

Northumbria Research Link

Citation: Hurst, Philip, Schiphof-Godart, Lieke, Hettinga, Florentina, Roelands, Bart and Beedie, Christopher (2020) Improved 1000-m Running Performance and Pacing Strategy With Caffeine and Placebo: A Balanced Placebo Design Study. *International Journal of Sports Physiology and Performance*, 15 (4). pp. 483-488. ISSN 1555-0265

Published by: Human Kinetics

URL: <https://doi.org/10.1123/ijsp.2019-0230> <<https://doi.org/10.1123/ijsp.2019-0230>>

This version was downloaded from Northumbria Research Link: <http://nrl.northumbria.ac.uk/40087/>

Northumbria University has developed Northumbria Research Link (NRL) to enable users to access the University's research output. Copyright © and moral rights for items on NRL are retained by the individual author(s) and/or other copyright owners. Single copies of full items can be reproduced, displayed or performed, and given to third parties in any format or medium for personal research or study, educational, or not-for-profit purposes without prior permission or charge, provided the authors, title and full bibliographic details are given, as well as a hyperlink and/or URL to the original metadata page. The content must not be changed in any way. Full items must not be sold commercially in any format or medium without formal permission of the copyright holder. The full policy is available online: <http://nrl.northumbria.ac.uk/policies.html>

This document may differ from the final, published version of the research and has been made available online in accordance with publisher policies. To read and/or cite from the published version of the research, please visit the publisher's website (a subscription may be required.)



UniversityLibrary



Northumbria
University
NEWCASTLE



Caffeine and placebo effects improve 1000-m running performance and pacing strategy: a balanced placebo design study

Journal:	<i>International Journal of Sports Physiology and Performance</i>
Manuscript ID	IJSPP.2019-0230.R1
Manuscript Type:	Original Investigation
Date Submitted by the Author:	18-Jun-2019
Complete List of Authors:	Hurst, Philip; Canterbury Christ Church University, Human and Life Sciences Schiphof-Godart, Lieke; Hague University Hettinga, Florentina; Northumbria University, Sport, Exercise and Rehabilitation Roelands, Bart; VUB, Human Physiology Research Group Beedie, Chris; University of Kent
Keywords:	belief, deception, ergogenic aids, nutrition, sport supplements

SCHOLARONE™
Manuscripts

1 Abstract

2 **Purpose:** To investigate the placebo effect of caffeine on pacing strategy and performance
3 over 1000-m running time-trials using a balanced placebo design. **Methods:** Eleven well-
4 trained male middle-distance athletes performed seven 1000-m time-trials (one
5 familiarisation, two baseline and four experimental). Experimental trials consisted of the
6 administration of four treatments: informed caffeine/received caffeine (CC), informed
7 caffeine/received placebo (CP), informed placebo/received caffeine (PC), and informed
8 placebo/received placebo (PP). Treatments were randomized. Split times were recorded at
9 200-, 400-, 600-, 800- and 1000-m and peak heart rate (HR_{peak}) and rating of perceived
10 exertion (RPE) were recorded at the completion of the trial. **Results:** Relative to baseline,
11 participants ran faster during CC ($d = 0.42$) and CP ($d = 0.43$). These changes were
12 associated with an increased pace during the first half of the trial. No differences were shown
13 in pacing or performance between baseline and the PC ($d = 0.21$) and open administration of
14 placebo ($d = 0.10$). No differences were reported between treatments for HR_{peak} ($\eta^2 = 0.084$)
15 and RPE ($\eta^2 = 0.009$). **Conclusions:** Our results indicate that the effect of believing to have
16 ingested caffeine improved performance to the same magnitude as actually receiving
17 caffeine. These improvements were associated with an increase in pace during the first half of
18 the time-trial.

19 **Key words:** belief, deception, ergogenic aids, nutrition, sport supplements

20 Introduction

21 The placebo effect is a desirable outcome resulting from a person's belief and/or learned
22 response to a treatment or situation.¹ Although there is considerable evidence for the effect
23 placebos can have on sports performance,² empirical evidence within sport and exercise
24 science has remained largely static in regards to the degree to which placebo effects interact
25 with the verum components of a treatment. Attempts to quantify the placebo effect in sport
26 and exercise science often rely exclusively on randomized control trials in which participants'
27 belief about the treatment they have been administered is held constant by blinding. Using
28 this type of design nevertheless does not provide sufficient information about whether there
29 are any interactions between a treatment and the belief that the treatment will influence
30 performance.³ Authors in placebo effect research^{4,5} have therefore advocated the use of the
31 four-treatment, balanced placebo design,⁶ which allows an assessment of each possible
32 combination of what the participant believes they have taken and what they have actually
33 taken.

