

## The Effects of Caffeine Ingestion on Time Trial Cycling Performance

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**Purpose:** The purpose of this work was to determine the effects of caffeine on high intensity time trial (TT) cycling performance in well-trained subjects. **Subjects:** Six male cyclists with the following physical characteristics (mean  $\pm$  SD) age 30.7  $\pm$  12, height 179.3  $\pm$  7.5 cm, mass 70.0  $\pm$  7.5 kg,  $VO_{2max}$  65.0  $\pm$  6.3 mL $\cdot$ kg<sup>-1</sup> $\cdot$ min<sup>-1</sup> undertook three 1-h TT performances, control (C), placebo (P) and caffeine (CAF), on a Velotron cycle ergometer conducted in a double-blind, random fashion. Subjects rested for 60 min and were then given CAF or P in a dose of 6 mg $\cdot$ kg<sup>-1</sup> body mass and then commenced exercise after another 60 min of rest. Before ingestion, 60 min postingestion, and at the end of the TT, finger-prick blood samples were analyzed for lactate. **Results:** The cyclists rode significantly further in the CAF trial (28.0  $\pm$  1.3 km) than they did in the C (26.3  $\pm$  1.5 km,  $P < .01$ ) or P (26.4  $\pm$  1.5 km,  $P < .02$ ) trials. No differences were seen in heart rate data throughout the TT ( $P > .05$ ). Blood lactate levels were significantly higher at the end of the trials than either at rest or postingestion ( $P < .0001$ ), but there were no differences between the three trial groups. **Conclusion:** On the basis of the data, we concluded that performance was improved with the use of a caffeine supplement.

**Keywords:** respiratory exchange ratio, performance, heart rate, lactate

Caffeine is one of the most widely consumed drugs in the world and is consumed by sportspeople as an ergogenic aid.<sup>1</sup> There would appear to be a case for caffeine as an ergogenic aid per se, but not necessarily other caffeine-containing substances such as coffee,<sup>2</sup> at least for endurance exercise (30–120 minutes) or where single bouts of high intensity exercise<sup>3–6</sup> are concerned. Furthermore, the effects of caffeine do not appear to be either intensity or mode specific.<sup>7,8</sup> Caffeine has been shown to stimulate the mobilization and oxidation of free fatty acids (FFA) during exercise<sup>7–11</sup> hence sparing muscle glycogen and improving endurance performance.<sup>12,13</sup> Le Blanc, Jobin, Cote, Sampson, and Labrie<sup>14</sup> have shown that caffeine augments the increased lipid oxidation in trained compared with untrained subjects. Other possible mechanisms for caffeine as an ergogenic aid have been postulated as central nervous system up-regulation,<sup>15</sup> increased Na<sup>+</sup>/K<sup>+</sup> ATPase

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activity,<sup>16</sup> increased plasma mobilization of intracellular calcium,<sup>17</sup> and increased plasma catecholamine concentration.<sup>18</sup> Graham<sup>5</sup> states that in exercise situations where fatigue ensues within 30 to 60 minutes, "There can be no doubt that caffeine is ergogenic in these situations" (p. 795), and Magos and Kavouras<sup>19</sup> have supported this view.

Although investigated previously, endurance exercise with intermittent sprinting such as occurs in team activities, has only recently been studied.<sup>20</sup> These authors found a significant, 8.5% (1st half) and 7.5% (2nd half) improvement in prolonged intermittent sprint ability in competitive team sport players. However, there has been little work undertaken in terms of individual high intensity but variable intensity performance, such as that seen in time trial (TT) cycling. Hence, the aim of this study was to investigate whether caffeine would improve the performance of well-trained cyclists undertaking high intensity aerobic work interspersed with high intensity activity, such as that seen in TT cycling.

## Methods

### Participants

Six male cyclists with the following physical characteristics participated in this study (mean  $\pm$  SD): age  $30.7 \pm 12$ , height  $179.3 \pm 7.5$  cm; 163 to 185; mass  $70.0 \pm 7.5$  kg,  $VO_{2max}$   $65.0 \pm 6.3$  mL $\cdot$ kg<sup>-1</sup> $\cdot$ min<sup>-1</sup>. Subjects were informed verbally and in writing as to the nature of the study and all signed informed consent. Approval for the study was granted by the Departmental Ethics Committee. All subjects were club cyclists and trained  $10.8 \pm 2.3$  hr $\cdot$ wk<sup>-1</sup>. A medical questionnaire, provided at the start of the study, determined that all were healthy and free from any disease.

