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Research report

Coffee for morning hunger pangs. An examination of coffee and caffeine on appetite, gastric emptying, and energy intake ☆

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ABSTRACT

Coffee is one of the most widely consumed beverages in the world and has a number of potential health benefits. Coffee may influence energy expenditure and energy intake, which in turn may affect body weight. However, the influence of coffee and its constituents – particularly caffeine – on appetite remains largely unexplored. The objective of this study was to examine the impact of coffee consumption (with and without caffeine) on appetite sensations, energy intake, gastric emptying, and plasma glucose between breakfast and lunch meals. In a double-blind, randomised crossover design. Participants (n = 12, 9 women; Mean ± SD age and BMI: 26.3 ± 6.3 y and 22.7 ± 2.2 kg•m^{-2}) completed 4 trials: placebo (PLA), decaffeinated coffee (DECAF), caffeine (CAF), and caffeine with decaffeinated coffee (COF). Participants were given a standardised breakfast labelled with ^{13}C-octanoic acid and 225 mL of treatment beverage and a capsule containing either caffeine or placebo. Two hours later, another 225 mL of the treatment beverage and capsule was administered. Four and a half hours after breakfast, participants were given access to an *ad libitum* meal for determination of energy intake. Between meals, participants provided exhaled breath samples for determination of gastric emptying; venous blood and appetite sensations. Energy intake was not significantly different between the trials (Means ± SD, $p > 0.05$; Placebo: 2118 ± 663 kJ; Decaf: 2128 ± 739 kJ; Caffeine: 2287 ± 649 kJ; Coffee: 2016 ± 750 kJ); Other than main effects of time ($p < 0.05$), no significant differences were detected for appetite sensations or plasma glucose between treatments ($p > 0.05$). Gastric emptying was not significantly different across trials ($p > 0.05$). No significant effects of decaffeinated coffee, caffeine or their combination were detected. However, the consumption of caffeine and/or coffee for regulation of energy balance over longer periods of time warrant further investigation.

Introduction

Energy balance is an important concept in weight and obesity management, as understanding and manipulating energy balance can lead to changes in body composition and/or body weight. Caffeine is the most widely consumed psychoactive substance in the world, with a recent study reporting 85% of a sample population (~38,000) consumed one or more caffeine-containing beverages a day (Mitchell, Knight, Hockenberry, Teplansky, & Hartman, 2014). Thus, it is important to examine the influence of caffeine on determinants of energy balance, as coffee and caffeine consumption have been found to have mild (but significant) associations with attenuated weight gain. Greenberg and colleagues reported that as caffeinated and decaffeinated coffee consumption increases, the likelihood of gaining weight decreases (Greenberg, Axen, Schnoll, & Boozer, 2005). This is supported by evidence from large cohort studies that reported increases in daily caffeine consumption led to a lower weight gain in older adults (Lopez-Garcia et al., 2006) and that increments of 1 cup of coffee per day were associated with 0.14 kg less weight gain per four-year period (Pan, et al., 2013).

However, the mechanisms of the potential weight-reducing effects of coffee and caffeine are not clearly known, although several have been postulated including alterations in energy expenditure and energy intake. There is strong evidence that caffeine can lead to moderate increases in resting energy expenditure (~5% over 24 h) (Hursel et al., 2011). The effects on appetite and energy intake are more variable, with some studies reporting reductions in energy intake in

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response to caffeine (Tremblay, Masson, Leduc, Houde, & Despres, 1988), while others do not report changes whether caffeine (Judice et al., 2013a,b) or coffee (Gavrieli et al., 2011, 2013) are ingested. Coffee's effects on gastrointestinal function have also been examined, as alterations in gut hormones or gastric emptying (GE) could influence appetite and energy intake (Horner, Byrne, Cleghorn, Naslund, & King, 2011). As with appetite and energy intake, results for GE responses to coffee ingestion remain equivocal, though responses to caffeine have not been separately examined (Akimoto et al., 2009; Franke, Harder, Orth, Zitzmann, & Singer, 2008). Finally, coffee and caffeine potentiate postprandial blood glucose responses (Gavrieli, Fragopoulou, Mantzoros, & Yannakoulia, 2013;), and the postprandial glucose response may be linked with subsequent energy intake (Flint et al., 2006).

The literature to date has some methodological issues that may limit applications to larger populations; namely the use of one bolus dose of coffee (Gavrieli et al., 2011, 2013; Greenberg & Geliebter, 2012) and GE assessment of coffee as a complete beverage (Akimoto et al., 2009; Franke et al., 2008). A recent study that examined the beverage consumption patterns of adults in the UK reported that consumption of hot beverages (i.e. coffee, tea, cocoa, etc.) peaks in the morning (0600–0800) with a second, smaller peak late morning (1000–1200), in both men and women (Gibson & Shirreffs, 2013). Thus, individuals may consume multiple beverages between meals, and the influence of this multiple dosing pattern on appetite and energy intake remains to be investigated.

