Effect of Caffeine on Golf Performance and Fatigue during a Competitive Tournament

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[1]Molecular and Applied Sciences Laboratory, School of Kinesiology, Auburn University, Auburn, AL; [2]Department of Human Performance Studies, Wichita State University, Wichita, KS; [3]Department of Applied Physiology and Wellness, Southern Methodist University, Dallas, TX; [4]School of Medical and Applied Sciences, Central Queensland University, Rockhampton, Queensland, AUSTRALIA; [5]MusclePharm Sport Science Institute, Denver, CO; and [6]Department of Cell Biology and Physiology, Edward Via College of Osteopathic Medicine, Auburn Campus, Auburn, AL

ABSTRACT

MUMFORD, P. W., A. C. TRIBBY, C. N. POOLE, V. J. DALBO, A. T. SCANLAN, J. R. MOON, M. D. ROBERTS, and K. C. YOUNG. Effect of Caffeine on Golf Performance and Fatigue during a Competitive Tournament. *Med. Sci. Sports Exerc.*, Vol. 48, No. 1, pp. 132–138, 2016. **Purpose**: This study aimed to determine the effect of a caffeine-containing supplement on golf-specific performance and fatigue during a 36-hole competitive golf tournament. **Methods**: Twelve male golfers (34.8 ± 13.9 yr, 175.9 ± 9.3 cm, 81.23 ± 13.14 kg) with a United States Golf Association handicap of 3–10 participated in a double-blind, placebo-controlled, crossover design in which they played an 18-hole round of golf on two consecutive days (36-hole tournament) and were randomly assigned to consume a caffeine-containing supplement (CAF) or placebo (PLA). CAF/PLA was consumed before and after nine holes during each 18-hole round. Total score, drive distance, fairways and greens in regulation, first putt distance, HR, breathing rate, peak trunk acceleration, and trunk posture while putting were recorded. Self-perceived ratings of energy, fatigue, alertness and concentration were also recorded. **Results**: Total score (76.9 ± 8.1 vs 79.4 ± 9.1, $P = 0.039$), greens in regulation (8.6 ± 3.3 vs 6.9 ± 4.6, $P = 0.035$), and drive distance (239.9 ± 33.8 vs 233.2 ± 32.4, $P = 0.047$) were statistically better during the CAF condition compared with those during PLA. Statistically significant main effects for condition ($P < 0.05$) and time ($P < 0.001$) occurred for perceived feelings of energy and fatigue. Compared with PLA, CAF reported more energy ($P = 0.025$) and less fatigue ($P = 0.05$) over the competitive round of golf. There were no substantial differences in HR or breathing rates, peak trunk acceleration, or putting posture between conditions or over the round ($P > 0.05$). **Conclusions**: A moderate dose (1.9 ± 0.3 $mg \cdot kg^{-1}$) of caffeine consumed before and during a round of golf improves golf-specific measures of performance and reduces fatigue in skilled golfers. **Key Words:** NUTRITION, GOLFERS, ENERGY, ACCURACY

Golf is a popular sport around the world with individuals playing competitively and recreationally. When played competitively, golf involves high cognitive loads, critical shot-making decisions, hand–eye coordination, high-level motor and biomechanical skill, and an extended duration of play that exceeds most other sports (28). From an intensity perspective, the physiological demands of golf are considered low, with one round of 18 holes taking approximately 4 h to complete and having an energy expenditure of 4.3–4.5 METs (1,11). However, one round of golf can result in walking well over 10,000 steps covering distances over 8000 m (13). Furthermore, competitive golf settings include preround warm-ups, practice swings, and execution of in-round swings. During an 18-hole round, swinging a golf club will be repeated, on average, 50 times and over 300 times during a practice session (30). This combination of critical shot-making decisions, multiple maximum effort swings, putting, and long distances of walking during the round can result in physical and mental fatigue, which can potentially have a negative effect on golf performance (9,29). Specifically, mental fatigue may affect the ability to select the correct club, shot type, and execution of the golf shot (28), whereas physical fatigue may affect the mechanics of the golf swing (14). Therefore, competitive golfers may benefit from preround and in-round nutritional and supplementation strategies aimed at offsetting fatigue experienced during a competitive round of golf (13).

