AN INVESTIGATION INTO THE EFFECTS OF CAFFEINE ON GOLF PERFORMANCE WITH FOCUS ON THE DRIVE

By
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Abstract

The purpose of the study was to examine the effect of caffeine on golf performance, focussing on the drive. Eleven male volunteers (age 29.36 ± 6.50years; height 180.27 ± 5.93cm; weight 85.48 ± 13.31kg; handicap 4.75 ± 3.68) were recruited. Each participant was tested on two occasions in a counterbalanced design involving three-phases; 1- ten-drives on a golf-simulator to assess performance variables (club head speed, ball speed, carry-distance, total-distance, offline and launch angle); 2- playing 18-holes of golf; 3- repeat ten-drives on the golf-simulator. Participants were administered (double-blind) 3mg • kg^{-1} caffeine or placebo over two-doses, firstly 30-minutes prior to commencing phase 2 and secondly, immediately following hole-9. Golf performance (total score, greens in regulation and total putts) hydration status, physiological (distance walked and mean heart rate) and environmental conditions (temperature and wind speed) were recorded. A 2x2 (condition x time) repeated-measures ANOVA and Paired-samples *t*-tests were used to compare performance differences between the two conditions. Analysis indicated significant interactions ($p<0.05$) for ball speed (154.65 ± 9.08 mph - 153.31 ± 9.05 mph, $d= 0.16$) and total-distance (278.55 ± 18.56 yards - 272.73 ± 15.45 yards, $d= 0.36$) in the placebo condition with no significant reductions ($p>0.05$) in the caffeine condition. However, no significant performance differences ($p>0.05$) were identified on the course over 18-holes. It was concluded 3mg • kg^{-1} caffeine consumed before and during golf attenuates the effects of fatigue on some performance variables associated with the drive, however did not improve performance on the course.

Declaration

No portion of the work referred to in this Research Project has been submitted in support of an application for another degree or qualification of this, or any other University or institute of learning.

The project was supervised by a member of academic staff, but is essentially the work of the author.

Signed: 

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1. Introduction

Golf is a popular sport played by all ages and abilities both competitively and recreationally (Fradkin, Sherman & Finch, 2004; Mumford et al., 2016). Golf has 3 fundamentals, driving, iron-play and putting, each of which is positively correlated with performance (Evans & Tuttle, 2015). Therefore being proficient in all aspects is key to continued success (Belkin, Gansneder, Pickens, Rotella & Striegel, 1994).

It is argued that the most influential stroke in golf is the drive, as it covers the most distance, affecting the strategy for the remainder of the hole (Torres-Ronda, Sanchez-Medina & Gonzalez-Badillo, 2011). The ability to generate high club head speed is considered the key determinant of driving ability (Keogh et al., 2009). However the flight of the ball after impact is influenced by several variables, such as ball-spin and launch angle (Sato, Kenny & Dale, 2013), which influence the amount of energy transferred from the club head to the ball, this interaction is also referred to as smash factor (Kempton, 2013). Accordingly the smash factor contributes to initial ball speed and ultimately drive-distance (Sweeney, Mills, Alderson & Elliott, 2013). Consequently if a high club head speed is achieved yet smash factor is sub-optimal, distance and/ or accuracy may be compromised (Kempton, 2013).

As a sport, golf is perceived as non-fatiguing, predominantly due to speed of play (Stevenson, Hayes & Allison, 2009). However, 18-holes of golf can take approximately 4-hours to complete and players can cover distances upwards of 8,000m (Mumford et al., 2016). Also a golf swing requires repeatedly producing explosive power through a wide range of motion (Wells, Elmi & Thomas, 2009). In addition to physical demands, golf requires

significant cognitive processes including decisions regarding club selection, shot selection and execution of the swing (Smith, 2010). Therefore fatigue may negatively affect performance through both central and peripheral mechanisms (Mumford et al., 2016).

The level of walking required (Green, Dafkin, Kerr & Mckinon, 2015) and the repetition of complex kinetic chain movements such as the golf swing can result in muscular fatigue (Smith, 2010). Previous research reported decreases in measures of energy as well as increases in perception of fatigue over 18-holes (Mumford et al., 2016; Stevenson et al., 2009). The impact of fatigue on golf can influence the mechanics of the swing through reorganisation of muscle activity patterns and recruitment of additional muscle (Smith, 2010). As small margins are involved within precise actions, even slight fatigue may compromise shot success (Higdon, Holmes-Finch, Leib & Dugan, 2012). Regarding performance outcomes, fatigue has been found to reduce club head speed (Green et al., 2015; Higdon et al., 2012) as well as the success rate of putting (Mathers & Grealy, 2013). Accordingly, nutritional interventions may be beneficial to those involved in skill based sports such as golf to offset fatigue (Mumford et al., 2016; Stevenson et al., 2009). However, research focussing on nutritional interventions in golf is limited, possibly due to difficulty in standardising conditions (Stevenson et al., 2009).

One of the most utilised supplements in sport is caffeine (a trimethylxanthine); recent research shows that ~75% of elite athletes consume caffeine prior or during competition (Del Coso et al., 2012) attempting to enhance performance (Davis & Green, 2009). The effect of caffeine on performance has been well documented (Graham, 2001).

Research has identified an ergogenic effect of caffeine on physical performance including increased time to exhaustion (Hogervorst et al, 2008), increased time-trial performance (Hodgson, Randell & Jeukendrup, 2013) as well as high-intensity endurance running (O'Rourke, O'Brien, Knez & Paton, 2008). The ergogenic effects of caffeine have also been found to increase performance in skill-based sports performed over long periods where cognitive fatigue may be a factor (Burke, Desbrow & Spreit, 2013). For example in epee fencing performance during a skill test was maintained (Bottoms, Greenhalgh & Gregory, 2013), in tennis serve kinematics were increased, specifically towards the final stages (Hornery, Farrow, Mujika & Young, 2007), as well as improved accuracy and ball control in a simulated soccer activity (Foskett, Ali & Grant, 2009).

