being resistance trained, defined by having at least 1 year of resistance exercise experience and by possessing the ability to lift ≥100% of their body mass in the bench press exercise. All 19 participants (mean [SD]): age 24 [5] y, height 183 [5] cm, body mass 83 [10] kg, habitual caffeine intake 67 [85] $mg \cdot d^{-1}$) completed the testing sessions and were included in the analysis (Figure 1). The Committee for Scientific Research and Ethics of the Faculty of Kinesiology at the University of Zagreb provided ethical approval for the study; written informed consent was obtained from all participants.

Exercise Tests

Vertical Jump. All testing sessions started with tests of jump performance. Here, the participants performed 3 squat jumps (SJ) followed by 3 countermovement jumps (CMJ) on a force platform (BP600600; AMTI, Inc, Watertown, MA) that was associated with custom-made software for data acquisition and analysis. The analyzed performance outcome was vertical jump height, which was automatically calculated by the software from the vertical

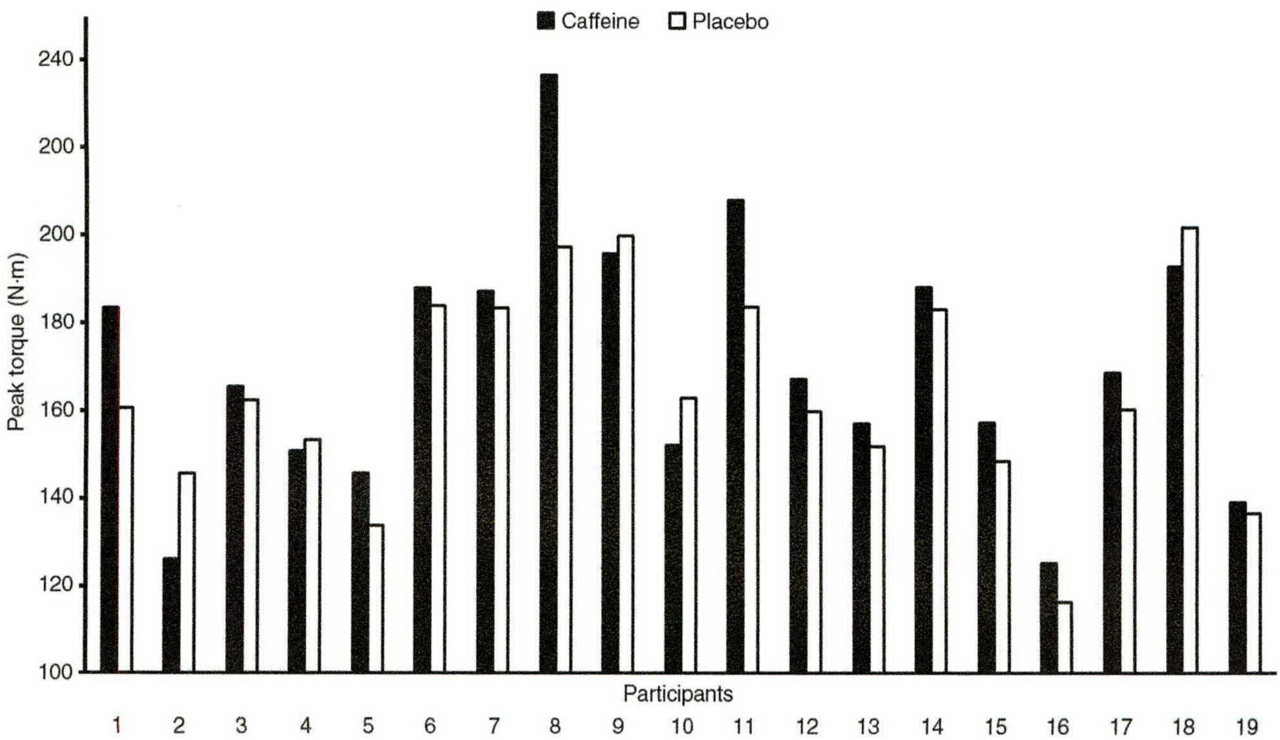

Figure 1 — Individual knee-extension peak torque data for the caffeine and placebo conditions, obtained at an angular velocity of 180 $°\cdot s^{-1}$ ($P = .073$ for the comparison between caffeine and placebo conditions).

