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Original research

Influence of coffeeberry extract on soccer specific skill performance during simulated soccer match-play and following fatiguing exercise in academy players

Paola Rodriguez-Giustiniani [a,g], Ian Rollo [b], Matthew Pahnke [c], Luke O'Brien [d], Gary Grant [e], Ben Desbrow [f], Stuart D.R. Galloway [g,*]

[a] Brighton and Hove Albion Football Club, United Kingdom
[b] Gatorade Sports Science Institute, PepsiCo Life Sciences, United Kingdom
[c] Gatorade Sports Science Institute, PepsiCo Life Sciences, United States
[d] Department of Sport, Exercise and Nutrition, Atlantic Technological University, Ireland
[e] School of Pharmacy and Medical Sciences, Griffith University, Australia
[f] School of Health Sciences and Social Work, Griffith University, Australia
[g] Faculty of Health Sciences and Sport, University of Stirling, United Kingdom

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A B S T R A C T

Objectives: To investigate the effects of acute coffeeberry extract ingestion on soccer-specific technical skill performance, sprint performance, high-intensity running capacity, and subjective perceptions of fatigue, energy, and alertness during a soccer match simulation in academy soccer players.
Design: Double-blind, randomised, placebo-controlled, crossover trial.
Methods: Twenty trained male soccer players completed two experimental trials (coffeeberry extract [300 mg] and placebo [flavour and colour matched] beverages), separated by 7–14 days. Each trial, conducted 1 h after ingestion of the test beverages, included a 45-min half soccer match simulation incorporating dribbling, sprinting, and passing tasks, followed 5 min later by a high-intensity running-to-fatigue protocol. Subjective measures (fatigue, mental/physical energy), physiological data (glucose, lactate), technical skills and running outcomes were assessed. Blood samples were analysed for chlorogenic acid and caffeine concentrations.
Results: Coffeeberry ingestion resulted in greater maintenance of passing speed ($p < 0.01$) and accuracy ($p < 0.01$) compared to placebo, most evident on short passes. No meaningful significant differences were observed in sprint performance, dribbling or running capacity. Subjective fatigue increased, and energy scores declined, similarly across trials. No difference was observed in blood glucose or lactate responses. No chlorogenic acid or caffeine was detected at quantifiable concentrations in plasma samples post-ingestion.
Conclusions: Acute ingestion of coffeeberry extract improved select aspects of soccer skill performance, particularly short-passing speed/accuracy, in academy soccer players. These findings suggest a potential cognitive or neuromuscular mechanism, independent of metabolic effects. Further research is warranted to explore the time course of chlorogenic acid absorption and its potential mechanistic role in skill performance.

Practical implications

- Ingesting coffeeberry extract before exercise may help academy soccer players maintain key technical skills like passing speed and accuracy.
- Coffeeberry ingestion resulted in better short and long passing speed and retention of short pass accuracy during a half-match simulation in academy soccer players.
- Coffeeberry had no impact on sprinting or running endurance, suggesting that effects are more skill- and/or neural-related rather than metabolic in academy soccer players.

1. Introduction

Physical and technical attributes are important for succeeding in soccer.[1] The distinguishing factors between elite and amateur soccer players are their cognitive abilities, high-level skill execution, and ability to maintain execution of those skills when fatigued.[2] Soccer skill

* Corresponding author.
E-mail address: s.d.r.galloway@stir.ac.uk (S.D.R. Galloway).
Social media: @galloway_stuart (S.D.R. Galloway).

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performance depends on cognitive, perceptual, and motor skills, which interact in rapidly changing environments. Therefore, acute nutritional interventions that can influence cognitive abilities and the quality of technical actions (i.e., skilled performances) might have an important role to play when seeking to optimise soccer specific performance.

There is consistent evidence that both acute supplementation and chronic supplementation of polyphenols can improve in vivo vascular function by enhancing nitric oxide-endothelium-dependent vasodilation.[3] Coffeeberry is the fruit of the coffee plant (also known as coffee cherry or coffee fruit) which is typically discarded during the coffee bean harvesting process. Coffeeberries contain a large quantity of antioxidants and polyphenols, especially phenolic components (prominently chlorogenic acids (CGAs)).[4] Antioxidants and polyphenols have been reported to improve endothelial dependent vasodilation which may enhance performance/recovery through altered tissue perfusion. This potential benefit of polyphenols appears particularly evident when 300 mg is ingested 1–2 h prior to start of exercise.[5] Other research has shown a relationship between cerebral blood flow and cognitive task performance. For example, Tari et al.[6] demonstrated that acute increases in cerebral blood flow, whether through exercise or hypercapnia, are directly linked to enhanced executive function (faster reaction time during an antisaccade task). The magnitude of cerebral blood flow increase was correlated with improvements in cognitive task performance. Acute cocoa flavanol ingestion has also been demonstrated to enhance cerebral oxygen delivery and cognitive task performance in healthy adults, especially during mentally demanding tasks.[7] In addition, pre-exercise high-flavanol cocoa ingestion enhances executive function (colour-word Stroop test) beyond the effects of exercise alone.[8] Thus, the active ingredients contained within coffeeberry extract could potentially alter blood flow and impact upon physical and/or cognitive task performance. To date, the only study examining the potential application of coffeeberry in sport and exercise did not observe any significant effects of ingesting 800 mg/day of coffeeberry extract or placebo over 28 days on anaerobic power, anaerobic fatigue, maximal heart rate, or blood lactate responses. However, these outcomes were obtained from short tasks including a 60 second vertical jumping task, with maximal heart rate obtained from a multistage shuttle running test.[9]

Several studies have directly explored the cardiovascular and cognitive effects of coffeeberry extract in humans, but not in exercise specific situations.[10–16] For example, the ingestion of beverages containing low (100 mg) and moderate (300 mg) amounts of coffeeberry extract was demonstrated to significantly attenuate both increases in self-reported fatigue and decreases in self-reported alertness resulting from the completion of a series of fatiguing cognitive tasks.[4] These effects of coffeeberry on alertness and fatigue became statistically significant 2 h after beverage consumption; however, the beverages began to exert effects from 1 h post-ingestion. In addition, Robinson et al.[15] suggested that the ingestion of a single dose of coffeeberry extract (100 mg) was associated with improved reaction time and may protect against cognitive errors on tasks of working memory and response inhibition in an ageing population with subjective cognitive decline. It was concluded that coffeeberry extract is associated with acute neurophysiological changes supportive of faster reaction times and increased, sustained attention. As such, it could be interpreted that coffeeberry is an interesting potential candidate to explore its impacts upon physiological, cognitive, and technical performance outcomes in team sport environments.

The present study aimed to generate preliminary evidence about the potential impact of coffeeberry as an ergogenic supplement by investigating its effects on skill performance, physical performance, and subjective measures of mood/arousal and mental/physical energy, under non-fatigued and fatigued conditions in academy soccer players. We hypothesised that coffeeberry may alter skill performance, physical performance, and subjective measures of mood/arousal and mental/physical energy. To our knowledge no studies have conducted an acute coffeeberry intervention in an applied exercise study on team sport players.