### Maximal Oxygen Uptake ( $VO_{2max}$ )

Before all experimental testing, subjects undertook a graded exercise test to measure  $VO_{2max}$ . All testing took place on an SRM (Schoberer Rad Mebtechnik, Julich, Germany) cycle ergometer in an air-conditioned laboratory maintained at  $22 \pm 2^\circ\text{C}$ . All subjects had previously ridden the ergometer which was adjusted to their dimensions before testing. Subjects started at a workload of 50 W for the first minute and then increased workload by  $4 \cdot 10 \text{ s}^{-1}$  until, with encouragement, they reached volitional exhaustion. A respiratory exchange ratio (RER)  $> 1.15$  and a heart rate of  $\pm 10$  beats $\cdot$ min<sup>-1</sup> age predicted maximum heart rate was taken as maximal effort. Expired air was analyzed breath-by-breath using an automated open-circuit gas analysis system (Quark b<sup>2</sup>, Cosmed Srl, Rome, Italy). The gas analyzers were calibrated immediately before each test using ambient air (assumed to contain 20.94% oxygen and 0.03% carbon dioxide<sup>21</sup>), and certified alpha standard gases containing 16.0% oxygen and  $5.0 \pm 0.02\%$  carbon dioxide (Cryoservice Ltd, Worcester, UK). The turbine flowmeter used for the determination of minute ventilation has a resistance of  $<0.7$  cm H<sub>2</sub>O L $\cdot$ s<sup>-1</sup> at a flow rate of 12 L $\cdot$ s<sup>-1</sup>, an accuracy of  $\pm 2\%$ , and was calibrated with a 3-L syringe (Cosmed Srl, Rome, Italy) immediately before each test. Heart rate was continuously measured with a heart rate monitor, with the

receiver built into the Cosmed Quark b<sup>2</sup> metabolic cart. Heart rate and metabolic data were processed by the Cosmed data management software.

## Performance Testing

Participants reported to the temperature-controlled laboratory ( $21 \pm 2^\circ\text{C}$ ) for testing on the prescribed day between 1300 and 1800 each day but always at the same time. Relative humidity remained consistent throughout the trials ( $38 \pm 2\%$  RH). The cycling test consisted of a predetermined cycling course on a VeloTronPro cycle ergometer. This ergometer has been previously found to have a low between trial coefficient of variation and a highly reproducible performance in competitive cyclists.<sup>22</sup> The course was designed to ensure 60 minutes of continuous cycling at a 2% grade, with a number of hills (every 5k for a distance of 0.25k and 8% grade) to ensure maximal work. We based this profile on pilot testing with several trained cyclists and found that this profile best simulated actual road racing. Subjects were instructed to cover as much distance as possible within the hour, and there was financial reward offered for the furthest distance traveled over the course of the study. All testing took place in a randomized, double-blind manner.

After resting for 2 hours subjects undertook 1 of the 3 tests, the control (C), the placebo (P), or the caffeine (CAF) trial. In the CAF trial, each subject ingested  $6 \text{ mg}\cdot\text{kg}^{-1}$  body mass of caffeine given in low-kilojoule flavored drink, while in the P trial they consumed only the drink. This dose of caffeine is similar to that which has been used in previous research.<sup>1,4,8,22,24</sup> Tests were always completed with at least 48 hours but no more than 96 hours break.

Subjects were all nonsmokers, and were required to attend the laboratory 4 hours postprandial and 2 hours before testing. They were all asked to refrain from any caffeine consumption in the 24 hours before testing. They were also asked to ensure that their pre-race meal was the same on all occasions and this was verified via questioning. On arrival they were given  $2 \text{ g}\cdot\text{kg}^{-1}$  body mass of 100% glucose to consume with 1 L of water to standardize food intake which ensured adequate carbohydrate and fluid supply before exercise. After 60 minutes they ingested either CAF or P, then rested for a further 60 minutes before the test began. Following the end of all trials, the work done (km) was determined from the VeloTron performance software. As previously, heart rate was continuously measured with a heart rate monitor (Polar s810, Polar, Kempele, Finland).