To the researcher's knowledge only two studies have previously investigated effects of caffeine on golf performance. Stevenson et al. (2009) investigated caffeine in combination with carbohydrate, however this was conducted in a simulated setting using a treadmill to replicate walking conditions, taking ~3 hours, where in reality 18-holes of golf can extend up to 6-hours on a variety of terrains (Smith, 2010). Furthermore Mumford et al. (2016) investigated a caffeine-containing supplement on golf performance during competition, in addition to a simulated test assessing iron-play accuracy. Both studies recognised positive effects within physical and cognitive parameters. Stevenson et al. (2009) found caffeine co-ingestion with carbohydrate attenuated the decline in alertness but did not reduce feelings of fatigue, however the authors could not distinguish between the effects of each ingredient and recommended future studies incorporate single ingredient

nutritional interventions. For example carbohydrate ingestion alone has already been found to increase skill performance (Jeukendrup, 2014), however this has mainly been identified in team-sports. Whereas Mumford et al. (2016) also found a caffeine-containing supplement to sustain ratings of energy but also attenuate ratings of fatigue, it is worth stating the dosage of caffeine (3.8mg • kg^{-1}) was over double that used by Stevenson et al. (2009) (1.6mg • kg^{-1}). The lower dose used by Stevenson et al. (2009) could have been a factor in not reducing feelings of fatigue, especially due to the length of play involved (Graham, 2001). In addition, both studies identified improvements in performance outcomes, Stevenson et al. (2009) in accuracy of putting whereas Mumford et al. (2016) in accuracy of iron-play, each in a simulated setting. A second notable finding from Mumford et al. (2016) was a significant improvement in driving distance during the caffeine condition compared to placebo, however this finding was not controlled for environmental conditions and no further variables of driving performance such as club head speed and ball speed were measured, therefore the authors' conceded this finding was speculative and warranted further investigation.

The fatigue delaying effect of caffeine is widely reported with a variety of mechanisms suggested (Sokmen et al., 2008), however it is believed only one within the physiological concentration range of caffeine is important (Graham, 2001). Caffeine acts on the Central Nervous System as a stimulant and can bind to cell membrane receptors, blocking the action of adenosine on the brain (Schneiker, Bishop, Dawson & Hackett, 2006). The major effect of adenosine is the decrease in concentration of several neurotransmitters, including serotonin, dopamine, acetylcholine, norepinephrine, and glutamate

(Meeusen, Roelands & Spriet, 2013); as a result reducing motor activity and decreasing wakefulness (Burke et al., 2013). Therefore the action of adenosine receptor antagonism is likely to be the primary mechanism of caffeine (Schneiker et al., 2006), which leads to increased excitability of neuronal tissue, level of arousal and cognition (Lorist & Tops, 2003; Mumford et al., 2016). As previously discussed the fatiguing effects of golf are two-fold, where continued motor performance and cognitive ability are required, therefore the use of caffeine to negate the fatiguing effects of golf is justified (Mumford et al., 2016; Smith, 2010; Stevenson et al., 2009).

It is recommended caffeine be administered relative to body mass, as absolute doses could create large variability between participants (Graham, 2001). Early dose-response studies of caffeine suggested doses of 3-6mg • kg^{-1} to improve performance (Desbrow et al., 2011) however, more recently research has shown benefits of caffeine can occur at 1-3mg • kg^{-1} (Burke, 2008). At higher doses (>6-9mg • kg^{-1}) caffeine ingestion can present negative side effects including increased heart rate, anxiety and inability to focus (Burke et al, 2013). Due to fine motor control and concentration required in skill sports such as golf, dosage must be taken into consideration (Burke et al, 2013). Therefore lower doses of caffeine have greater practical application (Desbrow et al., 2011), this has led to numerous practical recommendations for caffeine to be dosed at 3mg • kg^{-1} as the ergogenic effect is achieved without the avoidable side effects (Burke, 2008; Desbrow et al., 2011; Graham, 2001). As well as appropriate dose, correct timing is also necessary (Graham, 2001). Caffeine is rapidly absorbed and peak plasma concentrations are recognised approximately 30-75 minutes following

ingestion (Sokmen et al., 2008). The half-life of caffeine is 4-6 hours and individuals maintain circulating concentrations for 3-4 hours (Graham, 2001). Research suggests that repeat-doses to extend the elevation of plasma caffeine may have applications for prolonged events (Graham, 2001). Consequently due to lengthy play of golf (4-hours+) a second dose of caffeine following the first-9 holes to maintain plasma-concentration has been previously used (Mumford et al., 2016).

Therefore the aim of the present study was to investigate the acute effects of 3mg • kg^{-1} caffeine on 18-holes of golf performance with further testing focussing on the drive in a simulated setting. It is hypothesised that acute caffeine ingestion will attenuate the effects of fatigue developed over 18-holes of golf.

2. Methods

2.1.Participants

A convenience sample of 11 male golfers volunteered to participate in the present study (Participant Descriptive Information can be found in Table 2.1.). Participants were recruited from The Chase Golf Club, Penkridge, South Staffordshire membership base, following written permission of the General Manager. Participants were included if they were aged between 18-55 years, had an individual handicap <12, were free from any pre-existing medical conditions and were habitual caffeine users. Following ethical approval (16th June 2016) from the Faculty of Science and Engineering Research Ethics Committee at the University of Chester (Appendix 1) participants read and signed informed consent forms (Appendix 2) and completed health questionnaires including a questionnaire establishing habitual caffeine use (Appendix 3).

Table 2.1- Participant Descriptive Information

	n=11
Age (y)	29.36 ± 6.50
Height (cm)	180.27 ± 5.93
Weight (kg)	85.48 ± 13.31
Handicap	4.75 ± 3.68
Caffeine intake (mg • kg^{-1})	318. 18 ± 188.13

2.2 Design

In a double blind, placebo controlled, counterbalanced design, participants were required to visit the golf club on two occasions, separated by

approximately 7-days. A simple randomisation procedure was employed to counterbalance the participants. The study involved three testing elements on each visit, firstly participants were required to provide 10-drives using a golf simulator, followed by 18-holes of golf, before returning to the golf simulator for re-testing, a detailed schematic flow chart of events can be found in Figure 2.1.

