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Effects of caffeinated gum on a battery of soccer-specific tests in trained university-standard male soccer players

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Abstract

1

2 The purpose of this study was to determine whether caffeinated gum influenced performance in a
3 battery of soccer-specific tests used in the assessment of performance in soccer players.

4 In a double blind, randomised, cross-over design, ten male university-standard soccer players (age

5 19 ± 1 y, stature 1.80 ± 0.10 m, body mass 75.5 ± 4.8 kg) masticated a caffeinated (200 mg; caffeine)

6 or control (0 mg; placebo) gum on two separate occasions. After a standardised warm-up, gum was

7 chewed for 5 min and subsequently expectorated 5 min before players performed a maximal

8 countermovement jump, a 20 m sprint test and the Yo-Yo intermittent recovery test level 1 (Yo-

9 YoIR1). Performance on 20 m sprints were not different between trials (caffeine: 3.2 ± 0.3 s, placebo:

10 3.1 ± 0.3 s; $p = 0.567$; small effect size: $d = 0.33$), but caffeine did allow players to cover 2.0% more

11 distance during Yo-YoIR1 (caffeine: 1754 ± 156 m, placebo: 1719 ± 139 m; $p = 0.016$; small effect

12 size: $d = 0.24$) and increase maximal countermovement jump height by 2.2% (caffeine: 47.1 ± 3.4 cm,

13 placebo: 46.1 ± 3.2 cm; $p = 0.008$; small effect size: $d = 0.30$). Performance on selected physical tests

14 (Yo-YoIR1 and countermovement jump) was improved by the chewing of caffeinated gum in the

15 immediate period before testing in university-standard soccer players but the sizes of such effects

16 were small. Such findings may have implications for the recommendations made to soccer players

17 about to engage with subsequent exercise performance.

18

19 Key words: caffeine, gum, soccer, exercise performance, power, speed

20 Introduction

21 The prevalence of caffeine (1, 3, 7-trimethylxanthine; $C_8H_{10}N_4O_2$) usage within elite sport is
22 high, with 75% of athletes having reported its use prior to and/or during competition (Del Coso,
23 Muñoz, & Muñoz-Guerra, 2011). The ergogenicity of moderate caffeine doses (i.e., up to $3\text{ mg}\cdot\text{kg}^{-1}$ of
24 body mass [BM]) is well supported in athletic populations as numerous studies have shown that
25 caffeine can enhance performance of endurance (Ganio, Klau, Casa, Armstrong, & Maresh, 2009),
26 strength (Timmins & Saunders, 2014), power (Del Coso et al., 2012), agility (Jordan, Korgaokar,
27 Farley, Coons, & Caputo, 2014), skill (Russell & Kingsley, 2014), and reaction time (Santos et al.,
28 2014) tasks. Emerging evidence suggests that even lower doses of caffeine ($<3\text{ mg}\cdot\text{kg}^{-1}$ BM) have
29 been shown to improve alertness, vigilance, enhance mood and cognitive processes both during and
30 after exercise and these effects have been observed with few, if any, side effects (Spriet, 2014).
31 Collectively, these improvements could enhance performance in soccer as it is a physically
32 demanding intermittent sport that stresses both anaerobic and aerobic energy systems. During a
33 match, players are involved in soccer-specific actions requiring repeated high-intensity running and
34 high endurance capacity (Bangsbo, Mohr, & Krustup, 2006). Notably, caffeine has been repeatedly
35 shown to improve multiple sprint performance during simulated team sport activities (Schneiker,
36 Bishop, Dawson, & Hackett, 2006) as well as improving passing accuracy (Foskett, Ali, & Gant, 2009)
37 and jump performance in trained male soccer players (Del Coso et al., 2012; Foskett et al., 2009).