velocity of the center of mass at takeoff data, as explained in a study by Moir.[20]

In the SJ, the participant started from a semisquat position (knee ~90° and trunk/hips in a flexed position). This position was held for 2 seconds; after that, the participants jumped vertically as quickly and as explosively as possible with instructions to maintain fully extended lower limbs throughout the flight period. The hands remained akimbo during the jump. In the CMJ, the participants started from an upright standing position. Upon receiving the command of the tester, the participants performed a fast knee flexion (ie, a downward countermovement) whereby their lowest position should be a semisquat position (knee ~90° and trunk/hips in a flexed position), immediately followed by an explosive extension of the legs. The participants were instructed to jump as quickly and explosively as possible. In both jump techniques, the participants performed one warm-up and 3 official attempts. Each attempt was separated by 1 minute of rest, and the highest jumps from 3 official attempts were used for the analysis. From pilot testing among 5 participants who repeated the testing protocol twice over separate days, the calculated coefficient of variation (CV) for the jump height amounted to 1.3% both for SJ and CMJ.

Isokinetic Strength and Power. Peak torque and average power of the knee extensors and knee flexors were assessed on an isokinetic dynamometer (System 4 Pro; Biodex Medical Systems, Inc, Shirley, NY). The dynamometer was calibrated before each testing session, and assessment was performed only for the dominant leg. Upon placing the participants in a seated position, stabilization straps were applied to the trunk, waist, thigh, and shin. The lateral femoral epicondyle of the dominant leg was aligned with the dynamometer's axis of rotation.

The range of motion of the knee joint in this test was set at 80°, and the employed angular velocities were 60 and 180°·s^{-1} (tested in that order). To get accustomed to the speed of the lever arm, the participants initially performed 3 familiarization repetitions. This was performed for both angular velocities. After familiarization was completed, the participants were given a 30-second rest interval after which they performed 5 maximal knee extensions and flexions with instructions to extend and flex the knee (to "kick" and "pull") as hard and as fast as they could. Peak torque and average power of the knee extensors and flexors at both angular velocities were used for the analysis. From pilot testing, the calculated CV for the knee extension peak torque and average power at both angular velocities ranged from 1.7% to 2.7%. The corresponding CV values for the knee flexors ranged from 4.4% to 5.9%.

Bench Press. For the assessment of barbell velocity in the bench press exercise, we used the valid, reliable, and accurate PowerLift mobile phone application.[21] The values obtained using this application are in a high correlation (r = .97–.98) with linear position transducers, which represent the gold standard for the assessment of barbell velocity.[21] The application allows (1) video recording of the lift in slow motion, (2) frame-by-frame inspection of the recorded video, and (3) manual selection of the beginning and the end of the movement. For the exercise employed in this study (ie, bench press), the moment when the barbell left the chest of the participant was considered as the beginning phase of the movement. Full extension of the participant's elbows denoted the end of the movement. The outcome of this test was mean barbell velocity during the press. In this study, the participants performed 2, 1, and 1 repetition with loads corresponding to 50%, 75%, and 90% of their 1-repetition maximum (1RM), respectively. The participants were provided with instructions to press the barbell as fast as possible. Between loads and repetitions, the participants rested for 3 minutes. From pilot testing, the calculated CV for barbell velocity at 50%, 75%, and 90% of 1RM amounted to 1.7%, 3.6%, and 5.1%, respectively.

Rowing-Ergometer Test. Whole-body power was assessed on a Concept2 rowing ergometer (model D; Concept2, Morrisville, VT). In this test, the resistance control dial of the ergometer was set at the highest adjustable resistance (ie, 10; drag factor: 195). Initially, the participants familiarized themselves with the ergometer by rowing comfortably at their own pace for 5 minutes. Then, the participants rested for 2 minutes and then performed 6 "introductory" strokes that were immediately followed by 6 "all-out" strokes. For the "all-out" strokes, the participants were instructed to row as hard and as fast as they could, as suggested by Metikos et al[22] who previously validated this test. During these "all-out" strokes, peak power output was the highest external power output, as displayed on the Concept 2 performance monitor. The CV for this outcome amounted to 2.5%.