34 To our knowledge, seven studies have used the balanced-placebo design to examine the
35 placebo effect on sport performance.^{4,5,7-11} While most studies using this design have reported
36 significant placebo effects on time-trial performance,^{5,7,9} few studies have investigated the
37 potential mechanisms related to its response. Since the mid-1990s, there has been an
38 exponential increase in the number of studies investigating the placebo effect and the
39 neurobiological pathways underlying this phenomenon.² Qualitative data suggest that placebo
40 effects may be associated with a reduction in pain sensation, arousal regulation and increases
41 in motivation,¹² which may be mediated and moderated by various neurobiological pathways,
42 such as the endogenous opioid and neurotransmitter pathways.¹³ However, while there is
43 mounting evidence of the mechanisms underpinning this phenomenon, it is unclear how
44 placebo effects affect sport performance during the actual measure itself. It reasonable to
45 suggest that after ingesting caffeine, for example, athletes may anticipate an offset in fatigue
46 and alter their exercise behaviour. Thus, athletes' pacing strategy may depend on their belief
47 regarding the effect of a substance and their subsequent decisions during performance.

48 Pacing strategies are set according to an athlete's expectation of the task they are required to
49 perform, based on previous experiences that were used to form a performance template.¹⁴
50 Numerous studies have manipulated pacing strategies through deception about timing, the
51 presence of a competitor and inaccurate feedback.¹⁵ Konings and colleagues¹⁶ reported that
52 when riding against a virtual opponent, time to complete 4-km cycling times trials improved
53 compared to no opponent due to a faster pace at the start of the time-trial. It has been
54 suggested that this change in pacing behaviour is influenced through neurotransmitters, such
55 as dopamine, which are affected by motivation, drive and perception of effort.¹⁷ Based on
56 this, if an athlete receives a treatment they believe to be performance enhancing, that athlete
57 may be more likely to change their pacing strategy, thereby impacting on performance.
58 However, to the authors' knowledge, no study has investigated the effects of a placebo
59 treatment on pacing strategy.

60 In this study, we used a balanced placebo design to examine the placebo effects of caffeine
61 on pacing strategy and performance over 1000-m running time-trials. By using a balanced
62 placebo design, we specifically aimed to: 1) determine the influence both placebo and
63 caffeine have on performance and 2) analyse participants' pacing strategies after
64 administration of deceptive and open treatments of caffeine and placebo. We also aimed to

65 establish whether any changes in performance were associated with changes in peak heart
66 rate and whether this was made possible by participants' propensity to knowingly exert more
67 effort.

68 **Method**

69 *Participants and statistical power*

70 Eight participants were estimated to provide an *a priori* statistical power of 0.80. This
71 estimation was based on a study design using repeated measures ANOVA, an *a-value* of 0.05
72 and an explained effect of $1.4 \pm 1.6\%$.¹⁸ In case of drop out, fifteen participants were initially
73 recruited. Four withdrew (two due to injury and two because of a conflicting timetable),
74 leaving eleven well-trained male middle-distance athletes (mean \pm SD: age = 25.2 ± 5.6 yrs;
75 height = 176.3 ± 8.1 cm; body mass = 66.8 ± 6.1 kg; daily caffeine consumption; 269 ± 43
76 mg·d⁻¹). Eligibility criteria stipulated that participants must be nationally ranked in the United
77 Kingdom for 800-, 1500-, 3000- or 5000-m, aged between 18 and 35 and have trained
78 minimally five days per week for at least 3 months prior to the start of the study. Only light-
79 moderate caffeine (200-350 mg·day⁻¹) users were included in the study to control for
80 individual differences and familiarity of the effects of caffeine.¹⁹ The study was anticipated to
81 last approximately four weeks. For this reason, only males were recruited to avoid
82 confounding performance variation in the mid-luteal phase of the menstrual cycle.²⁰
83 Institutional ethics approval was granted, in agreement with the Declaration of Helsinki.
84 Participants were informed that participation was voluntary and they had the right to
85 withdraw at any time during the course of the study. Participants provided written informed
86 consent after reading the study information sheet.

87 *Design*

88 We used a quasi-randomised, repeated measures, balanced placebo design to determine the
89 effects of caffeine and placebo on 1000-m running time-trial performance. Participants
90 performed seven trials: familiarisation, two baseline and four as part of the balanced placebo
91 design. The four balanced placebo design trials were as follows:

- 92 1. Informed caffeine and given caffeine (CC) – participants were informed they received
93 caffeine and did
- 94 2. Informed caffeine and given placebo (CP) – participants were informed they received
95 caffeine but received placebo
- 96 3. Informed placebo and given caffeine (PC) – participants were informed they received
97 placebo but received caffeine
- 98 4. Informed placebo and given placebo (PP) – participants were informed they received
99 placebo and did

100 The balanced-placebo 1000-m trials were randomised using a computer generated
101 programme (www.randomization.com) and participants were deceived about the treatment
102 they received in CP and PC. Participants ran 1000-m and split times were recorded at 200-,
103 400-, 600-, 800- and 1000-m. Peak heart rate (HR_{peak}) and ratings of perceived exertion
104 (RPE) were recorded immediately after the trial.