38

39 Caffeine acts as an adenosine receptor antagonist, thus reducing the perception of effort at
40 a given intensity and increasing central drive (Davis et al., 2003). Traditionally, caffeine has been
41 provided in a capsule or beverage form approximately one hour prior to exercise, with peak plasma
42 caffeine concentrations realised 15 to 120 min post-ingestion (Magkos & Kavouras, 2005). Caffeine
43 from chewing gum, however, is more rapidly absorbed into the blood stream via the buccal mucosa,
44 resulting in a faster onset of effects compared to more traditional modes of ingestion (i.e. 5 min
45 versus 45 min, respectively) (Kamimori et al., 2002). Such responses may be beneficial for team

46 sport athletes in scenarios where limited time for nutritional interventions exist at specific points in
47 the competition day (e.g., the end of the warm-up, at half-time, or for substitutes required to enter
48 competition with limited notice), but where ergogenic effects are desired.

49 Several studies have examined the effects of caffeinated chewing gum on exercise
50 performance (McLellan et al., 2005; Oberlin-Brown, Siegel, Kilding, & Laursen, 2016; Ryan et al.,
51 2013) and the findings have been equivocal. Some have found that caffeinated gum can enhance
52 cycling (Ryan et al., 2013) and running (McLellan et al., 2005) performance as well as pacing
53 strategies (Oberlin-Brown et al., 2016), whereas other studies reported no benefit to cycling
54 performance (Oberlin-Brown et al., 2016). Surprisingly, limited studies have examined the effects of
55 caffeinated chewing gum on specific components of soccer performance, despite the ergogenicity of
56 caffeine relative to key performance indicators in soccer and the practicality of this mode of
57 administration. Soccer teams typically use a battery of fitness and performance tests to assess a
58 player's performance (e.g., the Yo-Yo Intermittent Recovery Test Level 1 [Yo-Yo IR 1] is used to test
59 aerobic fitness and has previously been shown to correlate with high intensity distance covered in a
60 match (Castagna, Impellizzeri, Cecchini, Rampinini, & Alvarez, 2009), the countermovement jump
61 test is used to assess explosive lower body power output which may relate to the ability to jump and
62 head the ball (Lara et al., 2014) and the 20 m sprint to measure speed (Turner et al., 2011)) at
63 various times throughout the season (e.g., pre-season). Accordingly, it was hypothesised that if the
64 caffeinated gum could enhance performance on these tests, the implications for transferability to
65 actual match-play could be examined. Therefore, the purpose of this study was to determine
66 whether a low dose of caffeine (200 mg) provided in a chewing gum would improve performance in
67 a battery of soccer-specific tests. A dose of 200 mg was chosen because this aligns with
68 manufacturer's guidance on use and because some soccer matches occur late afternoon/evening
69 when the use of a higher dose might perturb sleep.

70

71

72 **Methods**

73 *Design*

74 A double-blind, randomised, cross-over design was used where participants were randomly
75 allocated and counterbalanced into caffeine and placebo conditions using a random sequence
76 generator (GraphPad Software Inc. USA). University-standard male soccer players participated in
77 the study and data were collected between March and May 2017 towards the end of the university
78 competitive season. The battery of soccer-specific tests included the Yo-Yo IR 1 which is used to test
79 aerobic fitness, the countermovement jump test which is used to assess power, and the 20 m sprint
80 which is used to measure acceleration (Turner et al., 2011). These tests have been shown to be
81 reliable with typical co-efficient of variations for the Yo-Yo IR1, countermovement jump, and 20 m
82 sprint tests of 4.9% (Krustrup et al., 2003), 2.8% (Markovic, Dizdar, Jukic, & Cardinale, 2004) and
83 2.7% (Hulse et al., 2013) respectively.

84

85 *Participants*

86 In order to estimate the sample size required for this study, data from a previous
87 investigation that examined the effects of caffeine on the Yo-Yo IR 2 test (Mohr, Nielsen, & Bangsbo,
88 2011) was used. The power equation used an alpha level of 0.05 and power was set at 0.84 and it
89 was calculated that a sample size of 7 was required for this study. Ten male university-standard ($4 \pm$
90 0.9 years of competitive soccer experience, training 333 ± 28.7 min·wk⁻¹) soccer players (age 19 ± 1
91 y, stature 1.80 ± 0.10 m, body mass 75.5 ± 4.8 kg) volunteered for this study. None of the players
92 that participated in this study had any major or minor injuries nor any medical complications. During
93 recruitment, players were asked if they had ever experienced adverse effects from caffeine ingestion
94 and ones that had suffered negative effects were excluded. Players were members of the
95 University's second XI team and played in one competitive match per week throughout the season.
96 The study was approved by an institutional Health and Wellbeing Faculty Ethics Committee and all of

97 the participants completed an informed consent and pre-screening questionnaire prior to taking
98 part in any testing procedures.