2. Methods

2.1. Participants

Twenty male well-trained professional outfield soccer players (10 midfielders, 6 defenders, 4 strikers) from the United Kingdom, who were accustomed to skill assessments as part of their regular training were recruited from local Professional Football Club development squads to participate in this investigation. The study was conducted between January and May, meaning that fell between mid-season and end of season. All players had five or more years of playing experience, had been training consistently for 1 year or more, were regularly participating in match-play with their squad, and were free from injury at the time of the recruitment and testing (age: 18 ± 2 years, body mass: 73.9 ± 8.2 kg, stature: 178.1 ± 6.4 cm, body mass index: 23.2 ± 1.9 kg/m^2, $\dot{V}O_2$ max: 56.1 ± 1.7 mL/kg/min). Potential participants were provided with verbal and written information about the study. They were then allowed time to consider their involvement in the study (minimum period of 1 week) before providing their written consent for their participation. The experimental procedures were approved by a local Ethics of Research Committee (NICR (19 20) 055) and the study was conducted in accordance with the Declaration of Helsinki (2013).

2.2. Study design

The study followed a double-blind, randomised, placebo-controlled, crossover design. After receiving the signed consent form, and performing an initial pre-screening, participants undertook cardiovascular screening to confirm the absence of any ECG abnormalities. This was followed by a $\dot{V}O_2$ max test using a shuttle running protocol,[17] and after a short recovery period, a first habituation session of the skill performance outcome assessments (dribbling, sprinting, passing) was conducted. On a subsequent visit, participants went through a familiarisation trial that included a run-through of the full experimental trial protocol. This included a 45-minute half soccer match simulation protocol with embedded skill assessment, and a high-intensity running to-fatigue protocol. All testing sessions were performed on an indoor artificial grass pitch. The soccer match simulation (SMS) protocol was performed according to a modified version of the protocol described by Russell et al.[18] which has been found to be reliable.[19] In the SMS, participants were required to perform soccer dribbling, 15-m sprints, and passing skills, throughout six blocks of the modified protocol lasting a total of 45 min.[19,20] Each block of the SMS protocol consisted of 3 repeated cycles of three 20-m walks, one 20-m walk to the side, five 20-m jogs, one 20-m backward jog, two 20-m strides and an alternating timed 15-m sprint or a 20-m dribble followed by passing assessments (Fig. 1).

To assess dribbling speed and accuracy, players dribbled a ball between 7 cones (cones 2–7 were placed 3-m away from the preceding cone, and cones 1 and 7 were 1 m away from each end of the course, Fig. 1). Participants were required to dribble the ball as quickly and accurately as possible from one end to the other over the 20-m total distance. Participants dribbled towards a video camera that was placed directly in line with the cones. For the sprint assessment, players ran as fast as possible through timing gates (Brower®, USA) placed 15-m apart, with a 1-m run-in.

At the end of each block of activity, players performed a bout of passing where they directed alternate passes towards target zones placed to the left and right at distances of 4.2-m (short pass) and 7.9-m (long pass). Soccer mannequins (Diamond Football®, Senior Pro Free Kick) with their bases were used as passing targets. The base (0.5-m wide) was the central zone of the target, with cones at 0.5-m of each side as the lateral zones of the target. A pass to the centre area was worth 10 points and the two lateral areas were worth 5 points. Passes that missed the target areas were scored as 0.[20] Passing bouts consisted of 8 passes (2 with the dominant foot and 2 with the non-dominant foot to each of the short and long pass targets).

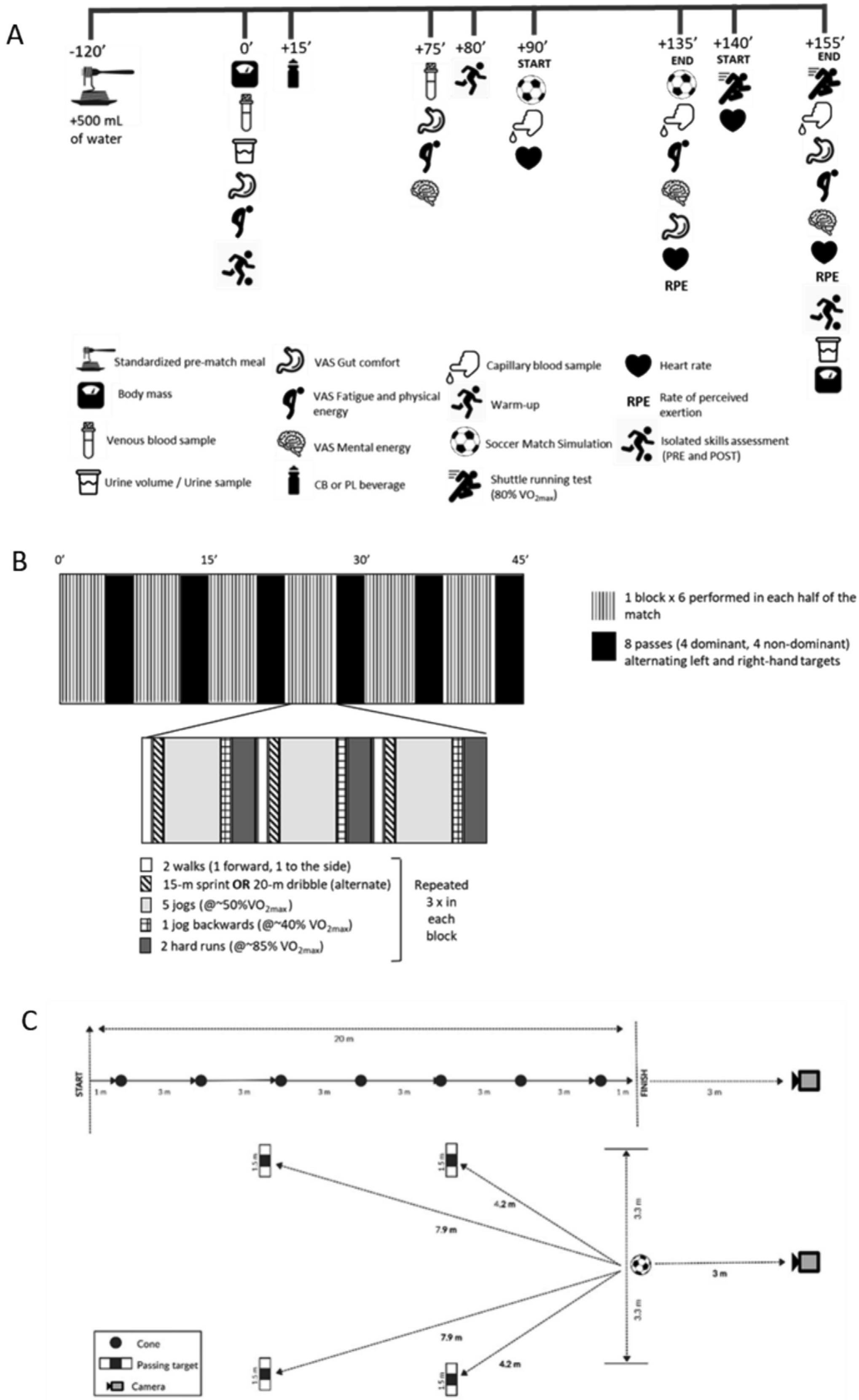

Fig. 1. Schematic diagram of study protocol (A), half soccer-match simulation (B) and dribbling and passing skill set-up (C).

Video footage of the skill tests was captured using digital cameras (GoPro®, Hero 5), one was placed 1-m from the last cone of the dribbling course and the other 1-m behind the passing and shooting zone. Manual digitisation (Kinovea® version 0.8.15; Kinovea Org., France) yielded dribbling speed over the known distance, dribbling accuracy (based on distance that the ball travelled laterally from the cones, measured from centre of cone to inside edge of the ball laterally in line with the cone). Accuracy was calibrated individually against a known distance marker at each cone. Dribbling accuracy was measured for cones 2 to 6 to give 5 values which were summed to give a total distance from the cones for each dribble. Passing accuracy was obtained from reviewing footage and determining which point of the target was hit with 10 points assigned to target centre, 5 points for lateral edges, and 0 points for missing the target. Passing speed was calculated from the time interval between ball contact with the foot and when the ball reached the target area.

