

The effect of caffeine and Rhodiola Rosea, alone or in combination on 5km running performance in men

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1 **The effect of caffeine and Rhodiola Rosea, alone or in combination on 5km running**
2 **performance in men**

3

4 Original Investigation

5

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12

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14

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20

21 **Abstract**

22 Background: To examine the effect of acute *R.Rosea* ingestion, acute caffeine ingestion or
23 combined caffeine and *R.Rosea* on 5km running time trial performance.

24 Methods: Twelve male, recreational exercisers (mean age \pm S.D. = 24.6 \pm 6 years) undertook
25 4 trials each (Placebo; Caffeine (3 mg/kg⁻¹), *R.Rosea* (3 mg/kg⁻¹), Caffeine (3 mg/kg⁻¹) and
26 *R.Rosea* (3 mg/kg⁻¹)) in a double blind, randomised order.

27 Results: There was a small but significant main effect of treatment for 5km run time (P =
28 .048) where performance was faster in the presence of caffeine compared to placebo but not
29 between any other combination of trials. Heart Rate, Blood Lactate and RPE all increased
30 with Km run, irrespective of substance ingested (all P<.05). Scores for Felt Arousal increased
31 pre ingestion to post ingestion (P = .028) and were maintained to post exercise (P = .026)
32 irrespective of substance ingested. There was a small, significant treatment X time interaction
33 (P = .011, $P\eta^2 = .255$) for Feeling Scale scores, where post exercise feeling scale scores were
34 significantly lower after caffeine ingestion compared to the other substances ingested.

35 Conclusions: Acute caffeine ingestion (3 mg·kg⁻¹) enhances 5km time trial performance
36 undertaken on a treadmill and results in more negative affect post exercise as compared to
37 ingestion of *R.Rosea*, combined *R.Rosea* and caffeine and placebo This study supports the
38 efficacy of caffeine, but not *R.Rosea*, as an ergogenic aid for time running performance.

39 **Keywords:** Ergogenic; supplementation; feeling states; affect

40

41

42 **Introduction**

43 The performance enhancing effects of caffeine ingestion on endurance¹ and short term, high
44 intensity performance² are well documented. However, less data is available that considers
45 the effect of caffeine on shorter term endurance type activities (typically lasting <30min).³
46 Bridge and Jones⁴ reported that caffeine ingestion enhanced 8km run time by 1.3% and more
47 recent research by O'Rourke et al,³ reported that 5 mg/kg⁻¹ caffeine resulted in small but
48 significant improvements (1%) in 5km time trial performance in recreational and well-trained
49 runners. This appears to be the only study that has examined the efficacy of caffeine ingestion
50 on 5km running time, a commonly used race distance for trained and recreational runners
51 alike. Thus, additional research may be warranted using this distance specifically.

52 There have also been recent calls to examine the efficacy of caffeine ingestion
53 alongside ingestion of other supplements,⁵ based on the rationale that many athletes consume
54 multiple substances in the belief they are both ergogenic and synergistic without substantial
55 scientific evidence for this assumption. This is an important point as although two given
56 substances might theoretically act synergistically, when combined there may be practical
57 considerations which confound a substance's positive effect. It is thus important to
58 experimentally examine combination of substances to best direct applied nutritional guidance
59 for athletes. Once such substance, *Rhodiola Rosea* (*R.Rosea*), has been cited as having a
60 number of ergogenic benefits related to exercise^{6,7} and may be synergistic with caffeine due
61 to its recently purported effect as a natural opioid⁶. Recent studies have identified antioxidant
62 and anti-inflammatory properties of *R.Rosea*,^{8,9} and further work has suggested ingestion of
63 *R.Rosea* appears to be effective, either acutely^{10,11} or with daily supplementation,¹¹ for

64 reducing perceived fatigue, improving cognition,^{9,12} as well as reducing markers of
65 physiological and psychological stress.¹³

66 The efficacy of *R.Rosea* ingestion during exercise is unclear. Animal based research
67 has shown increased swim time to exhaustion in rats.^{8,14} In humans, some studies have shown
68 no effect of *R.Rosea* ingestion on exercise performance^{9,15} whilst others have supported its
69 use.^{17,18} For example, research by Noreen et al¹⁸ reported that a 3 mg·kg⁻¹ body mass dose of
70 *R.Rosea* significantly decreased exercise heart rate, RPE and improved 6-mile time trial
71 performance time. Subsequent work has reported that acute *R.Rosea* ingestion resulted in
72 lower ratings of perceived exertion and increased mood state ratings during 30mins cycling at
73 70% $\dot{V}O_{2\text{ max}}$.¹¹ Studies have suggested that *R.Rosea* acts to acutely increase endogenous
74 opioid production or receptor sensitivity^{7,17} subsequently impacting on brain dopamine and
75 and attenuating perception of effort at a given workload.¹⁸ However, as few studies have
76 examined acute *R.Rosea* ingestion on exercise performance to date further data is needed on
77 this topic.

78 As caffeine is a known ergogenic which has direct effects of muscle and the CNS and
79 *R.Rosea* acts as an opioid, promoting more positive exercise based affective responses, it may
80 be possible that when these substances are combined performance gains are augmented due
81 to the mechanism by which both substances are purported to work. This study aims to build
82 on the recommendations of Burke⁵ by examining the effect of acute *R.Rosea* ingestion, acute
83 caffeine ingestion or combined caffeine and *R.Rosea* on 5km running time trial performance
84 in a population of recreationally-active men.