105 *Performance measure and equipment*

106 All trials were run on a 400-m, tartan track, in accordance with the International Association
107 of Athletics Federation's standards (polymer synthetic tartan track, with a depth of three
108 centimetres). Participants ran two and a half laps (1000-m) around the track as fast as
109 possible, with no assistance (e.g. pacemakers or external feedback). Times and splits were
110 measured using an automated, single-beam photocell, light gate system (Smartspeed Pro™,
111 Fusion Sport Inc., Australia) and were mounted in lane 1 of the 200- and 400-m start/finish
112 line. Single-beam light gate systems are the most common method for measuring running
113 performance and have shown to have good reliability.²¹ Weather measurements for wind
114 speed (m/s), temperature (°C), relative humidity (%) and wind chill (°C) were recorded using
115 the Pasco weather sensor (PS-2174, Pasco, Roseville CA, USA) attached to the Xplorer GLX
116 graphing data-logger (PS-2002, Pasco, Roseville CA, USA). Minimal differences were
117 reported for all time-trials (wind speed = 0.5 ± 0.2 m/s; temperature = 18.5 ± 1.9 °C; relative
118 humidity = 53.5 ± 0.9 %).

119 *Caffeine and placebo treatments*

120 Based on previous research in the deceptive administration of caffeine,⁴ in the CC and CP
121 treatments, participants ingested 200-mL of chilled saline with $3.0 \text{ mg} \cdot \text{kg}^{-1}$ of anhydrous
122 caffeine (Myprotein; Norwich, England). The dosage of $3.0 \text{ mg} \cdot \text{kg}^{-1}$ caffeine was chosen as it
123 has been suggested to be optimal for improving performance lasting ~3-minutes.²² Given that
124 peak plasma caffeine typically occurs 45-minutes post-ingestion,²³ participants were asked to
125 consume the treatments 1-hour prior to the start of the time-trial. In the CP and PP treatments,
126 participants consumed 200-mL of chilled saline only. In placebo effect research, the validity
127 of the balanced-placebo design relies on the credibility of the deception in the CP and PC
128 treatments. Extensive pilot testing was therefore conducted to ensure that no taste or
129 palpability differences could be identified between placebo and caffeine treatments.

130 *Belief manipulation*

131 Before any data collection, participants attended a short presentation on the benefits of
132 caffeine on middle-distance running performance delivered by the first author. Participants
133 were provided with literature reviewing the findings of published research on caffeine and
134 middle-distance running and were informed that caffeine was previously a banned
135 performance enhancing substance. To further augment the belief that caffeine is performance
136 enhancing, and in line with current recommendations for reporting fine details of participant
137 contact and communication,² anecdotal evidence relating to the first authors' experience in
138 the use of caffeine was explained. At the time of data collection, the first author competed as
139 an international level athlete against notable Olympians and participants were informed that
140 caffeine acted as potent ergogenic aid during competition. The efficacy of this manipulation
141 of beliefs was supported by data collected in post-study interviews.

142 *Procedure*

143 Participants performed seven 1000-m running time-trials. All trials were performed on
144 Monday and Friday evening at the same location. The time between trials allowed an
145 adequate wash out period for caffeine supplementation²⁴ and is sufficient for middle-distance
146 trained athletes to fully recover.²⁵

147 For all trials, participants were instructed to arrive in 'race-shape' condition. High intensity
148 exercise 48 hours preceding the trials was not permitted, as well as the consumption of
149 alcohol or sport supplements. Participants were asked to adhere to their regular pre-race diet,
150 rest and warm-up routines. Participants began all trials at the same time of day to minimise
151 circadian variation in performance²⁶ and each trial was started by a green LED, which would
152 flash up on the photocell. To limit the potential for participants to employ pacing strategies
153 based on knowledge of previous trials and performance during trials, they did not to wear a
154 watch and were given no encouragement. No information about split times was given and the
155 results of the trials were given after all data had been collected. HR_{peak} was recorded using a
156 Polar stopwatch (Heart Monitors, Polar Ltd, Finland) and RPE from 0 (nothing at all) to 10
157 (maximal) was measured using the Borg Category Ratio²⁷ immediately after participants
158 completed the trial.

159 For familiarisation trials, participants were informed: "Today you are performing a
160 familiarisation trial" and for baseline trials 1 and 2, participants were informed "Today you
161 are performing a baseline trial". For balanced placebo design trials, participants were further
162 reminded about which treatment they had received. For CC and CP treatments, participants
163 were informed: "Today you will be performing the trial with caffeine" and for PC and PP
164 treatments, participants were told: "Today you will be performing the trial with no caffeine."
165 Upon completion of all data collection, participants were debriefed about the true nature of
166 the study.

167 *Data analysis*

168 Times to complete the 1000-m time-trials for baseline 1 and baseline 2 and each split (200-,
169 400-, 600-, 800- and 1000-m) were inputted into an online reliability spreadsheet.²⁸ Data
170 were log transformed to reduce nonuniform errors and the intraclass correlation (ICC) and
171 Pearson correlation (r) provided estimates of reliability. The precision of ICC was interpreted
172 as extremely high (0.99); very high (0.90), high (0.75) moderate (0.50) and low (0.20).²⁸ r
173 was interpreted as trivial (<0.1), small (0.3), moderate (0.5), large (0.5), very large (0.7),
174 nearly perfect (0.9) and perfect (1.0). In addition, paired samples t -tests were conducted to
175 determine any systematic difference in performance between baseline 1 and baseline 2.