There were multiple dependant variables regarding performance during the simulated drive, including; ball speed, carry distance (defined as the distance the ball travels from the tee to the initial contact with the ground (Kempton, 2013)), total distance (defined as the distance the ball travels from the tee to the final resting place (Kempton, 2013)), accuracy, ball spin and launch angle (the angle at which the ball leaves the clubface relative to horizontal (Kempton, 2013)). The independent variables were time (pre/ post 18-holes of golf) and condition (caffeine/ placebo).

2.3 Procedures

All participants recruited for the present study were members of The Chase Golf Club, therefore had previous experience of the golf course prior to testing. Participants were allowed to use their own equipment; golf clubs, golf balls and tees during testing but were requested to maintain consistent between each of the testing occasions.

Participants were required to abstain from consuming caffeine containing foods and drink 48-hours prior to each testing occasion. The abstinence period was used to reduce the levels of caffeine in the circulation, which can successfully be achieved within the allocated time frame (Graham,

2001). Participants were additionally required to abstain from strenuous activity in the 24-hours prior to testing. Participants were also requested to arrive in a hydrated state and to have consumed a meal 2-hours prior to arrival, a procedure utilised in a similar previous study (Mumford et al., 2016). Participants were required to record the contents of the meal and asked to follow the same procedures prior to the second testing occasions to ensure consistency between conditions.

Upon arrival to the clubhouse participants were required to provide a urine sample, which was analysed as per manufacturer guidelines, to assess hydration status via Urine Osmolality (Osmocheck, VITECH, West Sussex, United Kingdom), if the urine sample presented an Osmolality of <900 mosmol•kg^{-1} the participant was assumed euhydrated (Shirreffs, 2000). Participants were asked to wear a GPS vest (Catapult Innovations, Melbourne; Australia) and Heart Rate Monitor (Polar T31 Transmitter, Polar Electro (UK), Warwick; United Kingdom) and were provided with verbal instructions on correcting fitting procedures. Participants were allowed 5-minutes to conduct a self-administered warm up prior to testing via use of the simulator (Foresight GC2, Foresight Sports, USA) without any restrictions placed on club selection. In an ideal situation participants would have conducted the testing outdoors with all outcomes directly measured, however due to the many external factors (i.e. wind speed/ direction, ambient temperature) using an indoor environment ensured consistency (Fradkin et al., 2004). The simulator was situated in a purposed built area as part of the Clubhouse at The Chase Golf Club and involved the participants performing golf strokes off a synthetic surface using a tee, striking the ball at a capture-

screen aligned with the launch monitor as per manufacturer instructions. Following the warm-up participants were then asked to provide 10 drives with the resulting data measured (ball speed ±0.5mph, ball spin ±50.0rpm and launch angle ±0.2°) and estimated (carry distance, total distance and accuracy). The number of drives chosen was to replicate a previous study that had been designed to assess similar performance measures (Fradkin et al., 2004).