85

86 **Method**

87 *Subjects*

88 Following institutional ethics approval and informed consent, 12 male, recreational exercisers
89 (mean age \pm S.D. = 24.6 \pm 6 years), recruited from University fitness classes/running groups,
90 participated in this study. Inclusion criteria included being male and habitually engaged in
91 recreational physical activity of more than 3 but less than 10 hours per week and not
92 including formal competitive sports performance.

93 *Design*

94 This study employed a randomised within-participants double-blind cross-over design
95 whereby participants visited the laboratory on 5 occasions in a well-rested and well hydrated
96 state (one familiarisation trial, four experimental trials). All participants completed a health
97 screen questionnaire prior to participation. All trials occurred in the morning for all
98 participants and, for each participant, the 5 trials occurred at the same time of day with each
99 participant completing all trials.

100

101 *Methodology*

102 All participants were asked to refrain from vigorous exercise and maintain normal
103 dietary patterns in the 48 hours prior to testing and were asked to abstain from caffeine 24
104 hours before testing. Habitual caffeine intake was 119.3 \pm 21.1 mg day. During the first visit
105 participants completed a familiarization session. Here participants the exercise affect
106 measures to be used in the subsequent experimental trials were presented and explained. In
107 addition the participants also completed an incremental exercise test to assess VO_{2max} . The
108 incremental exercise test was treadmill based (Woodway, Wisconsin, USA) and performed
109 using the Jones¹⁹ protocol for determination of maximal oxygen uptake. Expired gas was
110 collected via an online breath by breath system (Metamax 3B, Cortex Biophysik, Leipzig,

111 Germany) with recording of $\dot{V}O_2$ consumed, $\dot{V}CO_2$ produced, respiratory exchange ratio and
112 ventilation rate and volume. Heart rate (Polar Electro, Kempele, Finland) and rating of
113 perceived exertion (RPE), using the Borg 6-20 RPE scale,²⁰ was recorded during the final 15
114 seconds of each workload. Recognised criteria for the attainment of $\dot{V}O_{2max}$ was employed.²¹
115 Mean \pm S.D. of participants' baseline $\dot{V}O_{2max}$ values was $56.1 \pm 7.1 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$.

116

117 *Experimental protocol*

118 On completion of the $\dot{V}O_{2max}$ testing and following a period of at least 72 hours
119 participants completed four, 5-km running time trials in a fasted state. During each trial
120 participants were instructed to complete 5-km in the fastest time possible. Trials were
121 conducted on a Woodway Treadmill (Woodway, Wisconsin USA) with gradient set at 1%
122 and with participants having access to speed controls. All other controls (eg gradient) and
123 visual display information (eg running speed, time) was blinded from participants using a
124 purpose built shield to prevent pacing during the trials.

125 Self-report of dietary intake was employed to assess dietary intake in the 24 hours
126 prior to exercise trials. Participants were requested to maintain the same diet prior to each
127 exercise trial in relation to general content of carbohydrate, fat and protein. They were also
128 asked to refrain from consumption of caffeine and alcohol the day before each trial.
129 Participants also verbally confirmed this was the case prior to each trial. This was used to
130 ensure that caffeine and alcohol had not been consumed in the 24 hours prior to testing.
131 Conditions were randomised, separated by 48-72 hours, and consisted of a *R.Rosea* condition
132 where $3 \text{ mg}\cdot\text{kg}^{-1}$ body mass of *R.Rosea* (3% rosavins and 1% salidosides, Indigo Herbs,
133 Glastonbury, UK) was ingested, A caffeine condition where $3 \text{ mg}\cdot\text{kg}^{-1}$ body mass of caffeine
134 (Myprotein, Cheshire, UK) was ingested, a combined *R.Rosea* and caffeine condition where

135 3 mg·kg⁻¹ body mass of both substances was ingested and a placebo (3 mg·kg⁻¹ body mass of
136 maltodextrin, (MyProtein, Northwich, UK)) was ingested. Experimental solutions were
137 administered double-blind. In addition to the relevant solute, each solution consisted of 4
138 ml.kg⁻¹ tap water and 1 ml.kg⁻¹ of double strength no added sugar orange squash
139 (Sainsbury's, London, UK). The amount of total maltodextrin ingested was approximately
140 170 mg in the placebo condition and thus highly unlikely to have had any impact on exercise
141 performance or metabolism.¹⁸ The dose of *R.Rosea* used was based on the previous work
142 using this substance.^{11,17,18}

143 During each time trial, heart rate (monitored via Polar RS400, Polar Electro Oy,
144 Kempele, Finland), blood lactate concentration (BLA: mmol/l) taken from a fingertip
145 capillary blood sample (5 µl, Lactate Pro, Arkray Inc, Japan), and ratings of perceived
146 exertion (RPE) using the Borg 6-20 scale²⁰ were recorded after every 1 kilometre. The
147 memory-anchoring approach²² was employed to anchor RPE scores before the experimental
148 trials. Prior to substance ingestion, 60 min after ingestion (at the onset of each exercise bout)
149 and immediately on completion of each exercise bout, participants completed the feeling
150 scale (FS).²³ This 11 item, single item scale ranges from +5 (very good) to -5 (very bad) and
151 is used to quantify pleasure/displeasure. The Felt Arousal Scale (FAS) was also employed as
152 a measure of state arousal.²⁴ This is a six item scale ranges from 1 (low arousal) to 6 (high
153 arousal). Participants were introduced to these scales on first visit to the laboratory (prior to
154 establishment of $\dot{V}O_{2max}$). Standardised instructions for completing the FS and FAS were
155 read to participants at the beginning of each trial.