Because caffeine has psychological and physiological effects, it has become one of the most consumed ergogenic aids to date (3). Indeed, Del Coso et al. (8) reported that 74% of the 20,686 elite athletes sampled between years 2004 and 2008 were found to consume caffeine either before or during competition. Furthermore, consuming moderate doses of caffeine either 1 h before or throughout the cycling exercise has been shown to enhance performance and improve time to fatigue (7,20). The ergogenic benefits

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of caffeine are not restricted solely to physical performance outcomes because several studies support its effectiveness of enhancing cognitive ability during mentally (19) and physically fatiguing tasks (19,27). For instance, in situations where fatigue is forced such as in sleep deprivation studies, moderate doses of caffeine have been shown to reduce fatigue during short-term vigilance tasks (32). Therefore, caffeine may play an important role in performance outcomes during periods of increased cognitive demand, reaction time, and when technical/tactical skills have a major influence on physical and mental performance (15,33). To our knowledge, only one study has previously attempted to determine the effects of caffeine supplementation on golf performance. Stevenson et al. (29) determined the acute effects of a caffeine and glucose drink on golf performance in a laboratory setting to simulate competitive golf course play (29). Their findings suggested that consuming a combination of glucose and caffeine was beneficial for minimizing fatigue and improving golf performance. However, there is a lack of research on overall golf performance in a true competitive tournament setting. Therefore, the purpose of this study was to investigate the acute effects of a caffeine-containing nutritional supplement on golf performance and fatigue during a competitive 36-hole tournament.

METHODS

Subjects. A convenience sample of 12 male golfers (Table 1) were recruited from local golf courses, newspaper advertisements, and the local university campus. Participants were included if they were habitual caffeine consumers (35–300 mg·d^{-1}), had a United State Golf Association (USGA) handicap between 3 and 10, were between 20 and 55 yr of age, free of known cardiovascular, respiratory, metabolic, or musculoskeletal ailments, and were not taking any other purported performance-enhancing supplements/ergogenic aids. After ethical approval from the institutional review board, participants were informed of all experimental procedures, read and signed informed consent forms, and filled out medical history forms detailing caffeine use and golf playing history.

Experimental protocol. In a double-blind, placebo-controlled, crossover design, participants played an 18-hole round of golf on two consecutive days (36-hole tournament). A simple randomization procedure was used to assign participants to consume a caffeine-containing supplement (CAF) or placebo (PLA) during each 18-hole round. Participants reported to the human performance laboratory 1 wk before their first round of golf for anthropometric and physiological assessments. During this visit, participants were familiarized with tournament procedures and USGA rules. The tournament was conducted at the local university golf course where tee box markers and hole locations were held constant. To ensure a competitive setting, a $1000 purse provided by the researchers was awarded to participants on the basis of the place finished in the 36-hole tournament. Participants were allowed to use their own golf equipment (clubs/golf balls) but were restricted to remain consistent between 18-hole rounds. The brands/models of golf equipment were documented before the start of the tournament, and adherence was ensured by researchers before the start of each round. Importantly, each participant had previously played a round of golf on the golf course.

TABLE 1. Baseline male subject characteristics (mean ± SD).

	n = 12
Height (m)	1.76 ± 0.09
Weight (kg)	81.2 ± 13.1
Age (yr)	34.8 ± 13.9
BMI (kg·m^{-2})	26.3 ± 3.6
USGA handicap	5.5 ± 2.7
Caffeine intake (mg·d^{-1})	101.7 ± 59.8

BMI, body mass index.