Clearly, additional research is required to fully understand the influence of caffeine and coffee intake on psychological and physiological mediators of food consumption. Therefore, the aim of this study was to explore various potential mechanisms of how a split dose of caffeine and coffee may affect appetite sensations, energy intake, and gastric emptying. It was hypothesized that caffeine would independently, and in combination with coffee, acutely decrease hunger, and attenuate gastric emptying, without alterations in energy intake.

Methods

This study utilised a randomised, double-blind, placebo-controlled crossover design. The study was approved (GU HREC PBH/18/12) by the institutional ethics committee and conformed to the Declaration of Helsinki.

Treatments

Four distinct treatments were utilised in this study (Table 1). The control condition consisted of placebo capsules (Metamucil®) and water. The decaf condition was placebo capsules and decaffeinated coffee (Nescafe® Instant Decaf). The caffeine condition provided pure, encapsulated caffeine (PCCA, Matraville, NSW, Australia) with water, and the coffee condition involved participants consuming caffeine capsules and decaffeinated coffee. All caffeine doses provided a total dose of 4 mg•kg^{-1} BM in two equivalent doses. This dose was chosen because it was between the doses used in prior studies (Gavrieli et al., 2011; Greenberg & Geliebter, 2012) and similar to the estimated daily consumption of our participants. Capsules were used to mask the detection of the presence of caffeine dissolved in water or subtle differences between regular and decaffeinated coffee. The coffee was provided in two 5-g boluses dissolved in 225 mL of water and served at ~50 °C. Equal volumes of cool tap water (~15 °C) were provided in the non-coffee conditions (beverage temperature has been reported to have no influence on GI function (McArthur & Feldman, 1989)). We utilised Metamucil as our placebo as it has been previously used by our group (Desbrow, Barrett, Minahan, Grant, & Leveritt, 2009) due to its similar texture to anhydrous caffeine. While psyllium (Metamucil®) has been shown to influence gastric emptying, appetite, and energy intake, this requires significant amounts (10–20 g) (Bergmann et al., 1992; Turnbull & Thomas, 1995). The ~250 mg that participants received in the present study would have likely been insufficient to cause any confounding effects.

Table 1
Matrix of treatment conditions.

Condition	Beverage	Capsules
Placebo (PLA)	Water	Placebo (Metamucil®)
Caffeine (CAF)	Water	Caffeine
Coffee + CAF (COF)	Decaffeinated coffee	Caffeine
Decaffeinated coffee (DECAF)	Decaffeinated coffee	Placebo (Metamucil®)

We chose to utilise two bolus doses of coffee to mimic natural consumption, i.e. a beverage with breakfast followed by a second ingested mid-morning. Coffee consumption usually peaks in the morning (0600–0800) with a second, smaller peak late morning (1000–1200), during the week in both men and women (Gibson & Shirreffs, 2013). Time-to-peak caffeine concentration was also considered during study design; though it is highly variable depending on the individual (Skinner, Jenkins, Taaffe, Leveritt, & Coombes, 2013b), caffeine levels appear to peak around 2–2.5 h post-ingestion. Thus, the timing of the coffee/caffeine doses were designed to maintain elevated plasma caffeine levels during the trial.

Metabolic activity of the capsules was not verified in this study; however, the same capsules, prepared in the exact same manner and with a similar dosing regimen (2 × 3 mg·kg^{-1} BM), were recently used by us in a similarly designed study (Schubert et al., 2014). In that study, samples for plasma caffeine were determined at baseline (−30), +15 (45 min post), +60 (90 min post), 180 (30 min post-2nd dose), and 240 min (90 min post-2nd dose). Caffeine levels exhibited a 'double-peak' of ~20 μM•L^{-1} at 60 min and ~32 μM•L^{-1}at 240 min (exercise was conducted from 60–120 min and a 2nd caffeine dose ingested at 150 min) (Schubert et al., 2014).

Because it was not possible to blind participants to coffee versus water in the present design, they were aware of when they were receiving coffee – but they and the investigators remained blind to caffeine administration. As the true purpose of this study was to assess energy intake as a primary outcome, and appetite perceptions as a secondary outcome, participants were blinded by informing them that the aim of the study was to examine how encapsulated caffeine and caffeine in coffee influenced gastric emptying and markers of metabolism and oxidative stress. On completion of all trials participants were debriefed and asked to try and identify the order of their treatments and the associated certainty with their choices ("no idea", "somewhat certain", "reasonably certain", and "absolutely certain"). Participants were randomised according to a Latin Squares design and an individual not associated with the research allocated caffeine and placebo capsules into envelopes containing only a trial number and participant identification.

Participants, familiarisation and experimental controls

Participants provided written informed consent and completed questionnaires to assess health, physical activity habits, and dietary habits (Stunkard & Messick, 1985) before enrolment. The latter was used to ensure the exclusion of individuals with atypical or abnormal eating patterns which could have potentially confounded the study outcomes. Participants also completed a caffeine-consumption questionnaire to quantify daily caffeine consumption (Desbrow, 2011). The inclusion criteria for the recruitment of participants were as follows: non-smoking, non-obese men and pre-menopausal women (BMI < 30 kg•m^{-2}) between 18 and 45 years of age; not taking any medicine known to influence lipid, carbohydrate, or caffeine metabolism; not dieting and did not have any