156

157 *Statistical Analysis*

158 Data were analysed in a number of ways. A repeated measures analysis of variance
159 (ANOVA) with substance ingested as the within subjects factor was used to examine any
160 differences in total 5km time between conditions. In order to examine any within trial
161 variation a 4 (substance ingested) X 5 (time per km) ways repeated measures ANOVA was
162 used to examine any differences in running time per kilometre between the four conditions. A
163 series of 4(substance ingested) X 5 (time point) ways repeated measures ANOVAs were used
164 to examine any changes in heart rate, BLa and RPE at each kilometre of the time trial. A
165 series of 4 (substance ingested) X 3 (time point, pre ingestion, post ingestion but pre exercise
166 and post exercise) ways repeated measures analysis of variance was used to examine any
167 differences in perceptions of arousal and pleasure/displeasure. Where any significant
168 differences were discovered Bonferroni pairwise multiple comparisons were used to
169 determine where the differences lay. Partial η^2 was used as a measure of effect size, statistical
170 significance was set at $P = .05$ a priori, and the Statistical Package for Social Sciences
171 (Version 22) was used for all analysis (SPSS inc, Illinois, USA).

172

173 **Results**

174 There was a small but significant main effect of treatment for 5km run time ($F_{3,33} = 2.935$,
175 $P = .048$, $P\eta^2 = .211$; Table 1). Post-Hoc analysis indicated significant differences between
176 placebo conditions and caffeine conditions (Mean diff = 78.6, $P = .024$) but not between any
177 other combination of trials (all $P > .05$). There was a trend ($P = .06$) for 5km run to be faster in
178 the caffeine condition compared to the *R.Rosea* condition. Mean \pm SE of 5km time trial
179 across treatment conditions is presented in Figure 1.

180

181 ***Table 1 Here***

182

183

184 When data were considered using individual time per kilometre and across treatment
185 conditions, the small main effect for total time remained ($P = .048$, $P\eta^2 = .211$) and there was
186 a moderate significant main effect for time per kilometre ($P = .001$, $P\eta^2 = .340$). In regard to
187 main effect of treatment condition, the results using this analysis were identical to those
188 presented above for total time. For the main effect for time per kilometre, post-hoc analysis
189 indicated that the final kilometre was run significantly faster than kilometres 1 -4 (all $P =$
190 0.08 or better, See Figure 2). Mean \pm SE data of time per kilometre across the different
191 treatment conditions does appear to show different pacing strategies in Figure 2, particularly
192 for the placebo condition. However, there was no significant time per kilometre X treatment
193 interaction ($P = .324$).

194

195 In respect of heart rate (Table 2), there was no significant effect of treatment ($P = .210$) or
196 treatment X time interaction ($P = .730$). There was a large significant main effect for time (P
197 $= .0001$, $P\eta^2 = .703$). These findings were mirrored for BLa (Table 2) with no significant
198 effect of treatment ($P = .132$) or treatment X time interaction ($P = .721$) but a large significant
199 main effect for time ($P = .0001$, $P\eta^2 = .803$) and also for RPE (Table 2) where again there
200 was no significant effect of treatment ($P = .300$) or treatment X time interaction ($P = .566$)
201 but a large significant main effect for time ($P = .0001$, $P\eta^2 = .927$). In each case, HR, BLa
202 and RPE significantly increased with each successive Km ran, irrespective of substance
203 ingested. These main effects are presented in Figure 3a, b and c.

204

205 ***Table 2 Here***

206

207

208 When measures of affect were examined, results from a 4 (treatment) X 3 (time, Pre
209 ingestion, post ingestion, post exercise) for scores on the Felt Arousal Scale indicated no
210 significant main effect for treatment ($P = .505$) or time X treatment interaction ($P = .335$).
211 There was however a large significant main effect for time ($P = .009$, $P\eta^2 = .546$, See Figure
212 4) whereby felt arousal increased pre ingestion to post ingestion ($P = .028$) with the
213 difference also being significantly different from pre ingestion to post exercise ($P = .026$) but
214 with no difference between post ingestion and post exercise ($P = .084$). Mean \pm SE and 95%
215 Confidence Intervals for felt arousal scores and Feeling scales scores pre ingestion, post
216 ingestion and pre exercise and post exercise across placebo, *R.Rosea*, caffeine and combined
217 caffeine and *R.Rosea* trials is presented in Table 3.

218

219 ***Table 3 Here***

220

221 When scores from the Feeling Scale were examined there was a small significant treatment X
222 time interaction ($P = .011$, $P\eta^2 = .255$, See Figure 5). Post-Hoc analysis indicated no
223 significant differences in feeling scale scores pre ingestion ($P = .693$) or post ingestion (P
224 $= .431$). However, Post exercise feeling scale scores in the caffeine condition were
225 significantly lower as compared to the Caffeine + *R.Rosea* condition ($P = .027$) and the

226 *R.Rosea* condition ($P = .05$). There were also no significant differences pre ingestion to post
227 ingestion and post exercise for Placebo, *R.Rosea* and Caffeine + *R.Rosea* conditions (all P
228 $>.05$). For the caffeine condition there was significantly lower feeling scales scores post
229 exercise compared to pre ingestion ($P = .019$) and post ingestion ($p = .001$).