176 Data were entered into SPSS version 24.0 (IBM, Armonk, NY) and tested for homogeneity of
177 variance, normal distribution and anomalies. Repeated measures ANOVA identified
178 differences in time to complete 1000-m time-trials between each treatment (i.e. baseline, CC,
179 CP, PC and PP) and split (i.e. 200-, 400-, 600-, 800- and 1000-m). Differences in HR_{peak},
180 RPE and mean time to complete the 1000-m trials between each treatment were also
181 established using repeated measures ANOVA. Greenhouse-Geisser epsilon was reported
182 when sphericity was violated and post-hoc LSD tests were used. Cohen's d was calculated to
183 determine the effect size (d) of the mean differences. Differences between 0.2 and <0.5 were
184 interpreted as a small effect, between 0.5 and <0.8 as moderate, and >0.8 as large.²⁹ Data are
185 presented as mean \pm standard error of the mean with statistical significance set at $p < 0.05$

186 **Results**

187 Times were similar between baseline 1 and baseline 2 at 200- (mean differences = $-0.48 \pm$
188 0.34 s, $P = .290$, $r = 0.897$, ICC = 0.90), 400- (0.04 ± 0.40 s, $p = 0.936$, $r = 0.776$, ICC =
189 0.77), 600- (-0.56 ± 0.30 s, $p = 0.217$, $r = 0.885$, ICC = 0.85), 800- (-0.13 ± 0.53 s, $p = 0.149$,

190 $r = 0.584$, ICC = 0.61) and 1000-m (0.60 ± 0.61 s, $p = 0.189$, $r = 0.614$, ICC = 0.67). The
191 average of these two time-trials was thus used to measure baseline. Mean times to complete
192 1000-m trials in all treatments are shown in table 1.

193

194 *Main analyses*

195

196 Repeated measures ANOVA (treatment \times split) reported differences between treatment ($F_{(4, 160)} = 6.162$, $p = 0.006$; $\eta^2 = 0.381$) and split ($F_{(4, 160)} = 9.288$, $p < 0.001$; $\eta^2 = 0.482$). No
197 difference in time was shown for treatment \times split ($F_{(4, 160)} = 1.055$, $p = 0.266$; $\eta^2 = 0.108$).

199 *Differences in time between treatments*

200 Compared to baseline, participants ran faster in CC (mean differences = 0.64 ± 0.11 s, $p < 0.001$, $d = 0.42$) and CP (0.66 ± 0.18 s, $p = 0.004$, $d = 0.43$) treatments. Compared to PP,
201 participants ran faster in CC (0.80 ± 0.18 s, $p = 0.001$, $d = 0.47$) and CP (0.83 ± 0.21 s, $p =$
202 0.002 , $d = 0.48$) treatments. All differences between mean times to complete the trials and
203 treatments are shown in figure 1.

205 *Differences in treatment between splits*

206 At the 200-m split and compared to PP, participants ran faster in CC (mean differences =
207 0.94 ± 0.29 s, $p = 0.009$, $d = 0.42$) and CP (1.21 ± 0.38 s, $p = 0.010$, $d = 0.57$). At the 400-m
208 split, participants ran faster in CC compared to baseline (-0.87 ± 0.25 s, $p = 0.006$, $d = 0.55$),
209 PC (-0.91 ± 0.28 s, $p = 0.009$, $d = 0.54$) and PP (-1.69 ± 0.28 s, $p = 0.001$, $d = 0.84$).
210 Similarly, participants ran faster at 400-m in CP compared to baseline (-0.68 ± 0.27 s, $p =$
211 0.031 , $d = 0.41$), PC (-0.72 ± 0.31 s, $p = 0.044$, $d = 0.41$) and PP (-1.40 ± 0.28 s, $p = 0.001$, $d = 0.72$). At the 600-m split, participants ran faster in CP compared to baseline (-0.94 ± 0.27 s,
212 $p = 0.005$, $d = 0.64$) and PP (-0.81 ± 0.33 s, $p = 0.043$, $d = 0.47$). Participants also ran faster
213 at 600-m in PC compared to baseline (-1.01 ± 0.31 s, $p = 0.008$, $d = 0.60$), CC (-0.61 ± 0.23 s,
214 $p = 0.024$, $d = 0.36$) and PP (-0.88 ± 0.33 s, $p = 0.023$, $d = 0.46$). No differences were shown
215 between any treatments at the 800-m split ($p > 0.05$), but participants ran faster at 1000-m in
216 CC compared to baseline (-1.08 ± 0.43 s, $p = 0.030$, $d = 0.52$) and PP (-0.98 ± 0.40 s, $p =$
217 0.035 , $d = 0.45$). All differences between each treatment and split are shown in figure 2.