The high-intensity exercise fatigue protocol required the players to run at 80 % of their VO_2 max until the point of volitional exhaustion. All trials were completed in the afternoon to reflect the time at which this group typically engages in soccer match play. Soccer balls were inflated to a pressure of 14 psi before each trial.

2.3. Experimental trials

At least 7 days following the familiarisation visit, participants attended the first of their 2 experimental trial days (Fig. 1). Trials were a placebo trial and a coffeeberry extract trial (300 mg dose) was administered in a double-blind, cross-over design. Trials were separated by 7–14 days. Participants followed their habitual diets but were asked to avoid caffeine, caffeinated and decaffeinated products, apples, and berries/cherries for 24-h prior to main testing days and alcohol 48-h before the trials. Participants were asked to record all food consumed for 48-h before the first trial and replicate it 48-h prior to the second trial. Dietary analysis was performed by the lead author using the Nutritics Food Data Management software (www.nutritics.com). Participants were also requested to abstain from strenuous physical activity for 24-h before participation on testing days, and compliance was checked on arrival at the training ground. Participants attended the training ground at 8:30 a.m. and were provided with a standardised breakfast (2 eggs, 2 slices of white bread, and 1 medium-sized banana, providing 423 kcal, 46 g carbohydrate, 26 g protein, 14 g fat). A standardised lunch meal was also provided 2-h before beginning the trials, the meal (pasta in a tomato sauce) provided 2 g/kg of carbohydrates plus 500 mL of water. All trials started between 1:00 and 2:00 p.m.

Upon arrival at the indoor pitch for trials, players emptied their bladder (with urine volume collected into a container), before near nude body mass (in underwear only) was obtained (SECA Quadra 808, Hamburg, Germany). A baseline blood sample was taken (7 mL from an antecubital vein, into a KEDTA plasma tube, placed on ice, then spun at 4 °C), for assessment of caffeine and chlorogenic acids. Participants then completed a standardised warm-up (10-min, consisting of running, dynamic stretching, and 20-m sprints) and a baseline (Pre) assessment of the isolated skills (sprinting, dribbling and passing) before ingesting the allocated trial beverage (300 mL) over a 2–3-minute ingestion period. The coffeeberry (CB) and placebo (PL) beverages were ready-to-drink formulations (PepsiCo International Ltd., USA) matched for flavour, colour, and texture. The test drink contained water, citric acid, coffeeberry extract, gum arabic, natural flavour, sucralose, acesulfame potassium, glycerol ester of rosin, and yellow 6. The measured content of CGAs and caffeine in the CB test drink was 118.9 ± 0.8 μg/mL and 42.2 ± 0.4 μg/mL, respectively. The PL drink contained all the abovementioned ingredients except for coffeeberry extract and no CGAs or caffeine were detected in the analysis. After a 60-min rest period, to allow for delivery and absorption of the active ingredients in the test beverage, a second venous blood sample (7 mL) was obtained. Players then undertook a second 10-min standardised warm-up. Next, players performed the 45-min half soccer match simulation. After a short break of ~5 min for blood sampling and recording of subjective measures, participants then undertook the shuttle running test at 80 % of VO_2 max until the point of exhaustion. Exhaustion was defined as the inability to maintain the required pace for two consecutive shuttles. Running capacity performance was expressed as the total running distance completed during the test. Following the high intensity shuttle running test participants had their heart rate and subjective measures recorded and a capillary blood sample taken, before completing a final isolated skill assessment (Post) of sprinting, dribbling and passing skills. Upon completion, participants emptied their bladder, and a final urine sample was obtained prior to near nude body mass being recorded.

Fingertip capillary blood samples were drawn prior to simulated match play, at the end of the 45-min match play, and at the point of volitional fatigue, for assessment of blood glucose and lactate concentration. Urine samples from baseline and at the end of the trial obtained prior to body mass measurements were retained for the assessment of urine osmolality. Fluid (water) was allowed ad libitum during the first trial and the volume was replicated for the second trial. Baseline hydration status was assessed using a combination of body mass and urine osmolality. Urine production was assessed and sweat losses were determined from change in body mass corrected for fluid intake and urine losses (% body mass loss = body mass loss (kg) ∗ 100 / Pre-trial body mass). Subjective ratings of perceived exertion (RPE),[21] visual analogue scales (100 mm scale (0 minimal)) for determination of mental energy, physical energy, feelings of fatigue and gut comfort, and heart rate measurements were obtained at regular intervals during the protocol (Fig. 1).

2.4. Analytical procedures

Capillary blood samples (30-μL aliquots) were dispensed into 300 μL of ice cold 0.3-N perchloric acid and shaken vigorously before being placed in an ice bath. On completion of the trial, samples were centrifuged and stored at −70 °C until analysis. Analysis of blood glucose and lactate concentrations was completed using the method of Maughan.[22] Urine samples were collected into a 0.5-L plastic container and total mass (to the nearest 0.1 g) was assessed to determine urine volume. A 5-mL aliquot was then dispensed into a plain screw-capped tube and was analysed for urine osmolality after the trial ended using a portable osmometer (OsmoCheck, Vitech Scientific Ltd). Plasma obtained from venous blood samples was spun at 4 °C prior to being frozen at −20 °C and subsequently transferred to −70 °C storage. On completion of the study all plasma samples were sent on dry ice to Griffith University (Gold Coast, Australia) via a temperature tracked courier service (World Courier) where caffeine, chlorogenic acid and related metabolite content was assessed using liquid chromatography-mass spectrometry.[23–25]

2.5. Statistical analyses

An a priori power calculation based on our previous study[19] revealed that for passing accuracy and passing speed n = 7 and n = 11 participants were required, respectively, for 80 % power with a mean difference in outcome of 0.8 × SD and significance taken at $p < 0.05$. We aimed to recruit n = 20 participants to ensure good statistical power and allow for any loss to follow-up. Data were first analysed for trial order effects to determine whether order was required as a covariate in subsequent analyses. Subsequently, two-way repeated measures ANOVA was used to assess trial (intervention versus placebo), time (Pre, through SMS, and Post), and trial by time interaction effects. For any main effects or interactions observed, post-hoc analyses using two-tailed paired comparisons with Bonferroni correction were performed to determine where differences occurred. Priority was given to interaction effects in the Results and Discussion presentation. Data are presented as mean (SD), and mean differences (95 % confidence intervals) were calculated. Statistical significance was set at $p < 0.05$ for all analyses.

3. Results

3.1. Standardisation and baseline testing

Data were normally distributed for all variables ($p > 0.05$) with no trial order effects observed ($p > 0.05$). Participants reported to each experimental trial with a similar hydration status (body mass: CB: 73.7 ± 8.4 kg, PL: 73.8 ± 8.3 kg; urine osmolality: CB: 394 ± 194 mOsm/kg, PL: 460 ± 157 mOsm/kg) and there was no difference in body mass loss during trials (CB: 1.2 ± 0.6 %, PL: 1.2 ± 0.7 %). Dietary analysis revealed no difference in nutritional intake between coffeeberry (total energy: 8.3 ± 2.1 MJ/day; carbohydrates: 279 ± 68 g/day; proteins: 99 ± 50 g/day; fats: 47 ± 12 g/day) and placebo (total energy: 8.6 ± 1.8 MJ/day; carbohydrates: 290 ± 49 g/day; proteins: 98 ± 20 g/day; fats: 50 ± 17 g/day; all $p > 0.05$) trials, in the 48-h period before the main experimental trial days. Ambient temperature (CB: 9 ± 3 °C, PL: 9 ± 2 °C) and humidity (CB: 67 ± 12 %, PL: 67 ± 11 %) were similar between trials ($p > 0.05$). There were no differences noted between trials on pre-trial sleep duration (CB: 8 ± 1 h; PL: 8 ± 1 h) ($p > 0.05$).