230

231 **Discussion**

232 The present study is the first to combine caffeine and *R.Rosea* when examining exercise
233 performance. This is despite there being plausible evidence that both substances are
234 ergogenic alone and that potentially, when combined might be synergistic, due to caffeine
235 acting directly on muscle²⁵ and the CNS¹ and suggestions that *R.Rosea* results in increased
236 endogenous opioid production.¹⁷

237 The results of the present study suggest that ingestion of $3 \text{ mg}\cdot\text{kg}^{-1}$ caffeine has a
238 significant and positive effect on 5km run time in recreationally active males. The ingestion
239 of *R.Rosea* or *R.Rosea* combined with caffeine did not significantly improve 5km running
240 performance. When compared against performance in the placebo condition, 5km time trial
241 time following caffeine ingestion was approximately 5% faster than the placebo trial. Such a
242 magnitude of change in the presence of caffeine is greater than that reported by O'Rourke et
243 al³ following ingestion of a larger bolus of caffeine ($5\text{mg}\cdot\text{kg}^{-1}$) for 5km run and by Bridge
244 and Jones⁴ following ingestion of $3 \text{ mg}\cdot\text{kg}^{-1}$ caffeine for 8km run. Likewise, although not
245 significant, there was a 3.5% improvement following *R.Rosea* ingestion and a 4%
246 improvement following combined *R.Rosea* and Caffeine ingestion when compared against
247 the placebo condition. The reason for the larger performance improvement seen in the
248 caffeine trial may be attributed to a number of reasons. The participants utilised by O'Rourke
249 et al³ were a mixture of trained and non-trained runners and those used by Bridge and Jones⁴

250 were trained runners. Prior systematic review data suggested lack of standardisation of
251 training status may be one reason for the equivocal nature of the effects of caffeine on
252 exercise performance and that the effect of caffeine on performance may differ in individuals
253 of different training status.²⁶ In the present study, recreationally active men who were not
254 specifically running trained, nor were they competitive runners. Secondly, in both the
255 aforementioned studies, experimental trials took place outdoors, providing ample opportunity
256 for pacing by participants. The present study utilised a different methodology whereby
257 participants ran on a treadmill and had access to buttons to increase or decrease running
258 speed. There were no other available metrics to the participants, thus removing any explicit
259 cues for pacing. This lack of feedback may have resulted in lesser likelihood of a belief effect
260 interacting with the time trial task employed in the current study.

261 Taken collectively, these results would appear to support the ingestion of caffeine
262 alone as a means to enhance 5km time trial running performance. This finding adds further
263 support for the use of caffeine as a performance enhancer in short-term endurance activity.^{3,4}
264 The current results also question the validity of claims regarding the efficacy of acute
265 *R.Rosea* ingestion as a means to enhance exercise performance.¹⁸ Similarly, *R.Rosea* or
266 combined caffeine and *R.Rosea* ingestion did not significantly influence the affect either after
267 ingestion or after exercise. This is also contrary to prior research by Duncan and Clarke¹¹
268 using steady state exercise that suggested *R.Rosea* positively enhanced affect. The
269 discrepancy in findings regarding *R.Rosea* ingestion in the present study compared to prior
270 work^{17,18} may be due to a number of reasons relating to the methodologies employed in prior
271 work and the current study. In the study by DeBock et al¹⁷ a time to exhaustion test was used.
272 Authors have questioned the validity of this methodology because it does not mimic the
273 demands of most athletic events which require individuals to cover a set distance in the
274 quickest time possible.²⁷ Although this point was addressed in the subsequent study by

275 Noreen et al¹⁸, their design made feedback data available to participants during the time trial
276 task they used. This procedure is also problematic when examining the potential effects of
277 ingesting substances as athletes may pace using the available feedback and substance
278 ingestion can also elicit belief effects,²⁸ which can be both positive and negative²⁹. In the
279 present study, the use of a time-trial task without feedback would have limited any potential
280 interaction of potential belief effects with time trial pacing, resulting in a more accurate
281 demonstration of the effects of the various substances ingested. Of interest, in the present
282 study, acute caffeine ingestion resulted in significantly greater negative affect (feeling states)
283 post exercise compared to the other trials. Few studies have examined how affect changes as
284 a consequence of substance ingestion and exercise making it difficult to explain the findings
285 presented here. The results presented here are contrary to work by Astorino et al³⁰ which
286 reported improved scores for feeling states during a 10km cycling time trial in the presence of
287 caffeine compared to placebo. Athletes may therefore performance benefit from ingestion of
288 caffeine, but not *R.Rosea*, for short term endurance running performance. The present study
289 also illustrates the importance of investigating the combination of two potentially ergogenic
290 substances on performance. Theoretically, there appears to be a basis for a synergistic effect
291 of combining caffeine and *R.Rosea*. In practice, when these substances were combined, there
292 appeared to be no advantage to ingestion of caffeine and *R.Rosea* over ingestion of a placebo.
293 The reason for this is not known and it may be that when combined, additional side effects
294 are realised (although none of these were reported by participants) which do not occur when
295 either caffeine or *R.Rosea* are combined in isolation. Additional research would be needed to
296 examine this point specifically.