On the day of each round, participants were informed to abstain from consuming any foods, drinks, or nutritional products containing caffeine, to arrive hydrated, and to have consumed a meal 2 h before. Participants were asked to follow the same procedures for the second day including consumption of the same meal. Upon arriving, participants produced a urine sample, were fit with a mobile physiological monitoring device, and rested in a seated position for 10 min for collection of resting data. Afterwards, participants assigned to the CAF or PLA group consumed their first dose and were driven to the driving range where they were allowed 10 min to hit 20 golf balls and were not restricted to swinging specific clubs. Once completed, participants were taken to a practice hole for an iron club accuracy assessment. The time that elapsed between the first CAF or PLA oral dose and the accuracy assessment was approximately 25–35 min. This time course was maintained to allow caffeine levels to reach peak plasma concentration (4). After the assessment, participants were driven to the first tee box by a research assistant who collected in-round golf data and transported golf clubs via a golf cart. Participants then completed an energy/mood status questionnaire and began their round of golf thereafter. Participants walked the entire tournament and had access to chilled water bottles *ad libitum*. After completion of the first nine holes, participants consumed a second dose of CAF/PLA, were provided a standardized meal aimed at offsetting the decline in blood glucose levels (13), and completed a second questionnaire. Upon completion of the round, participants completed the final questionnaire, physiological monitors were turned off and collected, and participants were debriefed and reminded of the procedures for the following day/round. See Figure 1 for an overview of the protocol.

Anthropometric and physiological assessment. Standing height was measured to the nearest 0.5 cm using a calibrated stadiometer. Body mass was measured with a calibrated clinical scale to the nearest 0.01 kg with participants wearing minimal clothing (Table 1). After resting quietly, systolic and diastolic brachial blood pressure and HR were measured using an automatic blood pressure cuff (model HEM-773; Omron, Vernon Hills, IL) in a seated position. Urine samples were collected for determination of

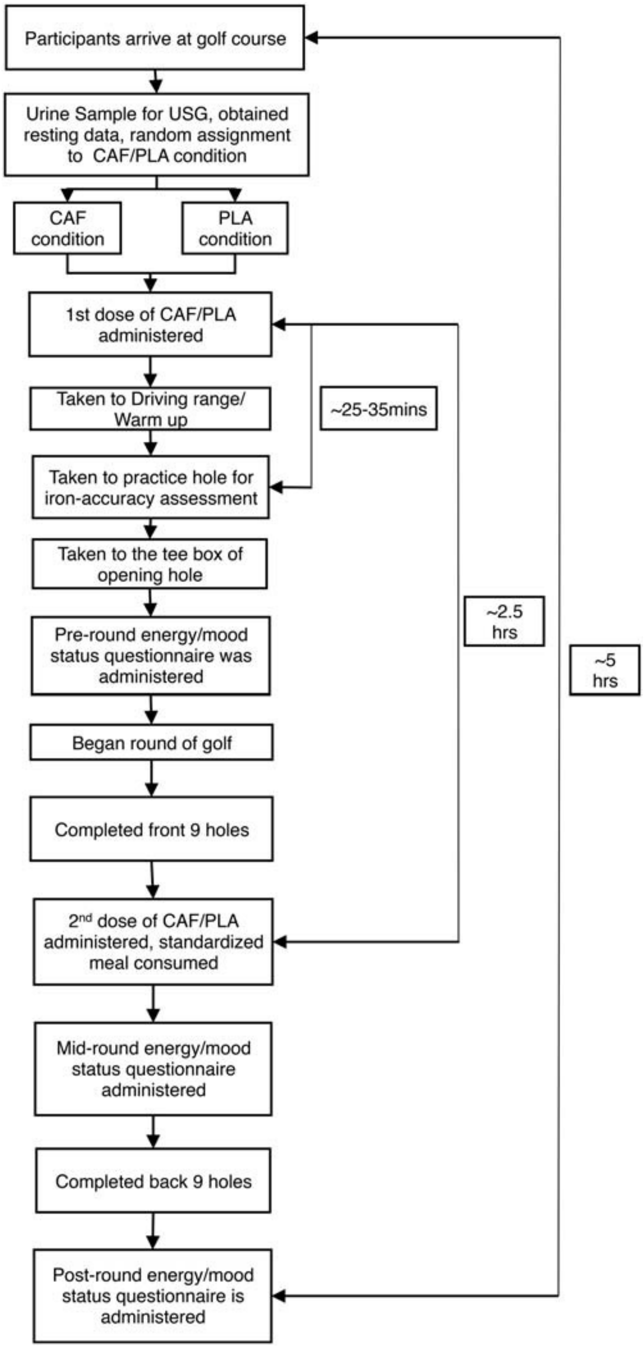

FIGURE 1—Overview of experimental protocol on the day of each round.

hydration status via urine specific gravity (USG) with a handheld refractometer (model CLX-1, precision = 0.001 ± 0.001; VEE GEE Scientific, Inc.). A USG reading between 1.000 and 1.029 was considered adequately hydrated (5). If participants had a USG reading at or above 1.030, they were instructed to drink water and rest comfortably until a second urine sample could be provided. Hydration was assessed as a precautionary measure to ensure participants' safety and to minimize the effects of dehydration on performance.