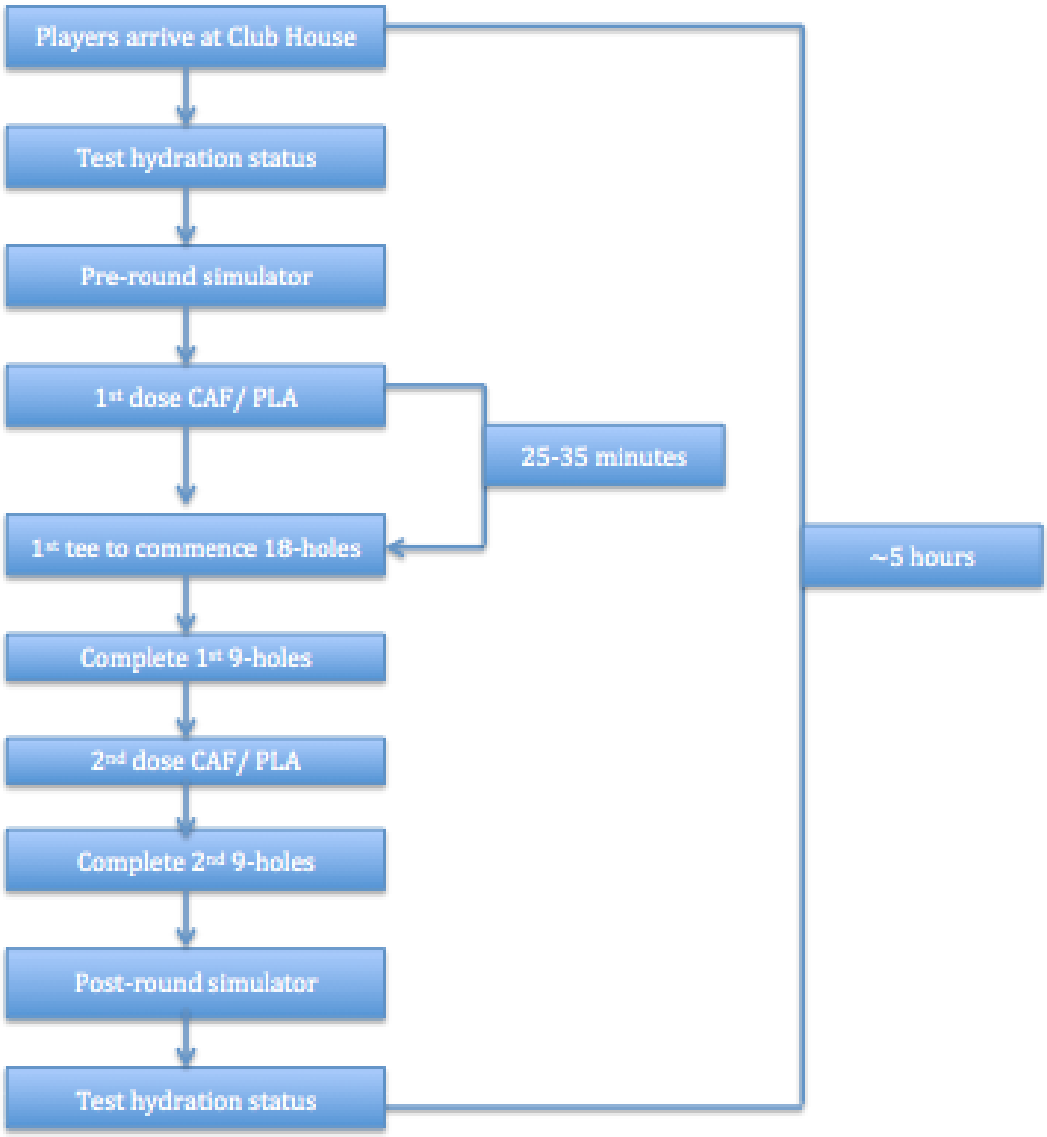

Figure 2.1- Schematic Flow Chart of Study Design

On completion of simulator testing, participants were provided with the first half of 3mg • kg^{-1} caffeine in the form of a capsule (Caffeine, MyProtein, The Hut.com Ltd, Cheshire, UK) or a placebo (Plain flour) and were asked to make their way to the 1st tee, 30-mintues was allowed between administering the caffeine and commencing 18-holes to allow peak plasma concentrations to be achieved (Sokmen et al., 2008). The Laboratory Technician for Exercise Physiology at The University of Chester weighed and provided all interventions in individually sealed envelopes to ensure double blinding. Immediately prior to the first-hole participants were fitted with a numbered Global Positioning Service (GPS) unit (Catapult Optimeye S5, Catapult Innovations, Melbourne, Australia), once the GPS Unit was fitted participants were asked to complete 18-holes, adhering to club rules set by The Chase Golf Club, in a stroke-play format, the par for the course is 73 strokes. Participants were allowed to consume water ad libitum throughout. The lead researcher accompanied the participants on each round to collect data which included environmental conditions; ambient temperature, wind speed and direction (UK Meteorological Office, 2016) as well as performance data; total score (defined as the number of strokes taken to complete the 18-holes), fairways hit (defined as the ball finishing on the fairway after the tee shot on a par 4 or 5), greens in regulation (defined as the ball finishing 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) and total number of putts per round (Mumford et al., 2016). Following hole-9 participants were provided with a second capsule with the second half of their condition (totalling 3mg • kg^{-1} in the caffeine condition). The participants were also provided with the opportunity to

have a snack that resembles an habitual round for the individual, which is recommended in the designing a testing protocol (Burke, 2008). Rather than a standard snack provided to all participants in a previous study (Mumford et al., 2016), again participants were asked to record the content and remain consistent on both testing occasions. Following the second 9-holes the GPS unit was switched off and collected for analysis. Participants were required to provide a second urine sample to identify any differences in hydration status between pre- and post- 18-holes, following the same procedures as pre-round. Participants were also required to provide another 10-drive strokes with the same resulting data collected as pre-round. Finally participants were verbally reminded of the required procedures for their second testing session including to remain consistent with dietary intake.

2.4 Statistical Analysis

Data was presented as mean ± SD throughout. Data was analysed using SPSS statistical software (SPSS Statistics, IBM, Seattle, USA). Before analysis, each variable was tested for normality using the Shapiro-Wilk method. If deemed normally distributed, dependent variables from the performance of the drive using the simulator were assessed using a 2x2 (condition x time) repeated-measures Analysis of Variance (ANOVA). If any significant interactions were discovered, follow-up analysis was conducted using Paired-Sample *t*-tests to identify where the difference occurred. Alpha level was set at $P < 0.05$ throughout. In addition Cohen's (*d*) were quantified for paired samples *t*-tests with the understanding set at 0.2 for a small, 0.5 for a moderate and >0.8 for a large effect to aid the interpretation for practical

significance (Mumford et al., 2016).

Paired-samples *t*-tests were used to compare all differences between the two conditions (caffeine trial and placebo trial) from pre to post 18-holes of golf for statistical significance including in round performance data (total score, fairways hit, greens in regulation and total putts), physiological data (heart rate and distance covered), hydration status and environmental conditions (ambient temperature and wind speed).

3. Results

3.1. Simulator 'Drive' Performance (Table 3.1.)

3.1.1. Club Head Speed

The main effect of time on club head speed was not significant F (1, 10) = .817, *P* >.05 from pre (M = 106.31 ±1.86) to post (M = 105.76 ±1.65) 18-holes of golf. The main effect of condition on club head speed was also not significant F (1, 10) = .229, *P* >0.05 between caffeine (M = 105.91 ±1.64) and placebo (M = 106.16 ±1.86). There was no significant time x condition interaction F (1, 10) = .757, *P* > .05.

3.1.2. Ball Speed

The main effect of time on ball speed was not significant F (1, 10) = .044, *P* >.05 from pre (M = 154.14 ±2.70) to post (M = 154.07 ±2.70) 18-holes of golf. The main effect of condition on ball speed was also not significant F (1, 10) = .215, *P* >0.05 between caffeine (M = 154.23 ±2.67) and placebo (M = 153.98 ±2.72). However the time x condition interaction was significant F (1, 10) = 6.988, *P* < .05 (Figure 3.1). Post hoc pair sampled *t*-tests revealed that ball speed was significantly reduced following the 18-holes in the placebo condition, *t*(10) = 2.3, *P* <0.05 (*d* = .16).