297 The current study does have some limitations. We recruited participants who were
298 recreationally active but were not trained athletes. It has been suggested that less fit
299 individuals may experience greater fatigue and discomfort during exercise which may reduce

300 feelings of pleasure and compared to more highly trained individuals.¹¹ It may therefore be
301 useful to compare the responses of participants of different training status in order to make
302 more conclusive statements regarding the effect of the substances, either alone or in
303 combination on variables such as, perception of exertion, arousal and pleasure. The
304 assessment of affect immediately on completion of the running bouts might have resulted in
305 elevated scores for feeling states due to the cessation of exercise as has been suggested
306 previously.³¹ It may be that the trajectory of pleasure and displeasure during and after
307 exercise exhibits two distinct phases.³¹ The first phase involves a decline or increase of
308 affective responses during exercise, whereas the second phase involves an improvement or
309 rebound of affective responses after exercise. As measures of affect were only taken on
310 completion of the exercise bouts, the data presented here are only representative of the
311 rebound phase of exercise in the presence of caffeine, *R.Rosea*, combined caffeine and
312 *R.Rosea* and placebo. Future research should therefore, attempt to assess affect during
313 exercise in addition to immediately on cessation in order to more effectively capture the time
314 course of affective responses to exercise following ingestion of different substances.

315

316 **Conclusions**

317 The current study suggests that acute caffeine ingestion ($3 \text{ mg}\cdot\text{kg}^{-1}$) enhances 5km time trial
318 performance undertaken on a treadmill and also results in more negative affect post exercise
319 as compared to ingestion of *R.Rosea*, combined *R.Rosea* and caffeine and placebo. As a
320 consequence this study supports the efficacy of caffeine as an ergogenic aid but also suggests
321 that acute ingestion of *R.Rosea* either alone or with caffeine does not enhance performance
322 over a placebo.

323

324

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326 collection during some of the exercise trials.

327

328

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Figure 1. Mean \pm SE of total 5km time across placebo, R.Rosea, caffeine and combined caffeine and R.Rosea trials

Figure 2. Mean \pm SE of time per kilometre across placebo, R.Rosea, caffeine and combined caffeine and R.Rosea trials

Figure 3. Main effects (Mean \pm SE) for a) heart rate (BPM), b) Blood lactate (mmol/L) , c) RPE (6-20), per kilometre irrespective of substance ingested.

Figure 4. Main effect for Felt Arousal per kilometre (Mean \pm SE) irrespective of substance ingested.

Figure 5. Mean \pm SE of Feeling Scale scores pre ingestion, post ingestion but pre exercise and post exercise across placebo, R.Rosea, caffeine and combined caffeine and R.Rosea trials

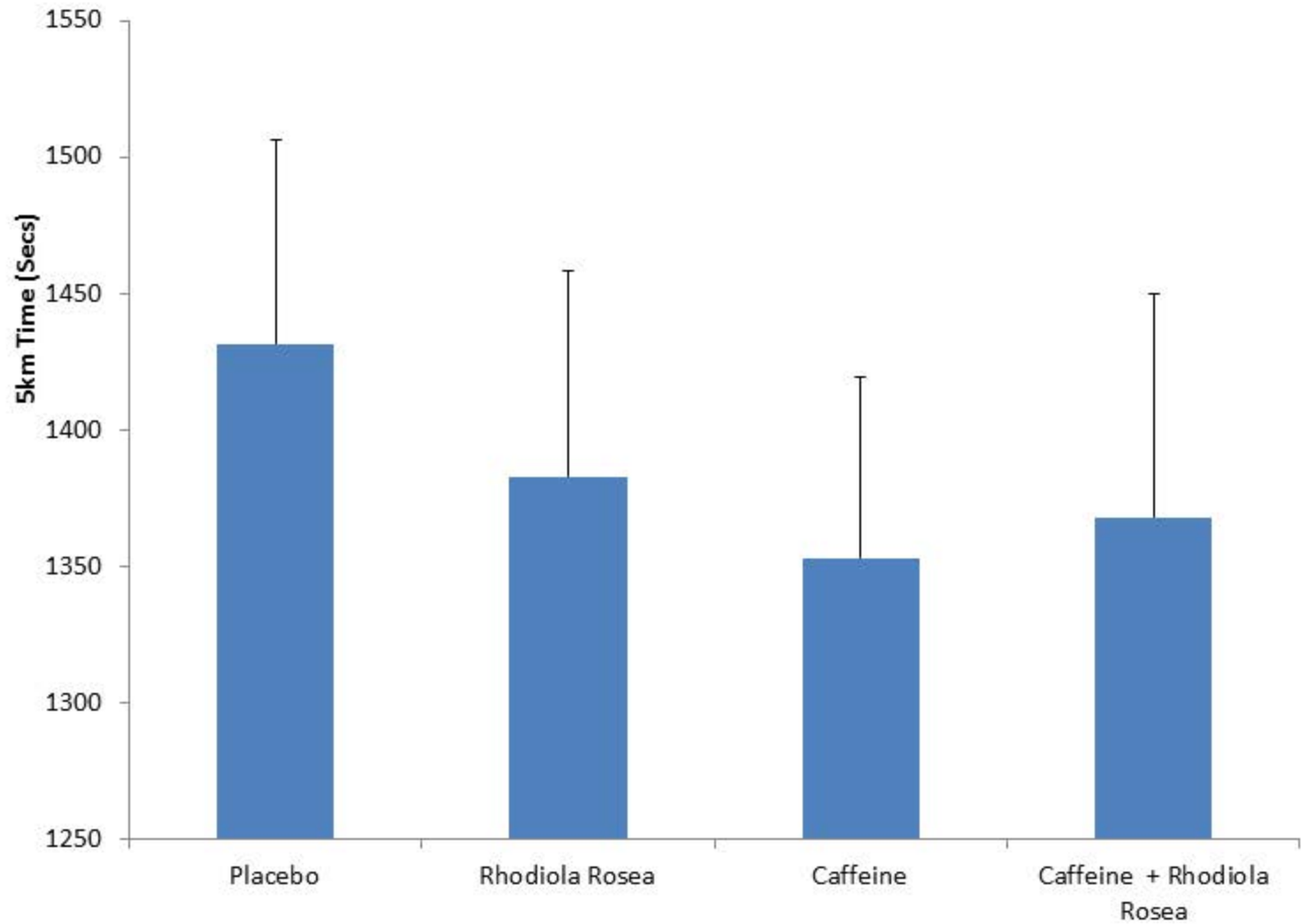


Figure 1.