219 *Differences in peak heart rate and RPE between treatments*

220 Repeated measures ANOVA revealed no differences between treatments for HR_{peak} ($F_{(4, 40)} =$
221 1.198 , $p = 0.327$, $\eta^2 = 0.084$) and RPE ($F_{(4, 40)} = 0.892$, $p = 0.641$, $\eta^2 = 0.009$). Across all
222 treatments, mean HR_{peak} and RPE average scores ranged from 180 to 184 bpm (183.5 ± 2.3
223 bpm) and 9 to 10 (9.6 ± 0.4), respectively.

224 **Discussion**

225 We used a balanced placebo design to investigate the effect of a placebo and caffeine on
226 pacing strategy during 1000-m running time-trials. Collectively, our results indicate that the
227 belief of receipt of caffeine improved performance, which was associated with a significant
228 increase in speed during the first **400-m of** the time-trial. In contrast, the hidden and open
229 administration of caffeine and placebo, respectively, did not improve performance compared

230 to baseline. Participants ran faster between 400- and 600-m during the hidden administration
231 of caffeine, but time to complete the trial overall was similar to baseline.

232 In our study, the effect of believing to have ingested caffeine improved performance to the
233 same magnitude as actually receiving caffeine. These findings complement previous findings
234 in this area, in which participants were able to significantly improve their performance after
235 being falsely informed they had received caffeine.^{30,31} However, in addition to previous
236 studies investigating the placebo effect of caffeine,^{4,30-32} we also examined participants'
237 pacing strategy during the trial, in order to establish if a change in pacing might help explain
238 the performance improvements. Given that we informed participants that they had received
239 caffeine in the CC and CP treatments, this information appears to have influenced their belief
240 of how fast they could perform, influencing the goal-directed process of decision-making
241 regarding how to distribute the available energy resources.³³ Results indicated that
242 participants were significantly faster at 400-m than baseline and also faster at 200- and 400-m
243 than when they were given a placebo and informed it was a placebo. This highlights that the
244 belief of receipt of caffeine, influences the pacing strategy at the start of a 1000-m running
245 time-trial, impacting on performance.

246 While both belief and actual receipt of caffeine improved performance at the start of the time-
247 trial, only the actual receipt of caffeine improved performance in the latter stages. At 1000-m,
248 participants ran significantly faster than baseline during the open administration of caffeine.
249 This suggests that caffeine may offset fatigue during the final stages of a 1000-m time-trial. It
250 has been reported that caffeine directly affects neuromuscular output,³⁴ which increases
251 muscular endurance and subsequently offsets fatigue.³⁵ However, no improvements in
252 performance at 1000-m were shown during the hidden administration of caffeine. Therefore,
253 the belief of receipt of caffeine was primarily responsible for the ergogenic effect of caffeine.
254 These results are similar to Atlas and colleagues,³⁶ who reported that the benefits of an
255 opioid drug were augmented after open administration compared to hidden and to a placebo
256 described as the drug. In the same study, follow up fMRI data revealed that drug and placebo
257 effects activate different neurobiological pathways, suggesting that the benefits from the drug
258 and placebo are additive. From the results reported in the present study, it could be suggested
259 that caffeine and placebo use different neurobiological pathways that affect performance.
260 Thus, when caffeine is administered openly, the verum and placebo components of caffeine
261 may combine to provide a greater improvement in performance. However, while these data
262 show additive effects for caffeine in the latter stages of the trial, it does not exclude the
263 possibility that other treatments may show interactive effects (i.e. use the same mechanisms).
264 A paucity of evidence in sport and exercise science is available in this area and future
265 research needs to design studies that examines the additive or interactive effects of treatments
266 and placebos.

267 Table 1 shows large variability between each treatment, which indicates that some
268 participants may be more likely to respond to a placebo than others. It is recognised that a
269 participant responding to a placebo can vary from study to study^{1,2} and even those who do
270 respond, may not do so consistently.³⁷ Researchers often focus on single-factor casual
271 mechanisms such as expectation theory^{4,31} or classical conditioning.^{38,39} However, placebo
272 effects are a manifestation of several factors, such as the context in which the treatment is
273 administered, the person administering it, and the psychology of the athlete (e.g. personality,
274 beliefs, and intentions). Beedie et al.³⁷ suggest that variability of the placebo effect can be a
275 function of 1) an athlete's response to the verum component of a treatment (e.g. caffeine); 2)

276 an athletes response to the placebo component only; and 3) an athletes response to both the
277 verum and placebo component. To increase knowledge and understanding of the placebo
278 effect, research is needed that helps identify the mechanisms underlying the variation in
279 placebo responsiveness.

280 Similar to previous research,^{4,31,40} no differences in peak heart rate or perceived exertion was
281 found between treatments. Given that the aim of a pacing strategy is to ensure physiological
282 limits are not surpassed while performing at an optimal level,¹⁵ a limitation of this study was
283 that the growth curve of heart rate and perceived exertion during each trial was not measured.
284 Future research should measure the differences in slopes of heart rate and RPE at each split to
285 provide a better insight into the variability in intraindividual patterns of change over time
286 between treatments.