99

100 *Procedures*

101 To control for diet and prior physical activity over the two testing sessions, players were
102 asked to record food intake and activity for 48 h before each main trial using written food and
103 activity diaries. Players were instructed to replicate the dietary intake and activity profiles recorded
104 before the first testing session prior to the second visit. Players were asked to avoid alcohol and
105 strenuous exercise for two days before each visit. Diaries were checked to ensure compliance and
106 we were satisfied that all of the participants adhered to the instructions given and that the food and
107 drinks consumed before each trial were the same. Data collection for both placebo and caffeine
108 trials occurred 72 h after a competitive match where training was replaced with a testing session.
109 Placebo and Caffeine trials were separated by 2 weeks. Players were required to visit the testing
110 venue on two occasions separated by seven days where caffeine was limited to 100 mg per day
111 throughout the washout phase. This was checked by the investigators by asking the participants
112 verbally. Health screening (PAR-Q), and collection of participant demographics (whilst wearing
113 minimal clothing) including age, stature (m; Leicester height measure; Invicta Plastics Limited, UK),
114 body mass (kg; HD-327 digital scales, Tanita, Japan) and playing position were recorded. Players
115 were instructed to wear appropriate sportswear that was identical for both visits. Players were
116 familiar with the tests being administered because they undertook these tests at the start and mid-
117 point of the football season as a standard part of their normal fitness testing.

118

119 *Caffeine gum and placebo*

120 The experimental gum contained 100 mg of caffeine per pellet (Military Energy Gum – Stay
121 Alert, Arctic Mint flavour; Chicago, IL) was flavoured to a mint taste and contained 2 g of
122 carbohydrate (sugar) per piece. The manufacturer produced placebo gum was identical in

123 appearance and taste but was void of caffeine. Gum was administered immediately after the warm-
124 up in a sealed opaque bag to aid double-blinding. Players were instructed to chew two pieces of
125 gum (200 mg caffeine; $2.7 \pm 0.2 \text{ mg}\cdot\text{kg}^{-1}$) for 5 min; congruent with 85% of the dose being released
126 within this time-frame (Kamimori et al., 2002). Gum was then collected in a disposable bag to ensure
127 expectoration.

128

129 *Soccer-specific Tests*

130 Participants completed a 10 min soccer-specific warm-up (consisting of jogging, 10 m
131 acceleration sprints, and speed/agility drills) before testing in an indoor sports hall **with a polished**
132 **concrete floor**. The order of the tests performed was the countermovement jump test, 20 m sprints,
133 and Yo-Yo-IR1; all completed within 30 min and five min passive recovery separated each test.
134 **Participants completed the tests in three separate groups (i.e. two groups of 3 and one group of 4).**

135 **After the warm-up, players carried out three countermovement jumps using an optical**
136 **measurement system (Optojump Next; Micro Grate; USA). Each participant started the**
137 **countermovement jump in the standing position, dropped down into the squat position, and then**
138 **immediately jumped as high as possible.** The first jump was used as a practice jump, and then two
139 maximal jumps were performed, with 45 s rest between each jump. Countermovement jump height
140 represents the maximal value achieved in the final two attempts. Five minutes later, the 20 m timed
141 (Brower timing systems, USA) sprints were performed using three attempts; the first attempt serving
142 as a warm-up, the second attempt at 70-80% intensity and the last attempt as the timed maximal
143 sprint. Thereafter, the Yo-Yo IR1 test (Bangsbo, Iaia, & Krustup, 2008) was performed and required
144 2 x 20 m shuttle runs that gradually increased in speed as dictated by audio signals. Each run was
145 separated by 10 s active recovery where participants jogged around a cone positioned 5 m behind
146 the start line. Two consecutive failures to reach the finish line before the audio signal indicated test
147 cessation and the distance covered at that point was the final test result. All tests were performed

148 with verbal encouragement from pertinent coaching staff and test administrators which was
149 replicated for the second visit to ensure consistency.