3.2. Dribbling

Dribbling speed (m/s) was different over time ($p = 0.02$), but was not different between trials ($p = 0.12$) and no time by trial interaction was evident ($p = 0.25$). The time effect was evident between Pre and Post time points ($p = 0.01$) only. Regarding dribbling accuracy there was a trial by time interaction ($p = 0.03$) but no time effect ($p = 0.43$) and no trial effect ($p = 0.60$). Post-hoc analyses were not able to detect any significant differences in dribbling accuracy between trials or time points (Fig. 2).

3.3. Sprinting

There was no trial ($p = 0.62$) or trial by time interaction ($p = 0.47$) but there was a significant time effect ($p < 0.001$) for 15 m sprint times during the protocol. Significantly slower sprint times were evident between baseline values obtained Pre drink ingestion (2.43 ± 0.15 s) and 30-min (2.59 ± 0.23 s) and 45-min (2.59 ± 0.26 s) time points in the half match simulation. The mean difference (95 % CI) in sprint times between CB and PL trials was 0.02 s (−0.13 to 0.18 s).

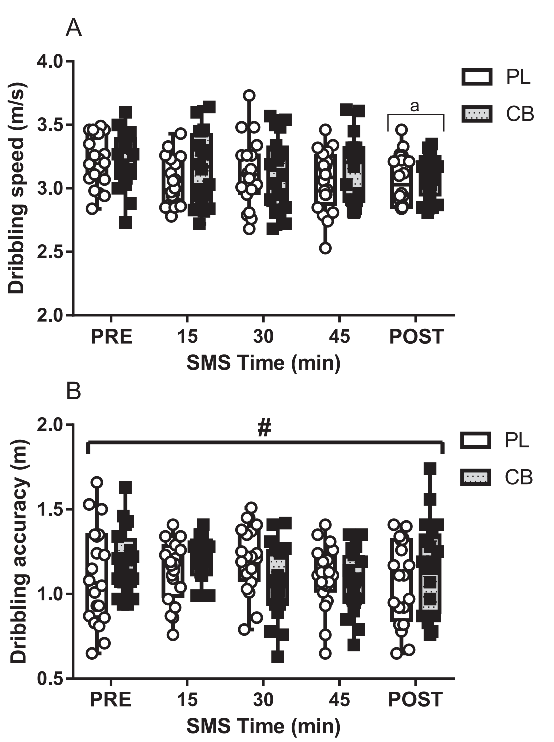

Fig. 2. Dribbling speed (A) and dribbling accuracy (B) before treatment ingestion (PRE), during the half soccer match simulation (SMS — 15, 30, 45), and following the high-intensity running capacity task (POST) on placebo (PL) and coffeeberry trials (CB). a — significant time effect ($p < 0.05$) compared with PRE value; # — significant time × trial interaction effect ($p < 0.05$).

3.4. Passing (short pass)

3.4.1. Both feet combined

There were time ($p < 0.01$) and trial ($p < 0.01$) effects and a trial by time interaction ($p = 0.04$) for passing speed (m/s; Fig. 3A). Passing speed decreased over time during the SMS from 15-min to 45-min in the PL trial (15-min: 10.7 ± 0.3 m/s vs 45-min: 10.2 ± 0.3 m/s, $p < 0.01$) but did not decline in the CB trial (15-min: 10.7 ± 0.4 m/s vs 45-min: 10.6 ± 0.3 m/s), with higher passing speed in CB than PL at 30-min and 45-min into the match simulation. Regarding passing accuracy, there were trial ($p = 0.002$) and time effects ($p < 0.001$) but no trial by time interaction ($p = 0.10$; Fig. 3B). Post-hoc analyses revealed that accuracy decreased significantly ($p < 0.001$) from 15-min to 30-min and that the accuracy score was higher in the CB trial than in the PL trial at 30 min ($p = 0.03$).

3.4.2. Dominant foot

Passing speed with the dominant foot decreased over time ($p < 0.001$) and there were significant trial ($p = 0.004$) and trial by time interactions ($p = 0.02$) observed. Post hoc analysis revealed a decline in passing speed during the SMS between 15-min to 45-min ($p = 0.01$), 15-min to Post ($p = 0.02$), and 30-min to 45-min ($p = 0.04$) on the PL trial only (Fig. 3C). Regarding passing accuracy, the mean difference (95 % CI) between CB and PL trials was 2.4 (−0.5 to 3.1). There were significant main effects of time ($p = 0.006$) but no effects of trial ($p = 0.24$), or trial-by-time interaction ($p = 0.98$).

3.4.3. Non-dominant foot

There was no main effect of trial ($p = 0.07$), or trial by time interaction ($p = 0.24$), but there was a time effect ($p = 0.008$) for passing speed with the non-dominant foot. Time effects were evident between Pre to 30-min ($p = 0.04$) and Pre to 45-min ($p = 0.01$). The mean difference (95 % CI) between CB and PL trials was 0.18 m/s (−0.05 to 0.25). Regarding passing accuracy with the non-dominant foot, the mean difference (95 % CI) between CB and PL trials was 3.0 (−1.0 to 7.0) and there were no significant main effects for trial by time interaction ($p = 0.38$), trial ($p = 0.06$), or time ($p = 0.26$).

3.5. Passing (long pass)

3.5.1. Both feet combined

There were significant trial ($p = 0.002$), and trial by time interaction ($p = 0.01$) effects for passing speed, but no time effect ($p = 0.08$). Passing speed dropped from 15-min to Post ($p = 0.016$) on the PL trial only (Fig. 4A). For passing accuracy there was no trial by time interaction ($p = 0.90$) but there were significant time ($p = 0.018$) and trial ($p = 0.002$) effects, with a drop in speed from 15-min to Post on the PL trial only (Fig. 4B).

3.5.2. Dominant foot

There were trial ($p = 0.02$) and time ($p < 0.001$) effects, but no time by trial interaction ($p = 0.07$) for passing speed (Fig. 4C). Regarding passing accuracy, there was a trial effect ($p = 0.015$), with accuracy scores generally higher during the SMS for the CB trial, but no time ($p = 0.22$) nor trial by time interaction ($p = 0.80$) effects encountered.

3.5.3. Non-dominant foot

When assessing passing speed (m/s) with the non-dominant foot, there was no time effect ($p = 0.44$) or trial by time interaction ($p = 0.37$); nevertheless, a significant trial effect ($p = 0.016$) was observed. For passing accuracy the mean difference (95 % CI) between CB and PL trials was 2.0 (−0.5 to 4.5) and there were no significant trial ($p = 0.50$), time ($p = 0.13$), or time by trial interaction ($p = 0.83$) effects observed.