287

288 **Conclusion**

289 In conclusion, this is the first study to show that the belief of receipt of caffeine improves
290 1000-m running time-trial performance on competitive level athletes. That is, believing to
291 have ingested caffeine, improved performance to the same magnitude as actually receiving
292 caffeine. These improvements were associated with an increase in speed during the first-part
293 of the time-trial. While slight changes in pacing strategy were demonstrated during the mid-
294 part of the time-trial with the hidden ingestion of caffeine, overall no changes compared to
295 baseline were shown. Therefore, for practitioners aiming to maximise the benefits of caffeine
296 on an athlete's performance, they should couple the administration of caffeine with a positive
297 belief of its effectiveness to increase the likelihood of that athlete improving performance.

298 Reference list

299

- 300 1. Hurst P, Foad AJ, Coleman DA, Beedie C. Athletes Intending to Use Sports
301 Supplements Are More Likely to Respond to a Placebo. *Med Sci Sports Exerc.*
302 2017;40(9):1877-1883.
- 303 2. Beedie C, Benedetti F, Barbiani D, et al. Consensus statement on placebo effects in
304 sports and exercise: the need for conceptual clarity, methodological rigour, and the
305 elucidation of neurobiological mechanisms. *Eur J Spor Sci.* 2018;18(10):1383-1389.
- 306 3. Beedie C, Foad AJ, Hurst P. Capitalizing on the placebo component of treatments.
307 *Curr Sports Med Rep.* 2015;14(4):284-287.
- 308 4. Foad AJ, Beedie C, Coleman DA. Pharmacological and psychological effects of
309 caffeine ingestion in 40-km cycling performance. *Med Sci Sports Exerc.*
310 2008;40(1):158-165.
- 311 5. McClung M, Collins D. "Because I know it will!": placebo effects of an ergogenic aid
312 on athletic performance. *J Sport Exerc Psychol.* 2007;29(3):382-394.
- 313 6. Rohsenow DJ, Marlatt GA. The balanced placebo design: Methodological
314 considerations. *Addict Behav.* 1981;6(2):107-122.
- 315 7. Clark VR, Hopkins WG, Hawley JA, Burke LM. Placebo effect of carbohydrate
316 feedings during a 40-km cycling time trial. *Med Sci Sports Exerc.* 2000;32(9):1642-
317 1647.
- 318 8. Bellinger PM, Minahan CL. Performance effects of acute beta-alanine induced
319 paresthesia in competitive cyclists. *Eur J Sport Sci.* 2016;16(1):88-95.
- 320 9. Duncan M. Placebo effects of caffeine on anaerobic performance in moderately
321 trained adults. *Serbian journal of sports sciences.* 2010;4(3):99-106.
- 322 10. Tallis J, Muhammad B, Islam M, Duncan MJ. Placebo effects of caffeine on maximal
323 voluntary concentric force of the knee flexors and extensors. *Muscle Nerve.*
324 2016;54(3):479-486.
- 325 11. Brazier J, Sinclair J, Bottoms L. The effects of hologram wristbands and placebo on
326 athletic performance. *Kineziologija.* 2014;46(1):109-116.
- 327 12. Beedie C, Foad AJ. The placebo effect in sports performance: a brief review. *Sports*
328 *Med.* 2009;39(4):313-329.
- 329 13. Frisaldi E, Piedimonte A, Benedetti F. Placebo and nocebo effects: a complex
330 interplay between psychological factors and neurochemical networks. *Am J Clin*
331 *Hypn.* 2015;57(3):267-284.