150

151 *Statistical Analyses*

152 Statistical analysis was performed using SPSS 24.0 for Windows (IBM, Chicago, IL). The
153 paired differences were checked for normality using the Shapiro-Wilks test. Differences in
154 performance variables were compared between groups using a paired-samples *t*-test. Effect sizes
155 were calculated for all of the dependant variables using Cohen's *d* formula using the pooled
156 standard deviation. Effect sizes were interpreted using the classifications of 0.2, 0.5 and 0.8 as small,
157 moderate and large effects, respectively (Cohen, 1988). Statistical significance was set at $p \leq 0.05$ and
158 data are expressed as mean values \pm SDs.

159

160 **Results**

161

162 *Side Effects and Effectiveness of Caffeine Administration*

163 There were no dropouts during the study and all of the players successfully completed two
164 trials. At the end of **the study**, players were asked **to write down** adverse side effects and to
165 evaluate whether they were given caffeine or placebo treatments. No adverse effects were reported
166 and three out of the ten participants correctly identified the condition they were given suggesting
167 that blinding was effective.

168

169 *Yo-Yo Intermittent Recovery Level 1 Test*

170 Caffeine enhanced performance on the Yo-Yo IR1 by 2% as players covered 35 m (**95% CI**
171 **8.18, 61.82%**) further distance on the test (caffeine: 1754 ± 156 m, placebo: 1719 ± 139 m; $p=0.016$;
172 small effect: $d=0.24$).

173

174 ***INSERT FIGURE 1 HERE ***

175

176 *Sprint (20 m) performance*

177 There were no statistically significant differences in 20 m sprint times between caffeine and
178 placebo (caffeine: 3.2 ± 0.3 s, placebo: 3.1 ± 0.3 s; $p=0.567$; mean difference 0.11 s; 95% CI -0.31,
179 0.05 s; small effect: $d=0.33$).

180

181

182 *Countermovement Jump Test*

183 Figure 2 shows the mean and individual data for differences in countermovement jump
184 height for caffeine and placebo. There were significant differences between the two conditions
185 where caffeine enhanced jumping performance by 2.2% (caffeine: 47.1 ± 3.4 cm, placebo: 46.1 ± 3.2
186 cm; $p=0.008$, mean difference 1.0 cm; 95% CI 0.32, 1.67 cm; small effect: $d = 0.30$).

187

188 ***INSERT FIGURE 2 HERE ***

189

190

191 Discussion

192 This is the first study to investigate the effects of caffeinated gum on a battery of soccer-
193 specific tests that assess aerobic capacity, power and speed in university-standard soccer players.
194 Although no effects on 20 m sprint performance were observed, we report that caffeine gum
195 enhanced performance on the Yo-Yo IR1 by 2% and increased countermovement jump height by
196 2.2% when compared to a placebo, **but these effects were small.**

197

198 Improved jumping ability attributed to caffeine ingestion in soccer players supports previous
199 literature (Del Coso et al., 2012; Foskett et al., 2009). Indeed, Foskett et al. (2009) observed that 6
200 mg·kg⁻¹ BM of caffeine ingested 60 min before completing simulated soccer activity enhanced jump
201 height by 2.7%. Similarly, Gant, Ali and Foskett (2010) reported that caffeine doses of 3.7 mg·kg⁻¹
202 BM co-ingested with 1.8 mg·kg⁻¹ BM of carbohydrate enhanced countermovement jump
203 performance versus a carbohydrate only drink by 2.3%. In addition, Del Coso et al. (2012) reported
204 that jump height was increased by 3.1% in semi-professional soccer players after consuming 3
205 mg·kg⁻¹ BM of caffeine. The enhancement in jump performance reported previously are similar to
206 what we have reported (2.2%) although our study is the first to examine the effect of lower doses of
207 caffeine (~ 2.7 mg·kg⁻¹ BM) administered via a chewing gum. These improvements in jumping could
208 be attributed to increases in force production after caffeine ingestion (Bloms, Fitzgerald, Short, &
209 Whitehead, 2016). It has previously been reported that caffeine ingestion increases both peak
210 torque and the rate of torque development (Duncan, Thake, & Downs, 2014) which are likely to be
211 the mechanisms responsible for enhancing jump height performance.