## Blood Analysis

On arrival at the laboratory, after CAF or P ingestion, and at the end of the TT, finger-prick blood samples were collected and analyzed in duplicate, for lactate and glucose using a YSI 2700 Stat (Yellow Springs Instruments, Yellow Springs, USA). The coefficient of variation for the lactate and glucose samples was  $<2\%$ .

## Statistical Analysis

The blood lactate and glucose is reported as the mean of the 2 samples analyzed. The performance results of the three trials and the glucose, lactate, and heart rate

data were analyzed by a 2-factor ANOVA with repeated measures. The alpha level for statistical significance was set a priori at 0.05.

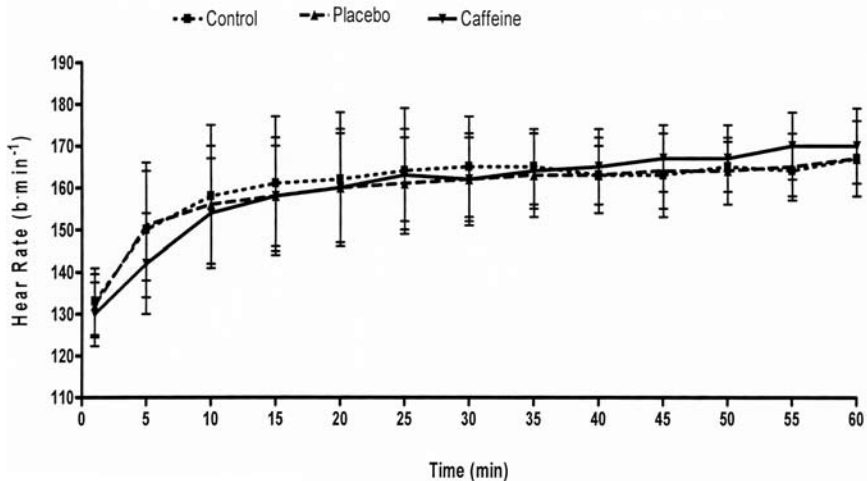
## Results

The cyclists in the 3 trials rode significantly further in the CAF trial ( $28.0 \pm 1.3$  km) than they did in the C ( $26.3 \pm 1.5$  km,  $P < .01$ ) or P ( $26.4 \pm 1.5$  km,  $P < .02$ ) trials. No significant differences were seen between C and P trials ( $P > .88$ ).

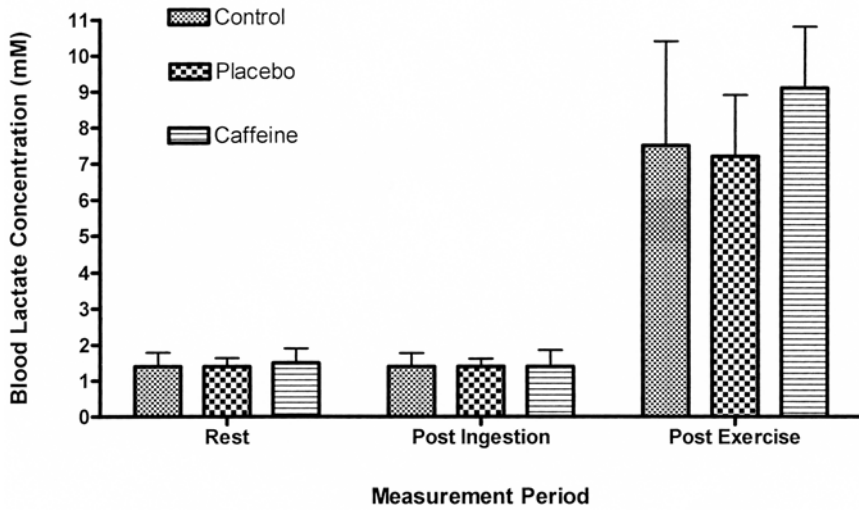
The heart rate data (Figure 1) between groups was not significantly different ( $P > .05$ ), but as expected, there was a significant increase in heart rate over the duration of the TT ( $P < .0001$ ).