- 332 14. Foster C, Hendrickson K, Peyer K, et al. Pattern of developing the performance
333 template. *Br J Sports Med.* 2009.
- 334 15. Jones HS, Williams EL, Bridge CA, et al. Physiological and psychological effects of
335 deception on pacing strategy and performance: a review. *Sports Med.*
336 2013;43(12):1243-1257.
- 337 16. Konings MJ, Parkinson J, Zijdwind I, Hettinga FJ. Racing an opponent: alteration of
338 pacing, performance, and muscle-force decline but not rating of perceived exertion.
339 *Int J Sports Physiol Perform.* 2018;13(3):283-289.
- 340 17. Schiphof-Godart L, Roelands B, Hettinga FJ. Drive in sports: how mental fatigue
341 affects endurance performance. *Front Psychol.* 2018;9.
- 342 18. Wiles J, Bird S, Hopkins J, Riley M. Effect of caffeinated coffee on running speed,
343 respiratory factors, blood lactate and perceived exertion during 1500-m treadmill
344 running. *Br J Sports Med.* 1992;26(2):116-120.
- 345 19. Irwin C, Desbrow B, Ellis A, O'Keeffe B, Grant G, Leveritt M. Caffeine withdrawal
346 and high-intensity endurance cycling performance. *J Sports Sci.* 2011;29(5):509-515.
- 347 20. Smith JR, Brown KR, Murphy JD, Harms CA. Does menstrual cycle phase affect
348 lung diffusion capacity during exercise? *Respir Physiol Neurobiol.* 2015;205:99-104.
- 349 21. Haugen T, Buchheit M. Sprint running performance monitoring: Methodological and
350 practical considerations. *Sports Med.* 2016;46(5):641-656.
- 351 22. Spriet LL. Exercise and sport performance with low doses of caffeine. *Sports Med.*
352 2014;44(2):175-184.
- 353 23. Graham T, Spriet L. Metabolic, catecholamine, and exercise performance responses to
354 various doses of caffeine. *J Appl Physiol.* 1995;78(3):867-874.
- 355 24. Culm-Merdek KE, Von Moltke LL, Harmatz JS, Greenblatt DJ. Fluvoxamine impairs
356 single-dose caffeine clearance without altering caffeine pharmacodynamics. *Br J Clin*
357 *Pharmacol.* 2005;60(5):486-493.
- 358 25. Tomlin DL, Wenger HA. The relationship between aerobic fitness and recovery from
359 high intensity intermittent exercise. *Sports Med.* 2001;31(1):1-11.
- 360 26. Drust B, Waterhouse J, Atkinson G, Edwards B, Reilly T. Circadian rhythms in sports
361 performance—an update. *Chronobiol Int.* 2005;22(1):21-44.
- 362 27. Borg G. Psychophysical scaling with applications in physical work and the perception
363 of exertion. *Scand J Work Environ Health.* 1990:55-58.
- 364 28. Hopkins WG. Spreadsheets for Analysis of Validity and Reliability. *Sportsci.*
365 2015;19:26-42.

- 366 29. Cohen J. A power primer. *Psychol Bull.* 1992;112(1):155-159.
- 367 30. Pires FO, Anjos CASD, Covolan RJ, et al. Caffeine and Placebo Improved Maximal
368 Exercise Performance Despite Unchanged Motor Cortex Activation and Greater
369 Prefrontal Cortex Deoxygenation. *Front Physiol.* 2018;9:1144.
- 370 31. Beedie C, Stuart EM, Coleman DA, Foad AJ. Placebo effects of caffeine on cycling
371 performance. *Med Sci Sports Exerc.* 2006;38(12):2159-2164.
- 372 32. Saunders B, de Oliveira LF, da Silva RP, et al. Placebo in sports nutrition: a proof-of-
373 principle study involving caffeine supplementation. *Scand J Med Sci Sports.*
374 2017;27(11):1240-1247.
- 375 33. Edwards A, Polman R. Pacing and awareness: brain regulation of physical activity.
376 *Sports Med.* 2013;43(11):1057-1064.
- 377 34. Mora-Rodríguez R, Pallarés JG, López-Gullón JM, López-Samanes Á, Fernández-
378 Elías VE, Ortega JF. Improvements on neuromuscular performance with caffeine
379 ingestion depend on the time-of-day. *J Sci Med Sport.* 2015;18(3):338-342.
- 380 35. Pethick J, Winter SL, Burnley M. Caffeine Ingestion Attenuates Fatigue-induced Loss
381 of Muscle Torque Complexity. *Med Sci Sports Exerc.* 2018;50(2):236-245.
- 382 36. Atlas LY, Whittington RA, Lindquist MA, Wielgosz J, Sonty N, Wager TD.
383 Dissociable influences of opiates and expectations on pain. *J Neurosci.*
384 2012;32(23):8053-8064.
- 385 37. Beedie C, Benedetti F, Barbiani D, Camerone E, Lindheimer JB, Roelands B. Are
386 placebo effects in sport a sham, or have we got things under control? Some potential
387 mechanisms and promising methods that might help answer the question. *Eur J Spor
388 Sci.* In Press.
- 389 38. Pollo A, Carlino E, Benedetti F. The top-down influence of ergogenic placebos on
390 muscle work and fatigue. *Eur J Neurosci.* 2008;28(2):379-388.
- 391 39. Rossettini G, Andani ME, Dalla Negra F, Testa M, Tinazzi M, Fiorio M. The placebo
392 effect in the motor domain is differently modulated by the external and internal focus
393 of attention. *Sci Rep.* 2018;8(1):12296.
- 394 40. Ross R, Gray CM, Gill JM. Effects of an Injected Placebo on Endurance Running
395 Performance. *Med Sci Sports Exerc.* 2015;47(8):1672-1681.