Environmental conditions. Ambient temperature (°C), relative humidity (%), wind speed (km·h^{-1}), and direction during each round were documented in 30-min intervals. Data was provided by the Wichita division of the National Oceanic and Atmospheric Administration from weather sensors located near the golf course.

Five-ball iron club accuracy assessment. On a 100.5-m practice hole, participants were allowed eight attempts to land the golf ball as close to the hole as possible. The first three attempts were for practice, and the last five were measured. Once the golf ball came to rest, distance (m) from the front of the ball to the middle of the hole and whether the ball rested on the green (# balls) were measured and documented. Distances were measured using a 92-m industrial tape measure. Participants chose a club of their choice but maintained the use of this club on both days. Furthermore, the same golf balls were used each day, which were provided by researchers.

Drive and putt distance. Drive distance (m) (when a driver club was used) was measured using a SkyCaddie LINX GPS device (SkyHawke Technologies, LLC, Ridgeland, MS). Once participants placed the tee and ball into the ground of the tee box, the location was marked with the GPS by standing directly over the ball, waiting 3 s, and then marked using the device's "mark ball" function. After the tee shot, the resting location of the ball was identified; the device was then held over the top of the ball for three seconds and "marked" again. The distance between the two locations was displayed on the device and documented by researchers. Intra- and interdevice test–retest reliability was previously determined on the same golf course from 15 distances measured twice and computed using intraclass correlation coefficients (ICC), SEM, and minimal difference (MD) to be considered real. Intradevice measurements resulted in an ICC of 0.999, SEM of 0.73 m, and MD of 2.02 m, whereas interdevice measurements resulted in an ICC of 0.997, SEM of 1.92 m, and MD of 5.32 m. On the basis of this analysis, each participant was assigned their own GPS, which was used for both rounds. All first putt attempts were measured for distance (m) from the front of the ball to the middle of the hole with a 92-m industrial tape measure. Care was taken to ensure that the tape was straight, taut, and laid flat against the putting surface.

Physiological and accelerometry measures. HR (bpm), breathing rate (BR, breaths per minute), trunk posture (POS (°)), and peak trunk acceleration (ACC_{peak} (g)) were determined using the Zephyr Bioharness^{TM} 3 (Zephyr Technology, Annapolis, MD). The device was worn just beneath the chest across the sternum and secured with an elastic nylon strap with extra support provided by a shoulder strap. The monitoring device is secured to the chest strap and acts as a transmitter and data logger. The device uses a piezoelectric triaxial accelerometer, electrode, and pressure sensors within the strap. The validity and reliability of this device have been described previously (HR: $r = 0.61$, $P < 0.01$; BR: $r = 0.67$, $P < 0.01$; ACC: $r = 0.90$, $P < 0.01$) (17). Specifically, trunk POS immediately before putting was assessed during the first and last three holes of each round. Trunk ACC_{peak} was assessed on all holes only when the driver club was used. Data were logged, time-stamped, and exported to Microsoft Excel (Microsoft, Redmond, WA) immediately after each round for subsequent analysis. To minimize interdevice error (17), all participants were assigned their own Bioharness device, which was used for both rounds (Table 1).

Golf-specific performance. Total score (number of strokes to complete 18 holes), putts per round, fairways hit in regulation (FIR, defined as the ball lying in the fairway after a tee shot on a par 4 or 5 hole), greens hit in regulation (GIR, defined as the ball lying on the surface of the green after the tee shot on a par 3, after the second shot on a par 4, or after the third shot on a par 5 hole), sand shots (defined as a ball being hit into a sand bunker), sand save percentage (SS%, defined as the percentage of time a golfer successfully hits the ball onto the green from a bunker and makes the following putt to save par), and shots hit out of bounds (OB, defined as a ball being hit out of the field of play resulting in a penalty stroke) were documented by research staff following participants throughout both rounds.