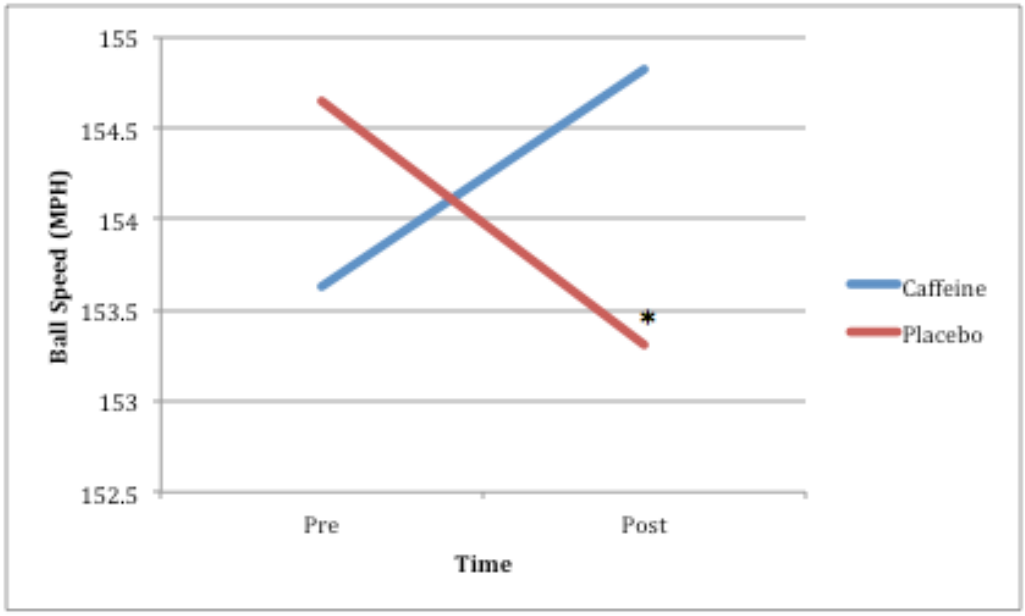

Figure 3.1. Ball Speed*- Changes in ball speed from pre- to post- 18-holes of golf Note: * denotes significant difference from pre- intervention in the placebo condition (p<0.05).*

3.1.3. Carry Distance

The main effect of time on carry distance was significant F (1, 10) = 7.34, *P* <.05 with a reduction from pre (M = 252.32 ±5.90) to post (M = 249.86 ±5.48) 18-holes of golf, but the main effect of conditions was not significant F (1, 10) = .34, *P* >.05 between caffeine (M = 250.91 ±5.88) and placebo (M = 251.27 ±5.64). There was no significant time x condition interaction F (1, 10) = 4.643, *P* = .06.

3.1.4. Total Distance

The main effect of time on total distance was not significant F (1, 10) = 1.151, *P* >.05 from pre (M = 276.18 ±5.57) to post (M = 274.64 ±5.48) 18-holes of golf. The main effect of conditions was also not significant F (1, 10) = .064, *P* >0.05 between caffeine (M = 275.64 ±5.07) and placebo (M = 275.64

±5.07). However the time x condition interaction was significant F (1, 10) = 6.073, *P* <. 05 (Figure 3.2). Post hoc pair sample *t*-tests revealed that total distance from pre to post intervention in the placebo condition was significantly shorter, *t*(10)= 3.25,*P* <0.01 (*d* = .36). Post hoc pair sample *t*-tests also revealed that the total distance was significantly longer for pre in the placebo condition compared to caffeine condition, *t*(10)= -2.39, *P* <0.05 (*d* = .26).

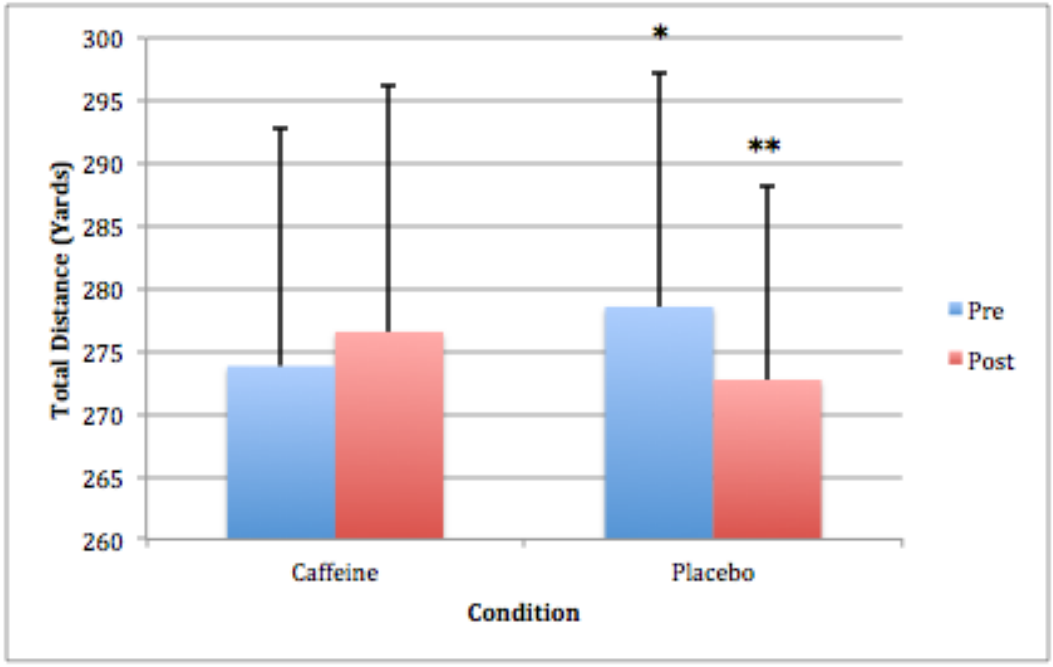

Figure 3.2. Total Distance*- Changes in total distance from pre- to post- 18-holes of golf in each condition. Note: ** denotes significant difference from Pre intervention in the placebo condition (P <0.01), * denotes significant difference between Pre in the placebo condition and the caffeine condition.*

3.1.5. Launch Angle

The main effect of time was significant F (1, 10) = 6.915, *P* <.05 with a reduction in launch angle from pre (M = 12.36 ±0.55) to post (M = 11.66 ±0.52) 18-holes of golf. There was no main effect of condition F (1, 10) = .113,

P >.05 between caffeine (M = 11.97 ±0.53) and placebo (M = 12.05 ±0.52). There was no significant time x condition interaction F (1, 10) = .011, *P* >.05.

Table 3.1. Simulator Data- data recorded via the golf simulator. Data presented as mean ±SD. *Denotes significant difference from pre- placebo, ^Denotes significant difference from pre- caffeine.