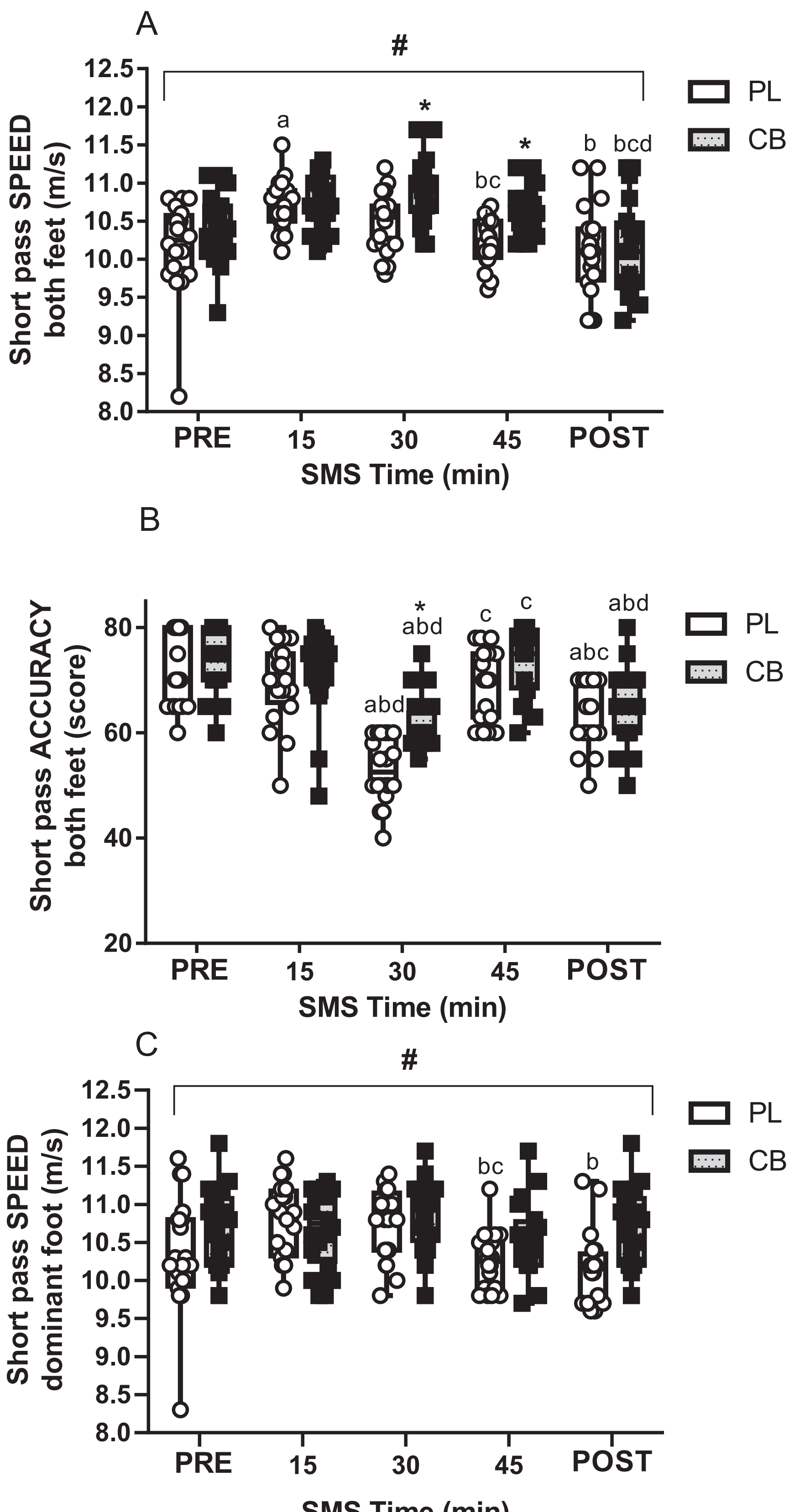

Fig. 3. Passing speed and passing accuracy on the short pass for both feet combined (A, B) and passing speed on the short pass for the dominant foot (C) obtained before treatment ingestion (PRE), during the half soccer match simulation, and following high-intensity running capacity task (POST). # — significant time × trial interaction effect; * — significant trial effect (CB different from PL, $p < 0.05$); a, b, c, d — significant time effect ($p < 0.05$ compared with PRE, 15, 30, 45 and POST values, respectively).

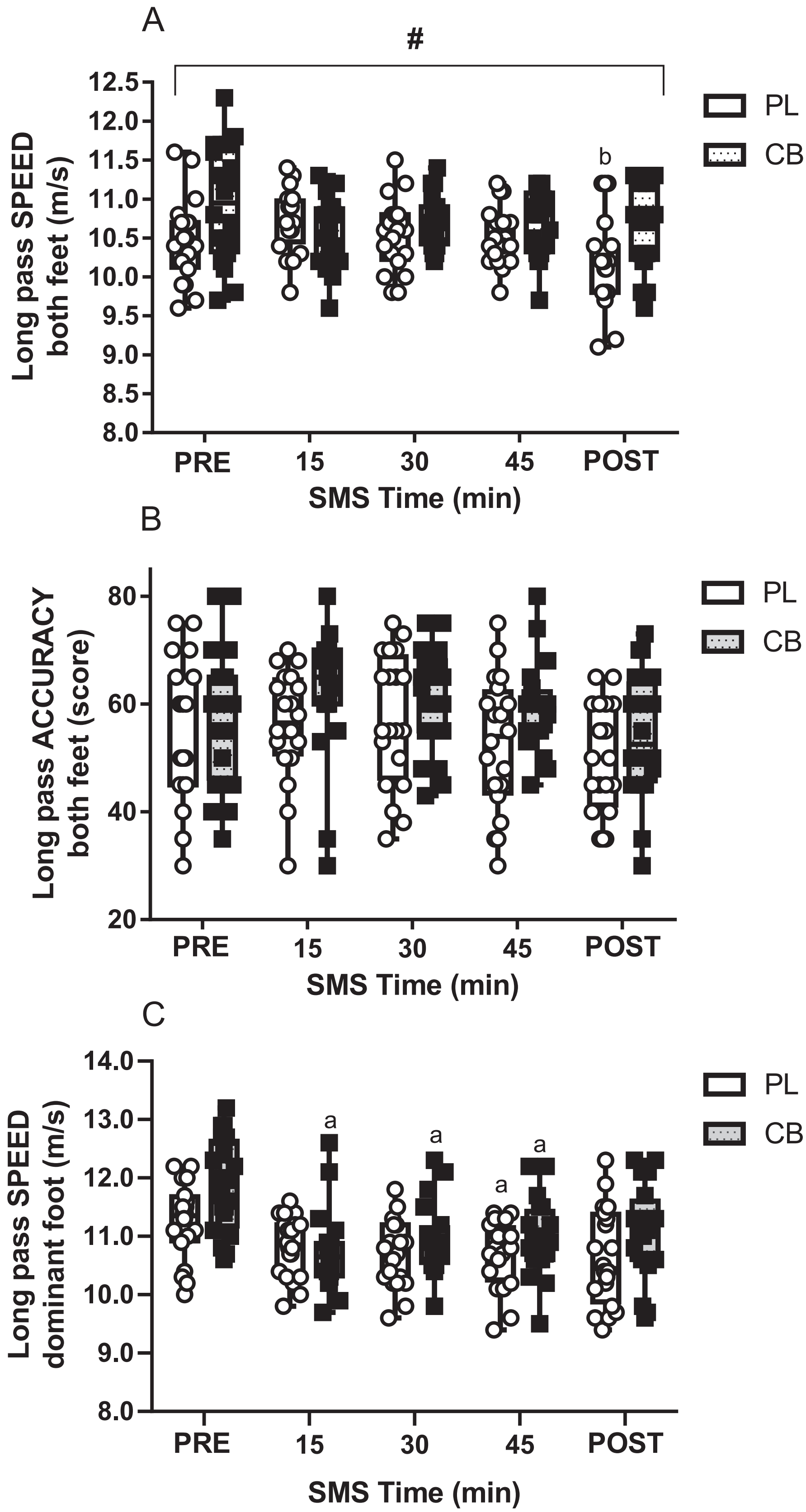

Fig. 4. Passing speed (A) and accuracy (B) on the long pass for both feet combined and passing speed on the dominant foot (C) obtained before treatment ingestion (PRE), during the half soccer match simulation, and following high-intensity running capacity task (POST). # — significant time × trial interaction effect; a, b, — significant time effect ($p < 0.05$ compared with PRE, and 15 values, respectively).