Side Effects. Immediately after the completion of the testing sessions and in the following mornings, the participants completed an 8-item survey with a "yes/no" response scale regarding the incidence of side effects. This scale has been used to assess the side effects of caffeine in previous research that examined caffeine's effects on exercise performance.[23]

Assessment of Blinding. To explore the effectiveness of the blinding procedures, we asked the participants (both preexercise and postexercise) to identify the supplement they had ingested. For this purpose, the question went as follows: "Which supplement do you think you have ingested?" The question had 3 possible answers: (a) caffeine, (b) placebo, and (c) don't know.[24]

Statistical Analysis

The normality of distribution was confirmed using the Shapiro–Wilk test. To analyze the differences between conditions (ie, placebo and caffeine) for all performance outcomes, a series of 1-way repeated-measures analyses of variance was performed. The statistical significance threshold was set at $P < .05$. Effect sizes (ESs) were calculated where the mean difference between the 2 measurements is divided by the pooled SD. The ES magnitude was classified as follows: trivial (<0.20), small (0.20–0.49), moderate (0.50–0.79), and large (≥0.80). Percentage differences between the conditions were also calculated. The Bang blinding index (BBI) was used to explore the effectiveness of the blinding, whereas the McNemar test was used in the comparison of the incidence of side effects between the placebo and caffeine conditions. All analyses were performed using the Statistica software (StatSoft, Tulsa, OK).

Results

Vertical Jump

Following the consumption of caffeinated chewing gum, vertical jump height improved in SJ (P = .023; ES = 0.21; +3.7%) and in the CMJ (P < .001; ES = 0.27; +4.6%) (Table 1).

Isokinetic Strength and Power

Significant effects of caffeine on peak torque at an angular velocity of 60°·s^{-1} were observed for the knee extensor (P = .048; ES = 0.21; + 3.6%) and the knee flexor muscles (P = .040; ES = 0.22; + 4.1%). Caffeine also increased the peak torque at an angular velocity of 180°·s^{-1} in the knee flexor (P = .021;

ES = 0.31; +5.9%) but not in the knee extensor muscles (P = .073; ES = 0.22; +3.5%). Caffeine increased the average power at angular velocity of 60°·s^{-1} in the knee extensor (P = .031; ES = 0.25; +4.5%) but not in the knee flexor muscles (P = .320; ES = 0.09; + 1.7%). At an angular velocity of 180°·s^{-1}, caffeine increased the average power in the knee extensor (P = .035; ES = 0.30; + 5.2%) but not in the knee flexor muscles (P = .265; ES = 0.17; + 4.1%).

Bench Press

A significant effect of caffeine was observed for barbell velocity at loads corresponding to 50% of 1RM (P = .044; ES = 0.30; + 3.2%), 75% of 1RM (P = .005; ES = 0.44; + 5.7%), and 90% of 1RM (P = .002; ES = 0.43; + 9.1%).

Rowing-Ergometer Test

A significant effect of caffeine was observed for peak power output on the rowing ergometer test (P = .006; ES = 0.41; + 5.0%).

Side Effects

The incidence of side effects is presented in Table 2. Based on the results of the McNemar test, none of the comparisons between the caffeine and placebo conditions were significant (P > .05 for all comparisons).

Assessment of Blinding

When using preexercise responses, the BBI for the placebo and caffeine treatments amounted to 0.78 (95% confidence interval [CI], 0.60 to 0.97) and 0.32 (95% CI, −0.01 to 0.73), respectively. When assessed postexercise, the BBI for the placebo and caffeine conditions amounted to 0.63 (95% CI, 0.33 to 0.93) and 0.53 (95% CI, 0.22 to 0.83), respectively.