	Caffeine Condition		**Placebo Condition**	
	Pre	Post	Pre	Post
Club Head Speed (MPH)	105.95 ± 6.17	105.85 ± 5.17	106.65 ± 6.25	105.66 ± 6.15
Ball Speed (MPH)	153.63 ± 8.95	154.83 ± 8.87	154.65 ± 9.08	153.31 ± 9.05*
Carry Distance (Yards)	250.45 ± 19.63	251.36 ± 19.88	254.18 ± 20.07	248.36 ± 17.63
Total Distance (Yards)	273.82 ± 18.98	276.55 ± 19.58	278.55 ± 18.56^	272.73 ± 15.45*
Launch Angle (Degrees)	12.31 ± 1.64	11.64 ± 2.01	12.41 ± 2.13	11.68 ± 1.56
Offline (Yards)	5.73 ± 11.81	2.09 ± 11.76	3.82 ± 14.33	4.64 ± 10.03
Total Ball Spin (RPM)	2847.36 ± 620.19	2896.55 ± 573.33	2760.73 ± 537.05	2819.55 ± 573.33

No other significant differences (*P* > 0.05) were identified during the analysis of the remaining variables, mean values summarized in Table 3.1.

3.2. On The Course

Paired sample *t*-tests identified no significant differences (*P* >0.05) between any of the performance variables on the course during 18-holes of golf in the two conditions (Table. 3.2.).

Table 3.2. On the Course Performance Data- *Data presented as mean ±SD.*

	Caffeine Condition	**Placebo Condition**
Total shots (Par 73)	80.64 ±4.48	78.27 ±4.47
Fairways Hit (of a possible 13)	4.45 ±2.29	4.27 ±1.19
Greens in Regulation (of a possible 18)	7.82 ±1.72	6.91 ±1.64
Total Putts	32.18 ±3.09	31.36 ±3.83

3.3. Heart Rate & GPS Data

In each of the conditions the participants' mean heart rate and distance covered (Table 3.3.) over the 18-holes were similar and not significantly different (P >0.05).

Table 3.3. Heart Rate and GPS Data- *Data presented as mean ±SD.*

	Caffeine Condition	**Placebo Condition**
Heart Rate (BPM)	103.88 ±4.36	107.88 ±4.67
Distance Covered (m)	10113 ±761	10063 ±702

3.4. Hydration Status

The participants' mean hydration status assessed via Urine Osmolality (Table 3.4.) was similar for both pre and post round values in each trial condition (P >0.05).

Table 3.4. Hydration Status- *Data presented as mean ±SD.*

	Caffeine Condition		**Placebo Condition**	
	Pre-round	Post-round	Pre-round	Post-round
Urine Osmolality (mosmol•kg^{-1})	507.27 ± 200.10	583.64 ± 197.55	560.00 ± 180.55	584.55 ± 232.22

3.5. Environmental Conditions

The mean environmental conditions (Table 3.5.) identified the temperature was similar for both trial conditions whereas the wind speed was significantly greater during the placebo condition compared to the caffeine condition (P <0.05).

Table 3.5. Environmental Conditions- *Data presented as mean ±SD. Note: *Denotes significant difference from caffeine condition*

	Caffeine Condition	Placebo Condition
Temperature (Celsius)	20.82 ±4.69	21.73 ±5.00
Wind Speed (MPH)	5.36 ±3.17	7.45 ±1.92*

4. Discussion

The purpose of the present study was to examine the effect of caffeine on golf performance, with particular focus on the drive and associated performance variables. Despite the large volume of literature investigating the effect of caffeine on sports performance only two studies have investigated the effects of caffeine on golf (Mumford et al., 2016; Stevenson et al., 2009).

The present study used a simulated setting to examine the variables of the drive in a controlled environment, both pre- and post- 18-holes of golf. The main finding suggests acute consumption of caffeine, totalling 3mg • kg^{-1} taken before and during 18-holes of golf seems to attenuate fatigue on some performance and outcome variables. To the author's knowledge, no previous study has examined the effect of caffeine on performance variables of the drive in golf i.e. ball speed, instead highlighting performance outcomes i.e. total-distance achieved. Therefore comparison regarding caffeine and performance variables associated with the drive proved challenging.

One key variable for the drive is club head speed (Fradkin et al., 2004), in the present study there was no significant difference for club head speed over time or between conditions, challenging suggestions club head speed reduces ~2.5% across 18-holes (Higdon et al., 2012). However, in the present study club head speed was estimated due to limitations with testing equipment, which utilised a constant smash factor across all participants but is known to be highly variable between golfers (Kempton, 2013). As a result this may not have given a true representation of club head speed, consequently future studies should endeavour to directly measure club head speed and highlight the effects caffeine supplementation.

Nonetheless, ball speed is another key variable associated with drive success and was directly measured in the present study. Analysis suggested a significant interaction between time and condition ($P < 0.05$), further analysis identified a significant reduction in ball speed from pre- to post- 18-holes in the placebo condition (154.65 ± 9.08 mph - 153.31 ± 9.05 mph, d= 0.16) where as, although not significant, ball speed increased in the caffeine condition (153.63 ± 8.95 mph - 154.83 ± 8.87 mph, d= 0.14). There was also a significant interaction between time and condition on total-distance ($P < 0.05$), as expected total-distance significantly reduced over time in the placebo condition (278.55 ± 18.56 yards - 272.73 ± 15.45 yards, d= 0.36) where as although not significant ($P > 0.05$), total distance increased in the caffeine condition (273.82 ± 18.98 yards - 276.55 ± 19.58 yards). The reduction in ball speed in the placebo condition theoretically facilitated the reduction in total-distance, as initial ball speed subsequently affects total-distance of a stroke (Kempton, 2013). It has been previously established increased driving distance is associated with a better total score (Torres-Ronda et al., 2011) and additional prize money earned on the PGA Tour (Keogh et al., 2009), therefore benefiting performance. However, there was a significant difference in total-distance between the conditions at the pre- time point with the placebo condition significantly further than the caffeine condition. One explanation for the variation could be due to circadian and diurnal rhythms and associated fluctuations on strength, flexibility and co-ordination (Chtourou, Hammouda, Souissi & Chaouachi, 2014), as the optimal time for performance of sports requiring both skill and strength remains unclear (Drust, Waterhouse, Atkinson, Edwards & Reilly, 2005).