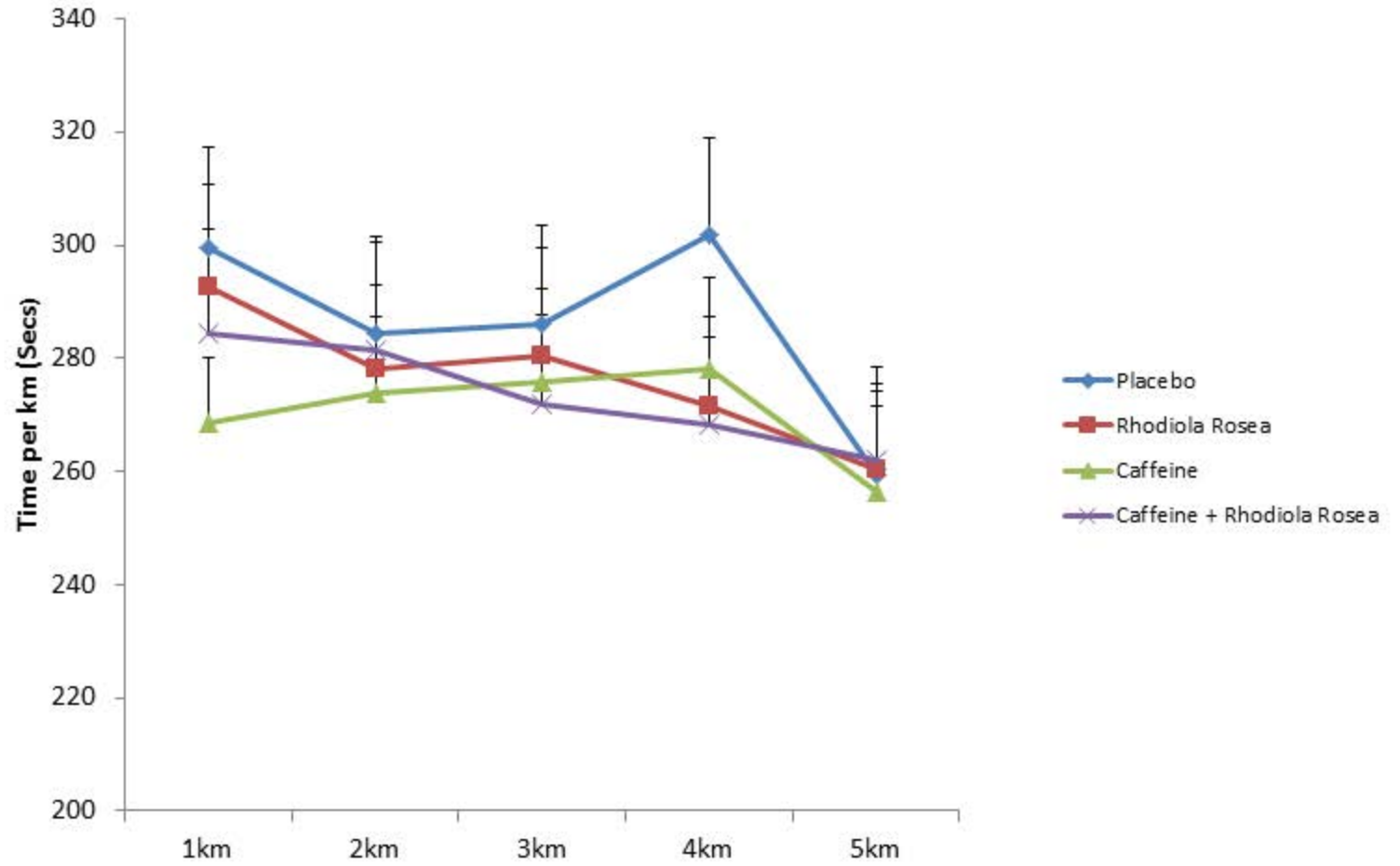
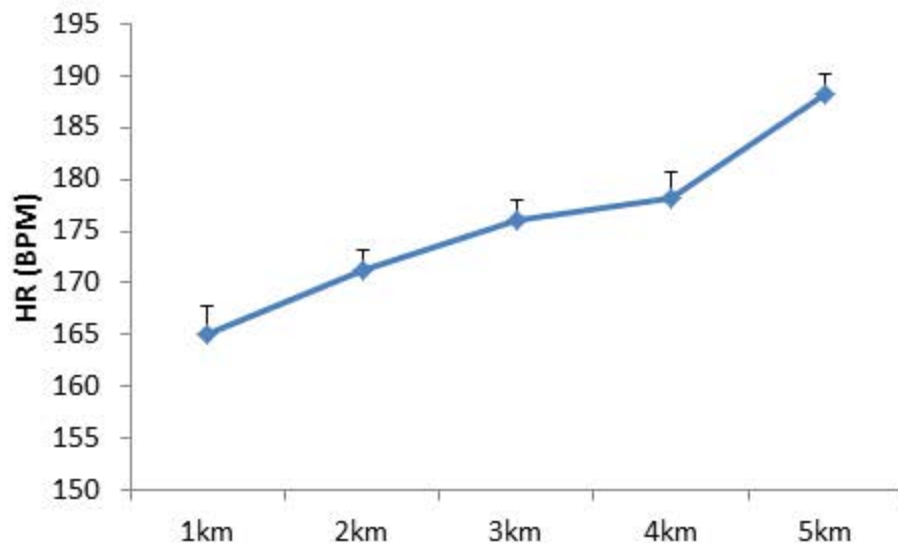
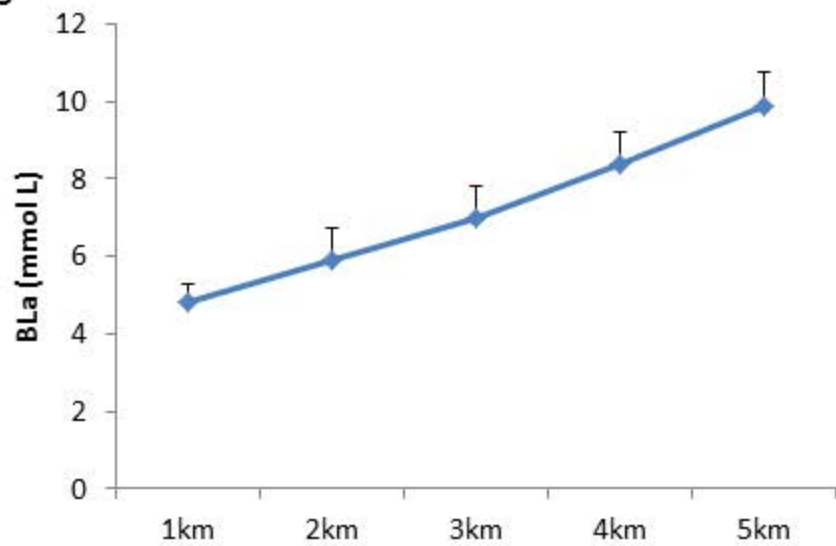