Discussion

This study explored the effects of caffeinated chewing gum on the performance of trained men in exercise tests that are very short in

Table 1 Differences in Placebo Versus Caffeine Conditions for the Performance Outcomes

Exercise test	Outcome	Caffeine condition, mean (SD)	Placebo condition, mean (SD)	Effect size	Relative effects, %	P
Squat jump	Jump height, cm	31.9 (6.0)	30.8 (5.3)	0.21	+3.7	.023*
Countermovement jump	Jump height, cm	36.4 (6.2)	34.8 (5.8)	0.27	+4.6	<.001*
Isokinetic knee extension at 60°·s^{-1}	Peak torque, N·m	245.0 (43.3)	236.6 (36.2)	0.21	+3.6	.048*
	Average power, W	180.0 (34.1)	172.1 (29.1)	0.25	+4.6	.031*
Isokinetic knee flexion at 60°·s^{-1}	Peak torque, N·m	142.7 (25.5)	137.1 (25.4)	0.22	+4.1	.040*
	Average power, W	111.3 (21.3)	109.5 (21.4)	0.09	+1.7	.320
Isokinetic knee extension at 180°·s^{-1}	Peak torque, N·m	170.2 (28.7)	164.4 (23.8)	0.22	+3.5	.073
	Average power, W	322.1 (59.1)	306.2 (48.4)	0.30	+5.2	.035*
Isokinetic knee flexion at 180°·s^{-1}	Peak torque, N·m	107.6 (17.6)	101.7 (19.9)	0.31	+5.9	.021*
	Average power, W	196.6 (41.9)	188.8 (48.9)	0.17	+4.1	.265
Bench press at 50% 1-repetition maximum	Barbell velocity, m·s^{-1}	0.85 (0.08)	0.82 (0.09)	0.30	+3.2	.044*
Bench press at 75% 1-repetition maximum	Barbell velocity, m·s^{-1}	0.57 (0.07)	0.54 (0.06)	0.44	+5.7	.005*
Bench press at 90% 1-repetition maximum	Barbell velocity, m·s^{-1}	0.38 (0.07)	0.35 (0.07)	0.43	+9.1	.002*
Rowing-ergometer test	Peak power, W	667.5 (78.5)	635.9 (68.7)	0.41	+5.0	.006*

*Statistically significant differences.

Table 2 Incidence of Side Effects Reported Immediately After and the Morning After the Ingestion of a Caffeinated Gel or a Placebo

	Immediately after testing session		Morning after testing session	
	Placebo	Caffeine	Placebo	Caffeine
Muscle soreness	0	11	0	0
Increased urine production	0	11	0	0
Tachycardia and heart palpitations	11	16	0	0
Increased anxiety	0	21	0	0
Headache	0	5	0	0
Abdominal/gut discomfort	0	5	0	0
Insomnia	n/a	n/a	0	0
Increased vigor/activeness	26	58	0	0
Perception of improved performance	21	63	n/a	n/a

Abbreviation: n/a, not applicable. Note: Data are frequencies for 19 participants, expressed as percentage of positive cases; none of the comparisons were significant based on the McNemar test (P > .05 for all).

duration and that require maximal exertion. Our results indicate that caffeine supplementation with chewing gum as a source of caffeine, administered 10 minutes before exercise, has an ergogenic effect on (1) vertical jump height in the SJ and CMJ; (2) upper-body muscular power, as assessed by the barbell velocity in the bench press exercise with loads ranging from 50% to 90% of 1RM; and (3) whole-body power, as assessed by the peak power output achieved during a rowing ergometer test. Furthermore, our results indicate that caffeine in the form of chewing gum has an ergogenic effect on most measures of strength and power of the lower-body musculature, as assessed by the isokinetic testing at 2 angular velocities. These results only partially confirm our hypothesis.