212

213 In contradiction to the jump data, caffeine had no effect on 20 m sprint times; a finding
214 which supports previous studies (Andrade-Souza, Bertuzzi, de Araujo, Bishop, & Lima-Silva, 2015;
215 Astorino et al., 2012) but also contradicts others (Carr, Dawson, Schneiker, Goodman, & Lay, 2008;
216 Del Coso et al., 2012). Admittedly, we only measured sprint time over a single 20 m sprint, whereas

217 studies that have found improvements in sprinting have used repeated sprint protocols. Gant et al.
218 (2010) used the Loughborough intermittent shuttle test, and found that caffeine improved mean
219 sprint times (caffeine: 2.48 ± 0.15 s, placebo: 2.59 ± 0.2 s; $p = 0.04$) over the final 15 min of the 90
220 min protocol. Del Coso et al. (2012) measured sprint performance using a 7 x 30 m sprint test and
221 highlighted that mean running speed was quicker after consuming $3 \text{ mg}\cdot\text{kg}^{-1}$ BM of caffeine
222 (caffeine: 25.6 ± 2.1 vs. placebo: $26.3 \pm 1.8 \text{ km}\cdot\text{hr}^{-1}$; $p < 0.05$). In another comparable study, Carr et
223 al. (2008) reported that ingesting $6 \text{ mg}\cdot\text{kg}^{-1}$ BM of caffeine 60 minutes beforehand enhanced
224 performance across set 1, 3 and 5 during a repeated sprint performance test consisting of five sets
225 of 6 x 20 m sprints. The lower caffeine dose administered in this study (i.e., 200 mg; where it is
226 assumed that ~ 170 mg was released) may explain the lack of effect in relation to high intensity
227 running performance versus those using higher doses $> 3 \text{ mg}\cdot\text{kg}^{-1}$ BM (Del Coso et al., 2012; Gant et
228 al., 2010; Carr et al., 2008). Additionally, we used a single 20 m sprint to assess performance relative
229 to previous studies that have observed ergogenic effects in repeated sprint protocols (Carr et al.,
230 2008; Del Coso et al., 2012). Intuitively, the likely ergogenic mechanism of caffeine improving
231 repeated sprinting relates to adenosine receptor antagonism and thus reduction in the perception of
232 pain; possibly mediating the challenge of repeated sprint performance versus a single sprint.

233

234 This is the first study to show that 200 mg of caffeine delivered via chewing gum can evoke a
235 small 2% (95% CI 0.48%, 3.60%) improvement on the Yo-Yo IR1. Previous studies have found mixed
236 results of caffeine on soccer-specific endurance tests although none have used comparable modes
237 of ingestion. Our findings support Mohr et al. (2011) who found a 16% performance increase; albeit
238 under conditions of a higher caffeine dose (i.e., $6 \text{ mg}\cdot\text{kg}^{-1}$ BM) using a different variant of the Yo-Yo
239 test. However, these findings are in contrast with other studies that reported no beneficial effects of
240 caffeine on the Yo-Yo IR2 in soccer players (Bassini et al., 2013). Other studies have examined the
241 effects of caffeine supplementation on total distance covered using Global Positioning System (GPS)
242 technology as well as other tests than used here. Del Coso et al. (2012) found that total distance