There was also a main effect of time on carry-distance; although the interaction of time and condition was not significant (*P* = .057) there was a reduction in the placebo condition (254.18 ± 20.07 yards – 248.36 ± 17.63 yards) yet a small improvement in the caffeine condition (250.45 ± 19.63 yards - 251.36 ± 19.88 yards). Again both carry-distance and total-distance variables were estimated and not directly measured. Ideally tests would have been performed in an environment allowing distances to be directly measured. Mumford et al. (2016) established a caffeine-containing supplement improved mean total-distance 6-yards (d=0.6) over 18-holes in comparison to a placebo, hypothesising the increase was due to caffeine attenuating the effects of fatigue. However this increase in distance did not control for environmental conditions, therefore it is impossible to account for the affect this had on drive strokes (James & Rees, 2008).

In the present study, there was a main effect of time on launch angle, which identified similar affects between both the caffeine (12.31 ± 1.64° - 11.64 ± 2.01°) and the placebo (12.41 ± 2.13° - 11.68 ± 1.56°) condition. As previously established, fatigue in golf has the potential to alter swing mechanics (Smith, 2010). Therefore the change in launch angle over time may be attributed to altered swing mechanics resulting from the associated fatigue of 18-holes of golf.

The proposed mechanism of action for caffeine is to act as a Central Nervous System stimulant, blocking the action of adenosine on the brain (Schneiker et al., 2006) leading to excitability of neural tissue, level of arousal and cognition (Mumford et al., 2016). Caffeine has previously been found to benefit skill-based sports such as maintenance of skill in an epee-fencing test

(Bottoms et al., 2013), increase serve kinematics in tennis (Hornery et al., 2007) and improve passing and control in a simulated soccer test (Foskett et al., 2009). As well as increased performance outcomes in golf including drive distance, iron-accuracy and putting-accuracy (Mumford et al., 2016; Stevenson et al., 2009). In the present study 3mg • kg^{-1} seemed to attenuate the effects of fatigue on a number of performance variables associated with the drive, therefore adding to previous research which supports the ergogenic effects of caffeine for skill based sports.

However, the findings did not translate to any significant improvements in performance during the 18-holes of golf. Unlike Mumford et al. (2016) where an improvement in total score and greens in regulation were observed. The lack of performance improvement may again be due to environmental conditions, as previously mentioned environmental conditions on the day could affect performance, which cannot be accounted for (James & Rees, 2008). In the present study there was a significant difference of wind speed between the conditions therefore cannot be ruled out. Previous research found putting accuracy improved following the co-ingestion of caffeine and carbohydrate (Stevenson et al., 2009), whereas in the present study there was no significant difference in the total number of putts taken between conditions, which supports the findings of Mumford et al. (2016). However there were major methodological differences between the studies, Stevenson et al. (2009) used a synthetic surface with fixed distances of 2m and 5m, where as Mumford et al. (2016) and present studies used true greens, with putting distances dependant on the success of the previous approach shot.

Also Stevenson et al. (2009) acknowledged that it was not possible to distinguish between the effects of caffeine and/ or carbohydrate on performance. To the authors knowledge the present study is the first to examine the effects of caffeine as a single ingredient on golf performance, as Mumford et al. (2016) and Stevenson et al. (2009) also involved other active ingredients as part of their intervention, vitamin B and carbohydrate, respectively. The amount of caffeine administered in the present study was 3mg • kg^{-1}, which has been recommended to achieve an ergogenic effect, without the caffeine related side-affects (Burke, 2008; Desbrow et al., 2011; Graham, 2001).

A limitation of the present study included the sample size (*n*=11), which could have underpowered the study and prevented further significant findings. Although similar to a previous study conducted by Mumford et al. (2016) (*n*=12), a *post hoc* power calculation using G*Power (Faul, Erdfelder, Lang & Buchner, 2007) and an observed effect size (Cohen's f = 0.27) in the present study, suggested a larger sample size (*n*=20) would have been required to provide the recommended statistical power of .80 (Field, 2009).

Also prior to testing the participants were required to abstain from caffeine containing foods and drink for 48-hours to reduce the levels of caffeine in circulation (Graham, 2001). Yet baseline caffeine concentration of the participants was not measured, such as through salivary levels as within previous research (Stevenson et al., 2009) therefore adherence can only be assumed. Additionally, due to the lengthy nature of golf, caffeine was administered at two time points, 30-minutes prior to hole-1 and immediately following hole-9 as utilised by Mumford et al. (2016). Once more the

participants' concentration levels of caffeine were not measured during or following the 18-holes, therefore the effect the employed dosing strategy had on concentration levels of caffeine are unknown, thus future studies may wish to assess caffeine concentration to design an optimal dosing strategy over 18-holes of golf.

In the present study participants were requested to consume a self-selected meal two-hours prior to testing as well as a snack following hole-9, remaining consistent between testing occasions in an attempt to standardise conditions similar to previous research (Mumford et al., 2016). Yet in the Mumford et al. (2016) study design, a standard snack was provided to all participants following hole-9 whereas in the present study the snack was self-selected. This protocol was deliberately utilised to allow participants to follow nutrition strategies that reflect their real-life habitual practise (Burke, 2008). However, food diaries were not collected or analysed, therefore dietary intake may have influenced the effect during the present study. Future studies should investigate the nutrition strategies of golfers and incorporate them into their study design.

In conclusion, the present study shows caffeine to attenuate the negative effects of fatigue for some, but not all, performance variables associated with the drive in golf, nonetheless no negative effects were witnessed. Therefore adding to the current body of research advocating caffeine supplementation for skill-based athletes, specifically golfers. These findings suggest male golfers may benefit from the ingestion of 3mg • kg^{-1} caffeine prior and during 18-holes of golf to improve their drive. However,

further investigation is required involving more direct measurement and controlled nutritional practises of athletes involved in golf.

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Appendices

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Appendix 6. Data Collection ……. Attached CD

Appendix 7. SPSS Outputs …….. Attached CD

Appendix 1. Ethical Approval

University of Chester

Faculty of Science and Engineering
Research Ethics Committee

Ryan Bristow
60 Furzebank Way
Willenhall
West Midlands
Wv12 4bg

16th June 2016

Dear Ryan,

Study title: A randomized cross-over trial to determine the acute effects of caffeine on 'the drive' in golf
FSE-REC reference: 059/16/RB/SES
Version number: 2

Thank you for sending your application to the Faculty of Science and Engineering Research Ethics Committee for review.