Vertical Jump

Caffeinated chewing gum acutely increased vertical jump height with small ES for both SJ and CMJ tests (0.21 and 0.27, respectively). A recent meta-analysis[4] also indicated that preexercise ingestion of a caffeine-containing capsule increases vertical jump height by a pooled ES of 0.17. Given that the present study is one of the first to explore the effects of caffeinated chewing gum on jump performance, the comparison of our results with results of other similar studies is currently limited. To the best of our knowledge, only one study thus far had a comparable design. Ranchordas et al[25] provided caffeinated chewing gum (200-mg dose of caffeine) to a sample of 10 university-standard soccer players 10 minutes before exercise and observed an increase in CMJ height by +2.2% (ES = 0.30). Our study, alongside the work by Ranchordas et al,[25] supports the ergogenic effects of caffeinated chewing gum on vertical jump height. Still, future work on the effects of caffeinated chewing gum on vertical jump performance is warranted given the current paucity of studies utilizing this caffeine form.

Isokinetic Strength and Power

As compared with placebo, caffeinated chewing gum acutely enhanced peak torque in the knee extensor and the knee flexor muscles. Of note here, we did not observe a significant effect of caffeine on peak torque of the knee extensor muscles at an angular velocity of $180°\cdot s^{-1}$. However, the *P* value of .073 is indicative of an effect that likely did not reach the threshold of statistical significance due to the considerable variability in responses to caffeine ingestion between individuals (Figure 1).[26] Although the present study is, to our knowledge, the first that explored the effect of caffeinated chewing gum on isokinetic strength and power, the results are still in line with a recent meta-analysis[5] and previous original studies[27] that reported ergogenic effects of caffeine provided in capsules on knee extension peak torque.

Caffeinated chewing gum consumption also enhanced the average power of the knee extensor but not of the knee flexor muscles. These results support the idea that caffeine consumption might have a more pronounced effect in the larger muscle groups of the body (ie, knee extensors), whereas its impact on smaller muscle groups, such as the knee flexors, may be in most cases less pronounced.[8] From a practical standpoint, isokinetic assessments are more often used for the evaluation of the function of the muscular system and not for training per se. Therefore, these results highlight that there is a need to control for caffeine intake when undertaking an isokinetic assessment.[5]

Bench Press

Consumption of caffeinated gum enhanced power of the upper-body musculature as it increased barbell velocity in the bench press exercise across all 3 loading schemes (ie, 50%, 75%, and 90% of 1RM). These results support previous research that examined caffeine's effects on barbell velocity. In one study, Mora-Rodríguez et al[28] investigated the effects of caffeine ingestion in the dose of $3\ mg\cdot kg^{-1}$ administered 60 minutes before performing the bench press exercise with a load of 75% of 1RM. In that study, caffeine ingestion enhanced barbell velocity by approximately 5%, which is comparable with increases observed herein.

In one study that examined the effects of caffeine ingestion on barbell velocity, Pallarés et al[29] explored the effects of caffeine in doses of 3, 6, and $9\ mg\cdot kg^{-1}$ on barbell velocity in the bench press with loads amounting to 25%, 50%, 75%, and 90% of 1RM. For the 2 lower loads, all doses were effective. For 75% of 1RM, doses of 6 and $9\ mg\cdot kg^{-1}$ were ergogenic. However, only a dose of $9\ mg\cdot kg^{-1}$ enhanced barbell velocity when using a 90% of 1RM. These results have led to speculation by researchers that the effects of caffeine on barbell velocity in resistance exercise may be external load- and caffeine dose-dependent.[10] Our results do not support this idea given that an absolute dose of caffeine of 300 mg (~$3.6\ mg\cdot kg^{-1}$) enhanced barbell velocity across all 3 loads. Diaz-Lara et al[23] observed that caffeine in the dose of $3\ mg\cdot kg^{-1}$ enhanced barbell velocity across different loads with the effects being statistically significant at loads corresponding to 25%, 43%, and 68% of 1RM. These results are similar to those of Del Coso et al[30] who reported that caffeine ingestion in the dose of $3\ mg\cdot kg^{-1}$ (but not $1\ mg\cdot kg^{-1}$) enhanced power in the bench press exercise with most of the employed loads that ranged from 10% to 100% of 1RM. The results of our study, alongside the works of others, indicate an ergogenic effect of caffeine on power in resistance exercise. Therefore, resistance-trained individuals aiming for acute power enhancements during resistance exercise may consider supplementing with caffeine preexercise.