Energy/mood questionnaire. A five-item visual analog scale questionnaire previously used in caffeine research and partly adapted from Rogers et al. (26) was used to assess self-perceived feelings of concentration, energy, fatigue, alertness, and overall confidence. Each mood state/feeling was followed by a 100-mm horizontal line with vertical lines anchored at each end. The left-end anchor was labeled "Very Low," and the right anchor was labeled "Very High." Participants were instructed to make a vertical mark through the line on the basis of how they felt at that moment. Responses were measured in millimeters (0–100) starting at the left anchor of the scale. The questionnaire was administered at the beginning of each round (pre), after the ninth hole (mid), and after the 18th hole (post).

Supplementation/in-round nutrition. Caffeine (CAF, 155 mg) was provided in two forms: raw caffeine and PURENERGY® (caffeine and pterostilbene; ChromaDex, Inc., Irvine, CA) in a multi-ingredient proprietary blend supplement in a purified water-based medium containing vitamin B complex, citric acid, elevATP® (VDF FutureCeuticals Inc., Momence, IL) and sucralose. PLA was provided in a similar purified water-based medium matched for color and consistency but containing only sucralose to match flavor profile. To maintain blinding, both CAF and PLA were delivered directly from the third-party manufacturer (BioZone Laboratories, Inc., Pittsburg, CA) in unmarked black and white plastic vials containing a single 2-mL serving. Vials were administered to participants before each round of golf and after the ninth hole. A second dose was given because of the half-life of caffeine and the lengthy play of golf (2). After consuming the second vial of CAF or PLA, a standardized meal providing 340 calories, 42 g of CHO, 12 g of fat, and 24 g of protein was provided in the form of two off-the-shelf meal replacement bars. After data analysis and drafting of the final report, researchers were notified by the manufacturer which color vials were the CAF and PLA.

Statistical analysis. Data are reported as mean ± SD for all dependent variables. Statistical analyses were performed using SPSS for Windows version 21.0 (IBM, Seattle, WA). Before analysis, the distributional properties of each dependent variable were tested for normality using the Kolmogorov–Smirnov procedure, with an alpha level of 0.05. Mean differences between conditions for all dependent golf-specific performance variables were examined using paired-samples *t*-tests. Dependent variables from the self-perceived mood and energy questionnaire were assessed using a 2 × 3 (condition × time) factorial ANOVA. Physiological and accelerometry data were analyzed using a 2 × 2 (condition × time) factorial ANOVA. If a significant interaction effect was found, follow-up analysis included one-way ANOVA with repeated measures and paired-samples *t*-tests with Bonferroni corrections. Statistical significance for all null hypothesis testing was set at $P \leq 0.05$. Furthermore, magnitude of the effect was calculated using the formula for the Cohen d effect size: (CAF mean − PLA mean)/pooled SD) for all performance variables with observed effects as well as 95% confidence intervals (CI) for the mean difference between conditions. Effect sizes of 0.2, 0.5, and ≥0.8 were considered small, moderate, and large, respectively.

RESULTS

Baseline subject characteristics are presented in Table 1. Mean ambient temperature (36.6°C ± 0.8°C vs 36.7°C ± 0.5°C), wind direction and speed (south 32.1 ± 5.6 $km{\cdot}h^{-1}$ vs south 30.9 ± 4.6 $km{\cdot}h^{-1}$), and humidity (24.3% vs 28.7%) were similar ($P > 0.05$) between rounds 1 and 2, respectively. Under the CAF condition, mean relative CAF intake was 3.8 ± 0.6 $mg{\cdot}kg^{-1}$ of body mass over the entire round. Furthermore, there was no substantial difference ($P > 0.05$) between conditions for total water intake (CAF vs PLA, 2.21 ± 0.44 L vs 2.12 ± 0.45 L) or preround USG (1.016 ± 0.006 vs 1.018 ± 0.006).