Figure 2.

a



b



c

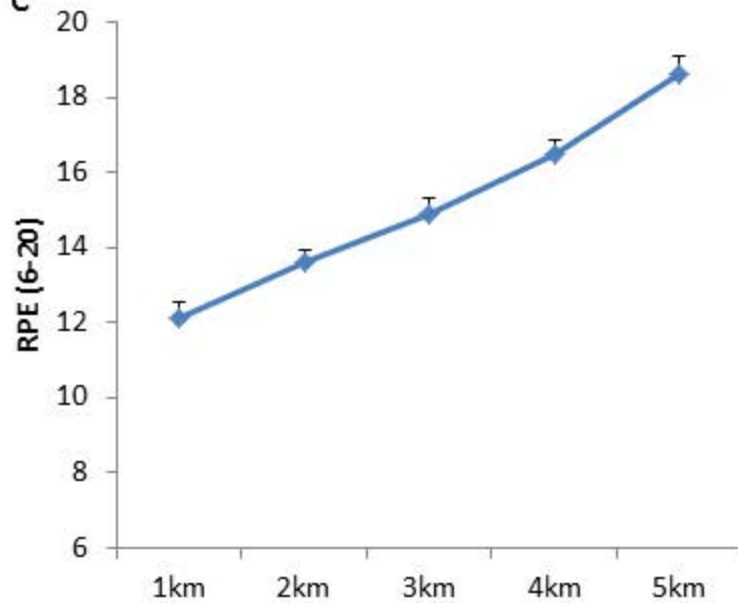


Figure 3.