Rowing-Ergometer Test

Whole-body peak power output as assessed using the rowing ergometer test was enhanced following the ingestion of caffeine (ES = 0.41; +5.0%). To the best of our knowledge, this study is the first that explored the effects of caffeine chewing gum on whole-body power. As such, the comparison with other studies in the literature is limited. Nonetheless, these results demonstrated 2 important novel findings, (1) caffeine ingestion might enhance power output even when using complex exercise tasks that require simulations coordinated activity of the upper and lower body, such as a rowing motion and (2) caffeinated chewing gum, administered 10 minutes before exercise, may have an ergogenic effect even in exercise tasks that are performed ~60 minutes postconsumption.

Side Effects

As evident from Table 2, the incidence of side effects of caffeine supplementation, as experienced by the participants, was minimal. An issue that some individuals may experience following caffeine ingestion is insomnia. However, when assessed in the morning after the testing session that included caffeine supplementation, none of the participants reported that they had experienced insomnia. These results may be related to the time of day at which caffeine was administered, as all testing sessions took place in the morning hours. Caffeine has a half-life of 4 to 6 hours; therefore, the ingestion of caffeine in the morning hours ensured no manifestation of the possible insomnia-related effects of caffeine. In summary, the assessment of side effects in the present study highlights that caffeine ingestion in the applied dose and form is relativity safe for young men.

Limitations

The major limitation of the present study is that the blinding procedures were not completely effective. When examining preexercise responses, 78% of the total sample correctly identified the placebo beyond random chance. In the postexercise responses, 63% and 53% of the participants correctly identified the placebo and caffeine conditions, respectively. The only effective case of blinding was when caffeine supplementation was provided preexercise (BBI = 0.32; 95% CI, −0.01 to 0.73). Therefore, the results might have been subject to bias given that participants were able (on some occasions) to correctly identify the substance consumed. With that being said, in one study, 80% of the sample correctly identified caffeine condition, yet no ergogenic effects of caffeine on 2000-m rowing performance were observed.[31] In another, even though the study did not have a blinding component, caffeine was not ergogenic for peak torque.[32] Finally, Tallis et al[33] noted that participants equally improved their peak torque when (1) they were told that they received caffeine and indeed received a dose of caffeine and (2) when they were told that they received placebo even though the capsule contained caffeine. While these results support an actual effect of caffeine, the limitation regarding the effectiveness of blinding still needs to be acknowledged.

In addition, the use of an absolute dose of caffeine needs to be highlighted as a limitation of the study. When prescribing caffeine supplementation, researchers and practitioners generally use a relative dose (ie, milligrams of caffeine per kilogram of body mass). When expressed relative to the body mass of the participants, the caffeine dose in the present study ranged from 2.7 to 4.5 $mg \cdot kg^{-1}$. Caffeinated chewing gums contain a fixed amount of caffeine (eg, 100 mg of caffeine per one piece of gum, for the gum used in the present study) that limits precise dosing relative to the body mass of a consumer; however, future studies may consider exploring ways to circumvent this confounding factor when administering caffeine in the form of a chewing gum.

Practical Applications

Caffeinated chewing gum with a 300-mg dose of caffeine, consumed 10 minutes before exercise, may acutely enhance vertical jump height, isokinetic strength and power of the lower-body musculature, barbell velocity in the bench press exercise with moderate to high loads, and whole-body power. Trained individuals interested in caffeine supplementation may consider consuming caffeinated chewing gum preexercise for the enhancements in exercise performance mentioned previously.

Conclusions

A relatively low absolute dose of caffeine (300 mg) provided in a form of a chewing gum, consumed only 10 minutes preexercise, seems effective for acute improvements in vertical jump height, isokinetic peak torque of knee extensors and flexors, bench press barbell velocity with loads of 50%, 75%, and 90% of 1RM, and whole-body power in a rowing ergometer test.

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