397 **Figure captions**

398 **Figure 1.** Mean split time between each treatment. Note: Data are means \pm 95% CI. * = $p <$
399 0.01 vs. CC and CP. ** = $p < 0.01$ vs. CC and CP

400 **Figure 2.** Differences in times between treatment and splits. Note: *PP vs. CC and CP ($p <$
401 0.05). **CC and CP vs. baseline, PC and PP ($p < 0.05$). #PC vs. baseline, CC and PP($p <$
402 0.05) and CP vs. baseline and PP ($p < 0.05$). †CC vs. baseline and PP ($p < 0.05$)

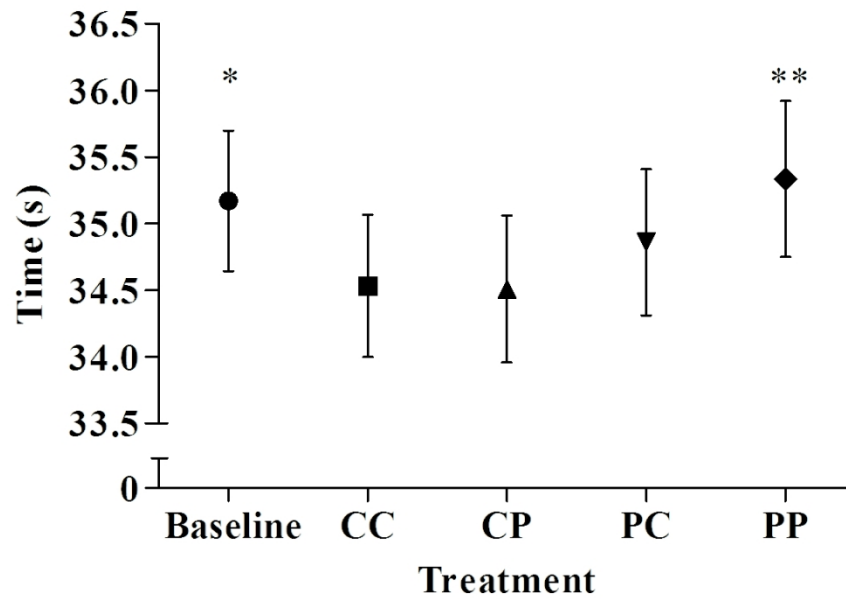
For Peer Review

403 Tables

Table 1. Mean times (s) to complete 1000-m time-trials in each treatment

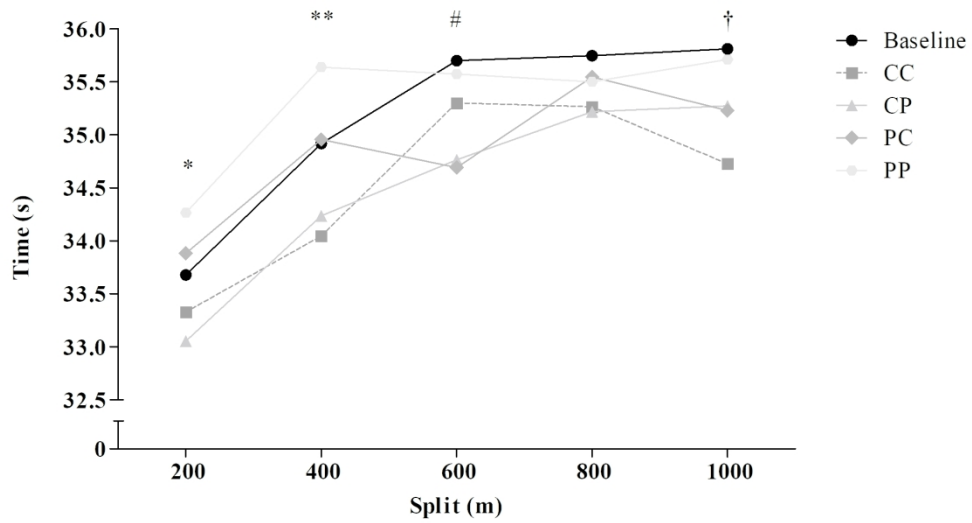
<i>Participant</i>	<i>Baseline</i>	<i>CC</i>	<i>CP</i>	<i>PC</i>	<i>PP</i>
1	166.9	164.3	165.4	172.1	165.1
2	187.3	182.9	180.9	187.1	193.1
3	179.4	174.9	175.4	174.7	178.2
4	176.4	171.1	170.5	173.7	175.3
5	168.4	164.1	160.3	163.0	164.8
6	180.4	178.4	178.7	177.8	184.5
7	169.3	164.6	165.9	165.9	169.8
8	166.3	162.5	163.7	164.3	168.1
9	183.3	180.4	179.2	182.4	181.6
10	175.2	173.3	173.6	173.9	179.1
11	181.8	182.8	184.4	182.4	183.9
Mean ± SEM	175.9 ± 0.55	172.7 ± 0.60	172.6 ± 0.60	174.3 ± 0.59	176.7 ± 0.68

Note: CC = Told caffeine/given caffeine; CP = Told caffeine/given placebo; PC = Told placebo/given caffeine; PP = Told placebo/given placebo



Mean split time between each treatment. Note: Data are means \pm 95% CI. * = $p < 0.01$ vs. CC and CP. ** = $p < 0.01$ vs. CC and CP

109x74mm (300 x 300 DPI)



Mean split time between each treatment. Note: Data are means \pm 95% CI. * = $p < 0.01$ vs. CC and CP. ** = $p < 0.01$ vs. CC and CP

179x99mm (300 x 300 DPI)