The blood lactate data can be seen in Figure 2. The repeated measures ANOVA indicates that there were no significant interaction effects ( $P > .3$ ) or differences between the 3 groups in the response to the exercise test ( $P > .2$ ). However, as was expected there was a significant effect of time ( $P < .0001$ ), with the postexercise concentrations significantly higher than either the resting levels or postingestion levels ( $P < .005$ ).

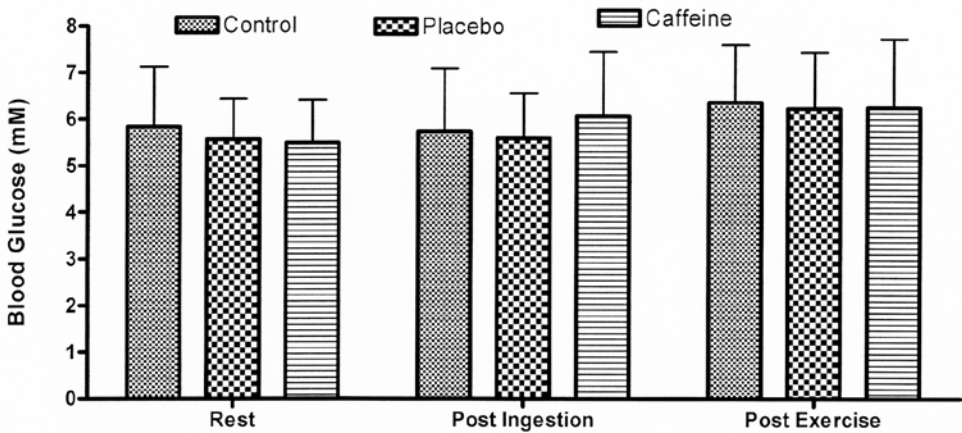
The analysis of blood glucose (see Figure 3) during the TT indicated that there was no significant interaction effects ( $P > .4$ ) and no significant time effect ( $P > .1$ ).



**Figure 1** — Heart rate data (mean  $\pm$  SD) during the course of the TT.



**Figure 2** — Blood lactate concentrations (mean  $\pm$  SD) during the course of the TT.



**Figure 3** — Blood glucose concentrations (mean  $\pm$  SD) during the course of the TT.

## Discussion

It is well known that where fatigue occurs within 30 to 60 minutes, caffeine can be of use as an ergogenic aid.<sup>7,25–27</sup> In an early study, researchers found that endurance performance was improved by 7.5 to 10 minutes compared with their other trials.<sup>2</sup> In a more recent study, Cox et al<sup>4</sup> found that caffeine improved cycling TT performance by 3.1 to 3.4%. This work supports the findings of this current study where we found improved TT performance of approximately 6% above that found in either the C or P trials. While most studies use a steady state exercise trial<sup>7,28,29</sup> and test capacity, our test differed to these in so much that it simulated more closely that of the real world and measured actual performance, with hill climbing as well as downhill sections. However, Kovacs, Stegen, and Brouns<sup>30</sup> also reported enhancement of TT cycling performance over 1 hour when caffeine was ingested with a carbohydrate supplement. Again, our work although somewhat different, with a number of hills and hence good ecological validity, is in agreement with these findings.

The research literature often reports an increase in blood lactate with caffeine following exercise,<sup>6,31</sup> which is surprising considering that increased fat mobilization is often considered to be the major reason for improved performance. Our results showed no differences between groups in blood lactate at the end of exercise, although there was a trend for the caffeine trial to have higher lactate concentrations (see Figure 2).

Some researchers have suggested that the ingestion of caffeine increases glucose levels<sup>4,6,27</sup> but according to Graham<sup>5</sup> in his review of the area, most studies show no difference.<sup>23,31,32</sup> Our work is in agreement with these studies.

In conclusion, and on the basis of the work conducted, we would suggest that caffeine can have an ergogenic effect during TT cycling when used in a dose of 6 mg·kg<sup>-1</sup> body weight and taken approximately 1 hour before exercise. Athletes should ensure that, before competition, caffeine has no deleterious side effects in such doses. At this time the mechanism for improved performance cannot be fully elucidated and more work needs to be undertaken in the study of this complex dimethylxanthine.

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