I am pleased to confirm ethical approval for the above research, provided that you comply with the conditions set out in the attached document, and adhere to the processes described in your application form and supporting documentation.

The final list of documents reviewed and approved by the Committee is as follows:

Document	Enclosed?	Appendix №	Version №	Date
FSE-REC application form	**Mandatory**		2	13/06/16
List of references	**Mandatory**	9	1	19/04/16
Brief C.V. for main	**Mandatory**	10	1	19/04/

researcher				16
Letter(s) of invitation to participants	**Y**	1	1	19/04/16
Participant Information Sheet(s) [PIS]	**Y**	2	1	19/04/16
Participant consent form(s)	**Y**	3	1	19/04/16
Pre-test health screening	**Y**	4	2	13/06/16
Written permission from relevant personnel (e.g. to use facilities) if required	**Y**	5	1	19/04/16
Risk Assessment form(s)	**Y**	7	1	19/04/16
Coffee Consumption Questionnaire	**Y**	6	2	13/06/16
Schematic flow chart	**Y**	8	1	19/04/16

Please note that this approval is given in accordance with the requirements of English law only. For research taking place wholly or partly within other jurisdictions (including Wales, Scotland and Northern Ireland), you should seek further advice from the Committee Chair / Secretary or the Research and Knowledge Transfer Office and may need additional approval from the appropriate agencies in the country (or countries) in which the research will take place.

With the Committee's best wishes for the success of this project.

Yours sincerely,

Eustace Johnson
Chair, Faculty of Science and Engineering Research Ethics Committee

Enclosures: Standard conditions of approval.

Cc. Supervisor/FSE-REC Representative

Appendix 2. Informed Consent

Participant information sheet

A randomized cross-over trial to determine the acute effects of caffeine on 'the drive' in golf

You are being invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. Thank you for reading this.

What is the purpose of the study?
This research is being undertaken on healthy males. The study is to find out the effects acute caffeine ingestion has on golf performance, particularly 'the drive'.

Why have I been chosen?
You have been chosen because you are a healthy adult. You have also been chosen because you are an active member of The Chase Golf Club with a handicap of 12 or below.

Do I have to take part?
It is up to you to decide whether or not to take part. If you decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect you in any way.

What will happen to me if I take part?
You will come to two different sessions. Both will involve a short performance test using the golf simulator (Foresight GC2), followed by 18 holes of golf before returning to the simulator for another short performance test including up to another '10 drives'. The short performance test will last around 10-minutes each.

Prior to testing on both occasions you will be asked to provide a urine sample to assess your hydration status. You will also be asked to wear Global Positioning System (GPS) in the form of a vest, underneath your usual golf attire to identify total distance covered during the 18-holes.

During one of the sessions you will be given two caffeine supplements, one prior to the commencement of the game of golf and another prior to hole 9. During the other session a placebo will be given at the same time points.

In the 48-hours prior to testing you will be asked to abstain from any caffeine containing foods and beverages, as well as strenuous exercise in the 24-hours prior.

All results will be kept confidential.

What are the possible disadvantages and risks of taking part?
As with many studies involving nutritional interventions, there will be some risk involved. High doses of caffeine have been associated with a risk of headaches, dizziness, gastrointestinal disturbances and nervousness. However, this has been taken into account and the risk has been limited where possible with the much lower dosage used for this study. If you have any concerns, feel free to contact me via the contact details at the bottom of this Information Sheet.

What are the possible benefits of taking part?
There may not be any direct benefits to you for taking part in this research, however the data collected could potentially increase the understanding of the use of caffeine as a supplement to enhance performance in golf.

What if something goes wrong?
If you wish to complain or have any concerns about any aspect of the way you have been approached or treated during the course of this study, please contact Executive Dean of the Faculty of Science and Engineering, University of Chester, Thornton Science Park, Pool Lane, Ince, Chester CH2 4NU 01244 513197

Will my taking part in the study be kept confidential?
All information, which is collected about you during the course of the research, will be kept strictly confidential so that only the researcher carrying out the research will have access to such information.

What will happen to the results of the research study?
The results will be written up into a dissertation for my final project of my MSc. Individuals who participate will not be identified in any subsequent report or publication.

Who is organising the research?
The research is conducted as part of a MSc in Sport Science (Sports Nutrition) within the Department of Sport and Exercise Sciences at the University of Chester. The study is organised with supervision from the department, by Ryan Bristow, an MSc student.

Who may I contact for further information?
If you would like more information about the research before you decide whether or not you would be willing to take part, please contact:

Ryan Bristow. 1425844@chester.ac.uk

Thank you for your interest in this research.

Title of Project: A randomized crossover trial to determine the acute effects of caffeine during 'the drive' in golf

Name of Researcher: Ryan Bristow

Please initial box

1. I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason and without my legal rights being affected. ☐
3. I agree to take part in the above study. ☐

_____	_____	_____
Name of Participant	Date	Signature

_____	____	_____
Researcher	Date	Signature

1 for participant; 1 for researcher

Appendix 3- Caffeine Consumption

A randomized crossover trial to determine the acute effects of caffeine during 'the drive' in golf

Researcher*:* *Ryan Bristow*

Name:_____

1. Do you knowingly have a caffeine allergy?

   Yes: No:

   If no, please complete the remainder of the questions.

2. Do you consume caffeinated beverages? (i.e. coffee, tea, energy drinks)

   Yes: No:

   If yes, please complete the remainder of the questions.

3. Please complete the table below (column 4: average consumed per day only), indicating how many you consume per day…

Beverage	**Serving size**	**Average caffeine per serving***	**Average consumed per day**	**Average caffeine per day**
Tea (brewed)	1 mug (200ml)	75mg		
Coffee (filter)	1 mug (260ml)	140mg		
Energy drinks i.e. red bull	1 can (250ml)	80mg		
Soft drinks **i.e. cola**	1 can (330ml)	40mg		
*Based on data provided by the Food Standards Agency http://www.food.gov.uk/news/pressreleases/2008/nov/caffeineadvice				

4. Would you be able to abstain from caffeine containing beverages for 48- hours?

   Yes: No:

5. Do you knowingly have any adverse reactions to the consumption of caffeine?

   Yes: No:

   If yes, please provide some details.