243 covered at a speed higher than $13 \text{ km}\cdot\text{h}^{-1}$ during a simulated soccer match was greater after $3 \text{ mg}\cdot\text{kg}^{-1}$
244 1 BM of caffeine when compared to a placebo (caffeine: $1436 \pm 326 \text{ m}$, placebo: $1205 \pm 289 \text{ m}$). The
245 improvements in total distance covered in the Yo-Yo IR1 in our study could be attributed to
246 caffeine's effects on the central nervous system via adenosine receptor antagonism. More
247 specifically, caffeine ingestion inhibits the effects of adenosine on neurotransmission in the brain
248 thereby reducing the perception of effort, increasing arousal, and delaying fatigue (Davis et al.,
249 2003), all aspects that could have enhanced performance on the Yo-Yo IR1. It has previously been
250 reported that caffeine present in chewing gum is primarily absorbed through the buccal mucosa
251 which has an excellent vascular supply and thus an excellent rate of absorption (Kamimori et al.,
252 2002). It is likely that when gum is chewed, some caffeine is released into the saliva that is then
253 swallowed and subsequently absorbed in the gastrointestinal tract. A combination of both methods
254 results in a faster plasma caffeine peak which could explain the performance enhancement observed
255 on the Yo-Yo IR1.

256

257 It should be acknowledged that a limitation of this study was that plasma caffeine was not
258 measured, however, Kamimori et al. (2002) have previously reported that chewing caffeine gum for
259 5 min results in 85% of the caffeine dose being released. In addition, as the caffeinated gum
260 contained 100 mg per piece, it was problematic to prescribe exactly $3 \text{ mg}\cdot\text{kg}^{-1}$ BM of caffeine as a
261 relative dose to participants, thus we had to provide an absolute dose of 200 mg. Despite this
262 limitation, the mean dosage given was $2.7 \pm 0.2 \text{ mg}\cdot\text{kg}^{-1}$ BM (range: 2.4 to 2.9) of caffeine. **It is**
263 **possible that we may have observed larger effects if we had administered a higher dose of caffeine.**

264 A second limitation of this study was that all three performance tests were conducted on the same
265 day with 5 min recovery periods in between each test. However, it is unlikely that three maximal
266 countermovement jumps and a maximal 20 m sprint would result in fatigue and subsequently affect
267 the results of the Yo-Yo IR1 test. Moreover, these tests are typically conducted in the field on the
268 same day when used to test players in the 'real world'. **Lastly, we did not determine the reliability of**

269 the three tests within our sample to confirm whether the coefficient of variation was similar to
270 previously reported values.

271

272 **Practical Applications**

273 Chewing caffeinated gum that contains 200 mg of caffeine for 5 min before performing
274 soccer-specific tests can enhance aerobic capacity by 2% and increase countermovement jumping
275 performance by 2.2%. Chewing gum provides an alternative mode of caffeine administration that is
276 more rapidly absorbed (via the buccal mucosa) than capsules and drinks and less likely to cause
277 gastrointestinal distress. Accordingly, this may be beneficial for team sport athletes where there is
278 limited time for nutrition intervention during competition such as at half-time where only 10
279 minutes are available to administer a nutritional intervention, for substitutes that would come on
280 when called upon by the coach and for players who cannot tolerate caffeinated beverages or
281 capsules because of gastrointestinal distress before kick-off. It is important to acknowledge that
282 caffeine gum should not be used during pre-, mid- and end-season testing in an attempt to enhance
283 performance on the testing battery as this could influence the interpretation of the data. **Future**
284 **studies should investigate the effects of caffeinated gum on technical aspects of soccer as well as**
285 **actual match play.**

286

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291

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397 **Figure Legends**

398 **FIGURE 1.** (A) Total distance covered on the Yo-Yo intermittent recovery test level 1 ($n = 10$). Data
399 are expressed in as mean \pm SD. * Caffeine significantly higher than placebo ($p = 0.016$). (B) Individual
400 participant data on percentage improvement after caffeine ingestion. Dotted line represents no
401 change.

402

403 **FIGURE 2.** (A) Countermovement jump height ($n = 10$). Lines are individual participant data. Data are
404 expressed in as mean \pm SD. * Caffeine significantly higher than placebo ($p = 0.008$). (B) Individual
405 participant data on percentage improvement after caffeine ingestion. Dotted line represents no
406 change.