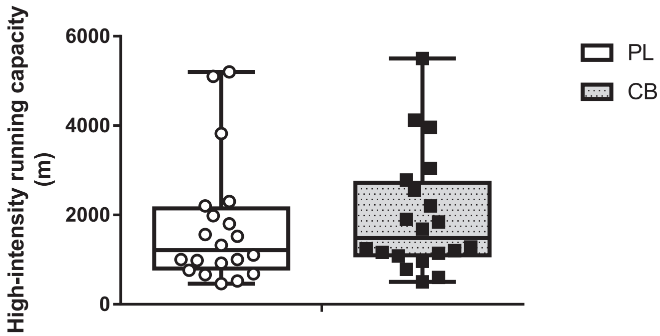

Fig. 5. High intensity running capacity on placebo (PL) and coffeeberry trials (CB).

3.6. High intensity running capacity

There was no significant difference between high intensity running and fatigue trials ($p = 0.30$; Fig. 5). The mean distance on the CB trial was 1976 ± 1328 m versus 1744 ± 1370 m on PL (mean difference (95 % CI): 232 m (−1035, 1499)). Although this corresponded to a 12 % mean difference in running capacity between trials it was not statistically significant.

3.7. Bloatedness, fullness, and nausea

There was no trial effect ($p = 0.79$) or trial by time interaction ($p = 0.59$) for bloatedness; however, a time effect was observed ($p < 0.001$) with a decrease in bloatedness 1 h after drink ingestion and for the remainder of the trial. Likewise, there was a time effect ($p < 0.001$) for fullness, with a decrease 1 h after drink ingestion and for the remainder of the trial, with no trial effect ($p = 0.31$) nor trial by time interaction ($p = 0.24$). Regarding nausea, there were no trial ($p = 0.79$), time ($p = 0.76$) or trial by time interaction ($p = 0.84$) effects (Table 1).

3.8. Fatigue, physical energy, and mental energy

Fatigue scores were low during the early stages of the trial then elevated at all time points after the SMS (time effect, $p < 0.001$); however, there was no trial effect ($p = 0.40$) nor time by trial interaction ($p = 0.80$). Regarding physical energy, there was no trial by time interaction ($p = 0.99$) and no trial effect ($p = 0.08$); however, a time effect was observed ($p = 0.01$) with a decrease in physical energy at all time-points after the SMS. Likewise, there was a time effect ($p < 0.001$) for mental energy evidenced by a decline at all time points after the SMS; however, no trial effect ($p = 0.26$) or trial by time interaction was observed ($p = 0.53$; Table 1).

3.9. Heart rate and rating of perceived exertion

There was no trial effect ($p = 0.61$) or trial by time interaction ($p = 0.77$) but there was a time effect ($p < 0.001$) for heart rate with an increase above baseline skill assessment values during more intense periods of activity, and reduction below baseline skill assessment values during rest periods over the course of the trial. The overall mean (SD) for heart rate was 133 ± 14 bpm and 134 ± 12 bpm for the CB and PL trials, correspondingly. Similarly, there was a time effect ($p < 0.001$) but no trial effect ($p = 0.93$) or trial by time interaction ($p = 0.57$) for RPE over the course of the trial, with increased RPE during exercise with ratings peaking after high intensity running. The overall mean (SD) RPE were 12 ± 2 for both the CB and PL trials.

3.10. Blood analyses (glucose, lactate, caffeine and CGAs)

There was no trial ($p = 0.30$) or time ($p = 0.46$) effect nor trial by time interaction ($p = 0.32$) for blood glucose concentration over the course of the trial. There was a time effect ($p < 0.001$), but no trial effect ($p = 0.48$) or trial by time interaction ($p = 0.92$) for blood lactate concentration, with increased lactate concentration with exercise peaking after high intensity running. Analysis of plasma did not detect any CGA or related metabolites at baseline, or in samples obtained 1-h following ingestion of the placebo or coffeeberry containing beverage. Caffeine was not detected in any plasma samples from $n = 19$ players but $n = 1$ player had caffeine detectable in baseline samples on both trial days (1.9 ± 0.4 μM) and this was also evident in the 1-h post beverage ingestion sample (1.1 ± 0.4 μM) on both trial days in this player. Since baseline samples were similar and at very low concentration (reflective of prior day ingestion), and this participant did not demonstrate any CGA or related metabolites in any samples, this player was not excluded from the analyses.

4. Discussion

The primary aim of this study was to compare the effects of CB ingestion versus PL on soccer-specific skills over a 45-min half soccer match simulation and following a subsequent high intensity running endurance capacity task. The study observed significant interaction effects for dribbling accuracy, short pass speed, and long pass speed during the protocol which require exploration.

Dribbling and passing performance are part of the fundamental skillsets of soccer players.[26] Executing a dribble with control and speed and accurate and quick passing is essential for retaining possession and will likely contribute to the outcome of a match.[27] Some previous research has demonstrated that dribbling performance can be influenced by fatigue, as it was shown to deteriorate after soccer match play[27–29] and was maintained by carbohydrate ingestion.[31–33] However, this is not always evident and the test–retest reliability for dribbling tasks is generally poor.[19,20] In the present study, although dribbling accuracy appeared to improve from Pre to 45-min of the soccer match simulation on the CB trial, and to no change or deteriorate on the PL trial, the difference in dribbling accuracy during the SMS was only ~4 %. When comparing this value to the test–retest variation in data over the first 45-min of the protocol in each visit from our previous reliability study,[20] it falls well within the test–retest reliability value of 23.1 %. Therefore, the interaction effect observed in the present study is likely not a meaningful one.

Table 1
Visual analogue scale (VAS) values for gastrointestinal comfort and energy levels during placebo (PL) and coffeeberry trials (CB).

		VAS Nausea	VAS Fullness	VAS Bloatedness	VAS Fatigue	VAS Physical Energy	VAS Mental Energy
Pre-trial	CB	22 ± 21	62 ± 20	43 ± 24	22 ± 15	68 ± 19	70 ± 23
	PL	18 ± 16	64 ± 20	45 ± 25	20 ± 15	63 ± 26	60 ± 26
Pre-SMS	CB	28 ± 24	42 ± 20*	24 ± 16*	24 ± 11	62 ± 19	63 ± 24
	PL	26 ± 19	42 ± 18*	26 ± 16*	32 ± 20	57 ± 20	56 ± 22
Post-SMS	CB	24 ± 18	25 ± 16*	18 ± 15*	57 ± 19*	44 ± 19*	48 ± 18*
	PL	26 ± 16	32 ± 17*	22 ± 17*	58 ± 19*	40 ± 20*	43 ± 21*
Post-high intensity running	CB	30 ± 23	19 ± 13*	16 ± 13*	70 ± 19*	32 ± 21*	39 ± 21*
	PL	26 ± 21	23 ± 15*	17 ± 18*	71 ± 22*	28 ± 18*	38 ± 22*

* A significant time effect within the trial compared to pre-trial values.