Iron club accuracy assessment. The mean number of balls on the green and distance to the hole for each condition is presented in Table 2. Both the number of balls on the green (mean difference (95% CI), 1.08 (0.34–1.82); P = 0.008; ES, 0.86) and distance left to the hole (−2.42 m (−3.95 to −0.88); P = 0.005; ES, 1.00) were statistically better under the CAF condition compared with those in the PLA, with the mean differences between conditions resulting in large and meaningful effects.

Golf-specific performance. There were no substantial differences in the number of FIR, putts/round, shots hit OB, sand shots, SS%, or first putt distance between conditions (Table 2). However, total score (−2.50 (−4.85 to −0.15) strokes; P = 0.039; ES, 0.3), GIR (1.75 (0.14–3.36); P = 0.035; ES, 0.4), and drive distance (6.70 m (0.10–13.31); P = 0.047; ES, 0.2) were statistically better under the CAF condition compared with those under the PLA condition.

APPLIED SCIENCES

TABLE 2. Golf-specific measures of performance for each condition (mean ± SD).

	PLA	CAF	P
Iron accuracy assessment			
Balls on green (*n*)	1.75	2.83	0.008
Distance to hole (m)	7.84	5.42	0.005
In-round			
FIR (*n*)	4.7 ± 2.0	5.3 ± 2.0	0.31
Putts per round (*n*)	33.4 ± 3.2	32.6 ± 4.7	0.49
Putt distance (m)	5.81 ± 0.86	5.58 ± 1.21	0.59
OB (*n*)	0.7 ± 1.2	0.2 ± 0.4	0.11
Sand shots (*n*)	1.0 ± 0.9	1.2 ± 1.0	0.50
SS%	25.0 ± 45.2	26.4 ± 41.1	0.67
GIR (*n*)	6.9 ± 4.6	8.7 ± 3.4	0.035
Drive distance (m)	233.3 ± 32.5	239.9 ± 33.8	0.047
Total score (strokes)	79.4 ± 9.1	76.9 ± 8.1	0.039

Physiological and accelerometry data. Average HR and BR over the entire round under the CAF condition was 120.0 ± 21 bpm and 19.0 ± 2.7 breaths per minute, respectively, and 117.0 ± 14.0 bpm and 20.0 ± 2.0 breaths per minute for the PLA condition, with no substantial difference between conditions ($P > 0.05$). Neither trunk posture while putting nor peak trunk acceleration while hitting a driver changed substantially over the round (front nine holes vs back nine holes) or between conditions (Table 3).

Mood and energy state questionnaire. There were no statistically significant condition–time interactions for self-perceived ratings of alertness ($P = 0.77$), overall confidence ($P = 0.06$), or concentration ($P = 0.64$). However, a significant main effect for condition ($P = 0.047$) and time ($P < 0.001$) was detected for self-perceived ratings of "energy" (Table 4). Follow-up analyses revealed that energy declined after 18 holes of golf compared with baseline for both conditions, but the CAF condition maintained greater feelings of energy after nine holes (mid) compared with PLA (9.58 (1.44–17.73) mm; $P = 0.025$; ES, 0.5). Furthermore, a statistically significant ($P = 0.045$) condition–time interactions effect occurred for self-perceived ratings of fatigue. *Post hoc* analysis revealed that fatigue increased over the PLA round but did not substantially change from baseline during the CAF round (Table 4). Lastly, golfers experienced less fatigue under the CAF condition compared with during the PLA condition after nine holes (−13.42 mm (−26.82 to −0.14); $P = 0.05$; ES, 0.6).

DISCUSSION

The objective of this study was to determine the effect of a caffeine-containing supplement on golf performance and fatigue in a competitive tournament setting. Our findings suggest that acute consumption of a caffeine-containing supplement taken before and during a round of golf 1) attenuates self-perceived ratings of fatigue and sustains ratings of energy compared with a placebo and 2) improves measures of golf-specific performance.

TABLE 3. Trunk posture while putting and peak trunk acceleration while swinging (mean ± SD).