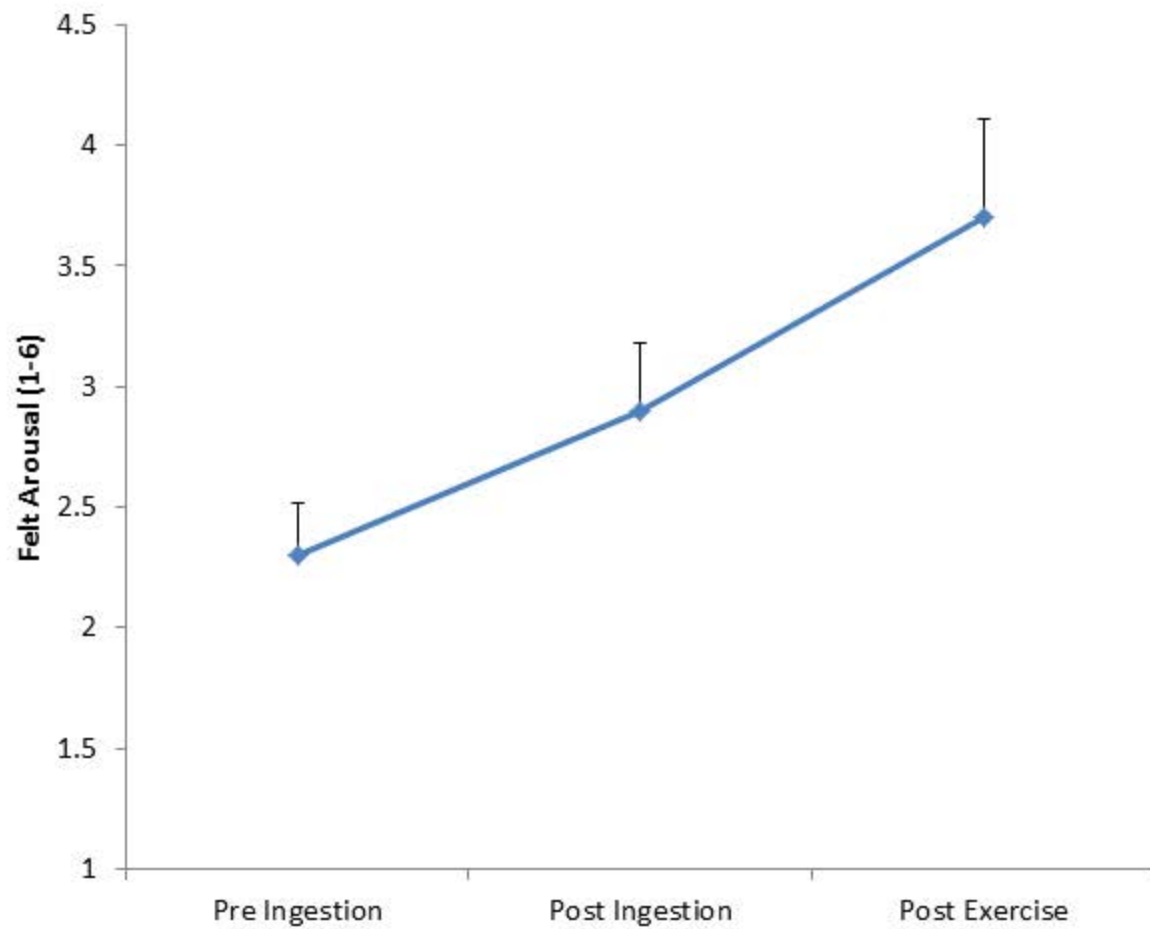


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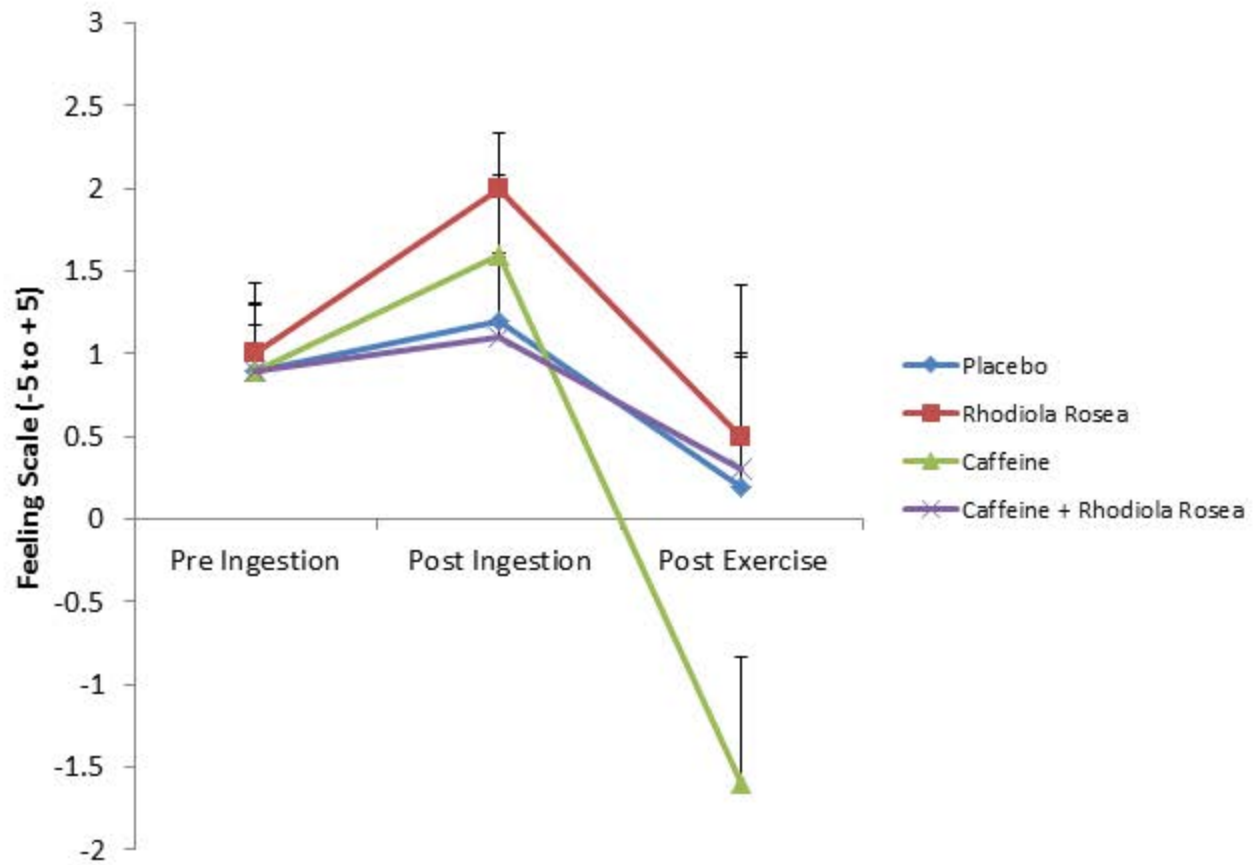


Figure 5.