For passing, the ability to maintain passing performance seems to differentiate successful and unsuccessful soccer teams.[1,34] Research has established that passing performance declines with fatigue as match-play progresses.[1,35,36] In the present study, passing speed with both feet on the short pass was maintained over 45-min of soccer match play in the coffeeberry trial but declined on the placebo trial and was higher on CB than PL at 30-min and 45-min. The potential trade-off between speed and accuracy is why both of these parameters were measured in the present study. Indeed, it is possible that passing speed could decline to maintain passing accuracy in these skill assessments. Our data indicates that there was also a higher passing accuracy on the short pass during the half match simulation on CB compared with PL, suggesting a real benefit in passing performance. Successful short passing was previously found to be a contributing factor to winning matches in the group stage of the 2014 FIFA World Cup[37]; therefore, our findings seem to have practical relevance. However, it has been stated that passing is greatly influenced by extrinsic factors including quality of the opponent,[38] playing formation,[39] and score line[40] meaning that controlled conditions are required to effectively evaluate intervention outcomes on passing skill. We have previously demonstrated using a controlled intervention that passing performance was positively affected by carbohydrate ingestion, with greater passing accuracy and retained passing speed during a soccer match simulation, particularly on the non-dominant foot.[19] In the present study, the effects were similar, with higher passing accuracy, and better retention of passing speed, on CB than on PL trials, but it seemed to be more evident on the dominant foot actions.

These findings, if translated to a real soccer match may result in a better pass execution following coffeeberry ingestion, with less chance of pass interception from the opposition. However, it cannot be conclusively identified if CB negated some effect of fatigue development on passing performance that was evident in the PL condition. In addition, the differences between trials in passing speed (4.7 %) were above the previously reported test–retest variation of 3.4 % for short pass and 4.3 % for long pass, meaning that our findings demonstrate a small but positive effect. This small positive effect of CB may be driven by a cognitive and/or neuromuscular action to enable retention of passing speed alongside passing accuracy. Theoretically, CB ingestion could have positively impacted cognitive pre-motor processes like visual and spatial processing as the ball was rolled out to players before the execution of the pass.[41] On the neuromuscular component, CB ingestion might have induced a faster central processing time, or greater activation of the muscle groups involved to enable greater motor recruitment when striking the ball to perform the pass.[42] Furthermore, potential effects on cerebral blood flow may have had an influence on cognitive processing that enabled better execution of the skill performance tasks. However, these are speculative explanations that require replication and detailed exploration in laboratory-based studies. Interestingly, the similar glucose and lactate response to the test protocol, and the absence of an impact upon high intensity running capacity, appears to indicate no differences in metabolism/glycolytic flux between trials. Thus, we would propose that there are no major metabolic effects of coffeeberry extract ingestion. It is worth noting that the effects we observed are also not attributable to caffeine, as the content of caffeine in the ingested beverages was minimal and well below any potential ergogenic value. Furthermore, analysis of plasma caffeine and related metabolites indicated that recent caffeine intake was not evident in the players. Therefore, we can suggest that coffeeberry extract itself may have a potential impact on cognitive and/or neuromuscular components that could explain the observed impact upon passing performance, but this too requires further exploration. It would be of interest to understand the impact of CB ingestion beyond 45-min of simulated match play. CB ingestion could potentially have a greater influence on skill performance in the second half of a simulated protocol when players experience greater levels of fatigue. Alternatively, the effects of a single pre-match dose may diminish in the second half without further CB ingestion at half time. Thus, further research to replicate our findings and address these questions is warranted.

The inability to detect CGAs or related metabolites in baseline plasma samples likely demonstrated that players had adhered to the pre-trial guidelines on dietary intake. However, the lack of detection of CGAs or metabolites in plasma at the 1-hour post-ingestion sample suggests that either the level of CGAs in the ingested beverage was insufficient to result in alterations in the systemic circulation, or that absorption was delayed beyond the 1-h post ingestion sample time point. Indeed, CGAs are reported to be bioavailable but across different absorption time periods ranging from 1–2 h to over 5–6 h or longer. The duration depends upon site of absorption and subsequent metabolism, and individual differences in absorption and excretion kinetics.[43] With the ingested beverage used in the present study, CGAs were likely absorbed in the stomach or small intestine but could have been subject to metabolism by gut microbiota and not reached the systemic circulation. Alternatively, plasma appearance may have been delayed due to slow gastric emptying linked to prior ingestion of the pre-trial meal taken 2-h prior to the test beverage. It is not possible to determine exactly the time course of absorption and/or excretion in the present study as we did not have further venous blood draws, or collection of urine for CGA metabolite analyses. However, it is notable that previous studies demonstrating centrally mediated effects of coffeeberry have not attempted to quantify systemic concentration of CGAs or its metabolites.[10,14] Future studies should explore the time course of appearance in plasma to determine optimal sampling points under the specific conditions of the study.

In summary, the ingestion of 300 mg of coffeeberry extract does not induce detectable changes in plasma CGAs or related metabolites at 1-h post-ingestion, but centrally mediated cognitive and/or neuromuscular factors could potentially be playing a role in the observed effects of CB on passing speed/accuracy. It would be interesting to explore potential effects of CB on visual processing, signal transduction from the motor cortex to the muscle, or on motor unit recruitment itself. Future studies should also explore the time course of responses in skill performance to a full match simulation following acute CB ingestion as this would enable determination of effects under greater fatigue, and/or identify specific time intervals for repeated beverage ingestion. However, the results from the present study can only be applied to our sample group of academy soccer players who are high level players signed with professional teams, but who do not have regular first team call-ups. So, our results cannot be generalised beyond this player group.

CRediT authorship contribution statement

SDRG and PRG designed the study in collaboration with IR and MP; SDRG and PRG undertook all approvals for the study and completed data collection and sample and data analyses; LO'B, GG, and BD contributed to sample and data analyses; SDRG, PRG and LO'B drafted the manuscript and GG, BD, IR and MP all contributed to manuscript revisions and final draft approval.

Confirmation of ethical compliance

The experimental procedures were approved by a local Ethics of Research Committee (NICR (19 20) 055) and the study was conducted in accordance with the Declaration of Helsinki (2013).

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Declaration of interest statement

IR and MP are employees of the Gatorade Sports Science Institute, a division of PepsiCo Inc. The views expressed in this article are those of the authors and do not necessarily reflect the position or policy of PepsiCo Inc. No other authors have any competing interests to declare.