	Condition	Front Nine	Back Nine	P
Posture (°)	PLA	36.5 ± 7.0	36.9 ± 7.7	Condition, 0.20
	CAF	34.9 ± 7.5	33.3 ± 5.3	Time, 0.43
				Condition × time, 0.54
ACC_{peak} (*g*)	PLA	3.6 ± 1.0	3.7 ± 1.0	Condition, 0.22
	CAF	3.6 ± 1.0	3.5 ± 1.0	Time, 0.88
				Condition × time, 0.15

TABLE 4. Self-perceived ratings of energy and mood questionnaire for each condition (mean ± SD).

	PLA	CAF
Energy		
Pre	63.8 ± 20.6	66.4 ± 19.1
Mid	53.2 ± 20.4	62.8 ± 20.9*
Post	42.2 ± 23.1**	49.8 ± 17.7**
Fatigue		
Pre	24.8 ± 14.5	30.5 ± 20.6
Mid	47.7 ± 22.6	34.3 ± 22.3
Post	46.4 ± 21.9	43.3 ± 21.9
Concentration		
Pre	67.8 ± 22.1	64.1 ± 24.1
Mid	57.8 ± 20.1**	59.9 ± 22.6*
Post	49.2 ± 20.5**	52.8 ± 18.9
Alertness		
Pre	70.2 ± 20.0	67.8 ± 19.7
Mid	59.9 ± 20.0	61.6 ± 22.1
Post	56.7 ± 20.5	54.2 ± 16.7
Overall confidence		
Pre	70.4 ± 14.5	67.9 ± 18.3
Mid	63.1 ± 17.5	59.8 ± 15.2
Post	52.6 ± 21.3	62.4 ± 14.5

*Significantly different from PLA, $P \leq 0.05$.
**Significantly different from pre, $P \leq 0.05$.

Typically, golf is perceived as a nonfatiguing sport because of the low physiological intensity at which it is played. However, laboratory-based (29) and on-course investigations (9) have found evidence of golf-specific fatigue. Specifically, Doan et al. (9) reported an increase in mental and physical fatigue in the latter half of a competitive golf tournament in collegiate male golfers. Similarly, Stevenson et al. (29) reported a significant decrease in measures of energy as well as a significant increase in mental fatigue from a laboratory-based simulated round of golf. Our findings support these results, as we found a decline in measures of energy and an increase in the perception of fatigue throughout a competitive round of golf. However, caffeine supplementation was able to significantly attenuate fatigue during the round, which may have contributed to our findings of improved measures of golf performance. Fatigue has been shown to affect both physical and cognitive performance, especially when cognitive tests are performed during or after physically fatiguing exercise (21). Because competitive golf demands a high level of cognitive and motor performance to be successful, fatigue may negatively affect golf performance through both central and peripheral mechanisms. The fatigue-delaying effects of caffeine are well-known. Caffeine acts as a CNS stimulant mainly by its interactions with adenosine receptors functioning as a receptor antagonist, leading to increased excitability of neuronal tissue, level of arousal, and cognition (10,22). Along these lines, consumption of moderate doses (100–300 mg) of caffeine has been shown to positively affect cognitive and motor performance during physically fatiguing tasks (15,31). Our data suggest that a moderate dose of caffeine reduces golf-specific fatigue, which seems to translate to improved accuracy and overall golf performance.

There are limited original nutritional investigations aimed at improving golf performance. To our knowledge, this is the first study to attempt such a task in a competitive tournament setting using skilled golfers. Stevenson et al. (29) sought to determine the effects of a CHO and caffeine sport drink on golf performance. Similar to our findings, they reported improvements of accuracy under the condition and a time effect for increases in measures of fatigue. However, unlike our findings, the sports drink failed to attenuate the fatigue response. These conflicting results may be from methodological differences, as caffeine doses in our study were almost twofold higher (29). Because of the metabolic clearance rate of caffeine in humans, we chose to have participants consume a second dose of the caffeine-containing supplement after the first nine holes with an aim to maintain blood caffeine levels over the entire round (4+ h). Moreover, we observed improvements in iron club accuracy from supplementation, whereas Stevenson et al. (29) reported improvements in putting accuracy. We did not see improvements in putting, and the methodological differences between studies render it incapable of adequate comparison. Specifically, Stevenson et al. (29) used the same synthetic surface at fixed distances (2 and 5 m) for putting assessments for all 18 holes, whereas we used true grass multifarious putting greens on the golf course. Nevertheless, our finding of improved iron club accuracy is substantial because of the importance of iron club play. Recently, Robertson et al. (25) reported that iron shot accuracy, on approach shots to the green, was a significant predictor of overall golf performance in a competitive tournament setting. Therefore, caffeine, at doses used in this study, has the ability to minimize golf-specific fatigue, which may contribute to overall golf performance by improving accuracy and drive distance, leading to a better golf score.

A second noteworthy finding in our study was the increase in drive distance under the CAF condition. Longer-drive distances result in less distance to the green, allowing the use of a more accurate iron club on the approach shot. Not considering environmental factors, maximum golf ball displacement during a drive is a function of the linear velocity and angle of the club head at the point of impact between the club face and ball (16). Importantly, Fletcher and Hartwell (12) reported a strong relation between club head speed and peak drive distance in skilled (mean handicap, 5.5) male golfers. In a laboratory-based golf-specific fatigue study, Higdon et al. (14) reported that fatigue resulted in a 2.0%–2.5% reduction in club head velocity when swinging a driver, which, statistically, was not related to trunk or pelvic rotation velocity (14). We did not observe differences in peak trunk acceleration between conditions, but average drive distance was significantly increased in the CAF condition. It is possible that the improved drive distance was due to the attenuation of fatigue via caffeine, which led to a maintenance and/or increase in club head velocity. However, because we did not directly measure club head velocity, this hypothesis is only speculative, and therefore, other factors that may have contributed to the increase in drive distance cannot be ruled out.

There are some limitations to our investigation. First, it is possible that some of the positive effects reported from caffeine supplementation were due to a withdrawal effect. Under the PLA condition, participants were asked to abstain from consuming caffeine, which may have impaired performance. Caffeine withdrawal symptoms typically appear 12 h after abstinence, and severity of symptoms is related to the chronically consumed dose of the user (18). Furthermore, most of our participants were low-dose caffeine users ranging between 35 and 180 $mg \cdot d^{-1}$. Second, there are other active secondary ingredients in the caffeine supplement that may have contributed to our findings. Vitamin B supplementation is considered beneficial when in a deficient or malnourished state. Our subjects were apparently healthy and did not report a history of malnourishment or hypovitaminosis. Furthermore, previous work reported that vitamin B supplementation failed to show an acute effect on enhancing cognitive ability (23). Therefore, we do not believe that B vitamins contributed to our findings. ElevATP™ is a proprietary blend of plant bio-inorganic trace minerals and polyphenols, which is purported to improve mitochondrial ATP production when consumed. To our knowledge, only one study has been published on the acute effects of elevATP ingestion on blood ATP concentration in humans (24). Their results suggested that whole blood ATP levels increased by 45% after ingestion of 150 mg of elevATP. However, bioavailability studies of adenosine and its products suggest that whole blood ATP is rapidly metabolized, on the order of minutes, by the blood components (6). Therefore, future research should test these ingredients individually to determine their specific effects on overall golf performance and fatigue.

Our findings suggest that skilled golfers experience fatigue and reduced energy levels during a competitive round of golf, which may negatively affect their playing ability. Importantly, caffeine supplementation offset this response, which seems to have contributed to improved iron club accuracy, drive distance, and overall golf score. With the lengthy duration of game play, walking long distances, and potential environmental challenges, it is important for competitive golfers to have evidence-based, practical recommendations to offset the physical and mental demands of competitive golf play. Pre- and in-round nutrition and supplementation strategies have thus far been lacking. For the first time, we show that a caffeine-containing supplement, consumed before and during a round of golf, can reduce fatigue and improve measures of golf performance in a true competitive tournament setting.

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J. R. M. works for the funding company, whereas the remaining authors proclaim no conflict of interest from the outcomes of this

study. J. R. M. had no influence on data collection or analysis but contributed to the drafting and editing of the manuscript.

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