References

1. Rampinini E, Impellizzeri FM, Castagna C et al. Technical performance during soccer matches of the Italian Serie A league: effect of fatigue and competitive level. *J Sci Med Sport* 2009;12(1):227-233.
2. Williams A. Perceptual skill in soccer: implications for talent identification and development. *J Sports Sci* 2000;18(9):737-750.
3. Hooper L, Kay C, Abdelhamid A et al. Effects of chocolate, cocoa, and flavan-3-ols on cardiovascular health: a systematic review and meta-analysis of randomized trials. *Am J Clin Nutr* 2012;95(3):740-751.
4. Mullen W, Nemzer B, Ou B et al. The antioxidant and chlorogenic acid profiles of whole coffee fruits are influenced by the extraction procedures. *J Agric Food Chem* 2011;59(8):3754-3762.
5. Bowtell J, Kelly V. Fruit-derived polyphenol supplementation for athlete recovery and performance. *Sports Med* 2019;49(Suppl 1):3-23.
6. Tari B, Vanhie JJ, Belfry GR et al. Increased cerebral blood flow supports a single-bout post-exercise benefit to executive function: evidence from hypercapnia. *J Neurophysiol* 2020;124(2):731-741.
7. Gratton G, Weaver SR, Burley CV et al. Dietary flavanols improve cerebral cortical oxygenation and cognition in healthy adults. *Sci Rep* 2020;10(1):19409.
8. Tsukamoto H, Suga T, Ishibashi A et al. Flavanol-rich cocoa consumption enhances exercise-induced executive function improvements in humans. *Nutrition* 2018;46: 90-96.
9. Ostojic SM, Stojanovic MD, Djordjevic B et al. The effects of a 4-week coffeeberry supplementation on antioxidant status, endurance, and anaerobic performance in college athletes. *Res Sports Med* 2008;16(4):281-294.
10. Reed R, Mitchell E, Saunders C et al. Acute low and moderate doses of caffeine-free polyphenol-rich coffeeberry extract improve alertness and reduce fatigue during cognitive tasks. *J Cogn Perform* 2019;3:193-206.
11. Naylor J, Zimmermann D, Guitard-Uldry M et al. Acute dose-response effect of coffee-derived chlorogenic acids on the human vasculature in healthy volunteers: a randomized controlled trial. *Am J Clin Nutr* 2021;113(2):370-379.
12. Jackson P, Wightman R, Veasey R et al. A randomized, crossover study of the acute cognitive and cerebral blood flow effects of phenolic, nitrate and botanical beverages in young, healthy humans. *Nutrients* 2020;12(8):2254.
13. Jackson P, Haskell-Ramsay C, Forster J et al. Acute cognitive performance and mood effects of coffee berry and apple extracts: a randomised, double-blind, placebo-controlled crossover study in healthy humans. *Nutr Neurosci* 2022;25:2335-2343.
14. Robinson J, Hunter J, Reyes-Izquierdo T et al. Cognitive short- and long-term effects of coffee cherry extract in older adults with mild cognitive decline. *Neuropsychol Dev Cogn B Aging Neuropsychol Cogn* 2020;27(6):918-934.
15. Robinson J, Yanes J, Reid M et al. Neurophysiological effects of whole coffee cherry extract in older adults with subjective cognitive impairment: a randomized, double-blind, placebo-controlled, cross-over pilot study. *Antioxidants* 2021;10(2):144.
16. Robinson J, Hunter J, Kern M et al. Whole coffee cherry extract improves working memory and response inhibition: acute and longitudinal results from a remote, randomized, double-blind, placebo-controlled clinical trial. *Nutrients* 2024;16(14):2348.
17. Bangsbo J, Iaia F, Krustrup P. The Yo-Yo intermittent recovery test: a useful tool for evaluation of physical performance in intermittent sports. *Sports Med* 2008;38(1):37-51.
18. Russell M, Rees G, Benton D et al. An exercise protocol that replicates soccer match-play. *Int J Sports Med* 2011;32(7):511-518.
19. Rodriguez-Giustiniani P, Rollo I, Witard O et al. Ingesting a 12% carbohydrate-electrolyte beverage before each half of a soccer-match simulation facilitates retention of passing performance and improves high-intensity running capacity in academy players. *Int J Sport Nutr Exerc Metab* 2019;29(4):397-405.
20. Rodriguez-Giustiniani P, Rollo I, Galloway S. A preliminary study of the reliability of soccer skill tests within a modified soccer match simulation protocol. *Sci Med Footb* 2022;6(3):363-371.
21. Borg G. Perceived exertion: a note on “history” and methods. *Med Sci Sports* 1973;5(2): 90-93.
22. Maughan R. A simple, rapid method for the determination of glucose, lactate, pyruvate, alanine, 3-hydroxybutyrate and acetoacetate on a single 20-µL blood sample. *Clin Chim Acta* 1982;122(2):231-240.
23. Yang F, Gong J, Shen L et al. Development of an LC-MS/MS method for quantitative analysis of chlorogenic acid in human plasma and its application to a pharmacokinetic study in Chinese patients with advanced solid tumor. *J Pharm Biomed Anal* 2020;177:112809.
24. Ye J, Wei W, Quan L et al. An LC-MS/MS method for the simultaneous determination of chlorogenic acid, forsythiaside A and baicalin in rat plasma and its application to pharmacokinetic study of shuang-huang-lian in rats. *J Pharm Biomed Anal* 2010;52(4): 625-630.
25. Clifford M, Johnston K, Knight S et al. Hierarchical scheme for LC-MSn identification of chlorogenic acids. *J Agric Food Chem* 2003;51(10):2900-2911.
26. Reilly T, Holmes M. A preliminary analysis of selected soccer skills. *Phys Educ Rev* 1983;6:64-71.
27. Stone K, Oliver J. The effect of 45 minutes of soccer-specific exercise on the performance of soccer skills. *Int J Sports Physiol Perform* 2009;4(2):163-175.
28. Smith M, Coutts A, Merlini M et al. Mental fatigue impairs soccer-specific physical and technical performance. *Med Sci Sports Exerc* 2016;48(2):267-276.
29. Trecroci A, Boccolini G, Duca M et al. Mental fatigue impairs physical activity, technical and decision-making performance during small-sided games. *PloS One* 2020;15(9): e0238461.
30. Currell K, Conway S, Jeukendrup A. Carbohydrate ingestion improves performance of a new reliable test of soccer performance. *Int J Sport Nutr Exerc Metab* 2009;19(1): 34-46.
31. Harper L, Hunter R, Parker P et al. Test-retest reliability of physiological and performance responses to 120 minutes of simulated soccer match play. *J Strength Cond Res* 2016;30(11):3178-3186.
32. Harper L, Stevenson E, Rollo I et al. The influence of a 12% carbohydrate-electrolyte beverage on self-paced soccer-specific exercise performance. *J Sci Med Sport* 2017;20(12):1123-1129.
33. Adams D, Morgans R, Sacramento J et al. Successful short passing frequency of defenders differentiates between top and bottom four English Premier League teams. *Int J Perform Anal Sport* 2013;13(3):653-668.
34. Carling C, Dupont G. Are declines in physical performance associated with a reduction in skill-related performance during professional soccer match-play? *J Sports Sci* 2011;29(1):63-71.
35. Russell M, Rees G, Kingsley M. Technical demands of soccer match play in the English Championship. *J Strength Cond Res* 2013;27(10):2869-2873.
36. Taha T, Ali A-Y. Greater numbers of passes and shorter possession durations result in increased likelihood of goals in 2010 to 2018 World Cup Champions. *PloS One* 2023;18(1):e0280030.
37. Taylor J, Mellalieu S, James N et al. The influence of match location, quality of opposition, and match status on technical performance in professional association football. *J Sports Sci* 2008;26(9):885-895.
38. Bradley P, Carling C, Archer D et al. The effect of playing formation on high-intensity running and technical profiles in English FA Premier League soccer matches. *J Sports Sci* 2011;29(8):821-830.
39. Paixao P, Sampaio J, Almeida C et al. How does match status affect the passing sequences of top-level European soccer teams? *Int J Perform Anal Sport* 2015;15(1): 229-240.
40. Jansen P, Lehmann J, Van Doren J. Mental rotation performance in male soccer players. *PloS One* 2012;7(10):e48620.
41. Cerrah A, Gungor E, Soylu A et al. Muscular activation patterns during the soccer in-step kick. *Isokinet Exerc Sci* 2011;19(3):181-190.
42. Clifford MN, Kerimi A, Williamson G. Bioavailability and metabolism of chlorogenic acids (acyl-quinic acids) in humans. *Compr Rev Food Sci Food Saf* 2020;19(4): 1299-1352.