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Case study: dose response of caffeine on 20 km handcycling time trial performance in a Para-triathlete

Abstract

Caffeine's ability to influence upper-body exercise (UBE) endurance performance may be related to an individual's training status. This case study therefore aimed to investigate the ergogenic effects of caffeine dose on 20 km time trial (TT) performance of an elite male Para-triathlete (wheelchair user) (age 46 y, body mass 76.9 kg, body fat 25.4%, handcycling $\dot{V}O_{2\ peak}$ 3.45 l·min^{-1}). The athlete completed four 20 km handcycling TT's on a Cyclus II ergometer under laboratory controlled conditions following the ingestion of 2, 4 and 6 mg·kg^{-1} caffeine (CAF) or placebo (PLA). Blood lactate concentration [Bla], power output (PO), arousal and ratings of perceived exertion (RPE) were recorded. Ingestion of 2, 4 and 6 mg·kg^{-1} CAF resulted in TT times which were 2, 1.5 and 2.7% faster than PLA (37:40 min:sec). The participant's [Bla] increased throughout all trials and was greater during CAF compared to PLA. There were no obvious differences in RPE between trials despite different performance times. Baseline arousal scores differed between PLA and 4 mg·kg^{-1} ('1-low'), and 2 and 6 mg·kg^{-1} ('3-moderate'). Arousal increased at each time-point following the ingestion of 4 and 6 mg·kg^{-1}. The largest CAF dose resulted in a positive pacing strategy, which when combined with an end spurt resulted in the fastest TT. Caffeine improved 20 km TT performance of an elite male Para-triathlete, which may be related to greater arousal and an increased PO for a given RPE.

Background

Caffeine is used by athletes with a physical impairment (Graham-Paulson et al., 2015a) yet very few studies have been conducted using trained and elite athletes (Flueck et al., 2015; 2014), which is understandable given the practicalities involved. Evidence of caffeine's ergogenic effects during upper-body exercise (UBE) remain equivocal but suggests that caffeine may be more advantageous during short-term, explosive events (e.g. 20 m sprint, 3-min all out test) compared to endurance events (e.g. 30 min preloaded 10 min performance test, 10 km TT) (Black et al., 2015; Flueck et al., 2015; 2014; Graham-Paulson et al., 2015b; 2016b). Black et al. (2015) and Graham-Paulson et al. (2016b) reported improvements in leg cycling but not arm cranking/handcycling performance (10 min performance test and 10 km TT, respectively) following the ingestion of 4-5 $mg \cdot kg^{-1}$ caffeine and 30 min at 60-65% $\dot{V}O_{2\ peak}$. The participants' in these studies were recreationally active males with limited experience of UBE. However, in the latter study participants with a handcycling $\dot{V}O_{2\ peak}$ above and below the mean changed their handcycling 10 km time trial (TT) performance by 3.2% and -0.3%, respectively (Graham-Paulson et al., 2016b). This indicates there may be some influence of training status on caffeine's ability to influence performance. Collomp et al. (1992) suggested that the intra and/or extracellular adaptations resulting from specific training are necessary to benefit from caffeine. Well-trained/elite athletes are also likely to have greater motivation to perform maximal exercise (Burke, 2008). The current case study provided a unique opportunity to investigate the effects of caffeine in an elite Para-triathlete.

Presentation of the sporting issue

At the London 2012 Paralympic Games the medal winning times for handcycling and wheelchair racing were within a 0.3-0.6% time frame (Perret, 2015) and hence winning margins are small. Para-triathlon was a new sport at the Rio 2016 Games in which male wheelchair athletes competed in the PT1 category. The sport involves three separate

disciplines; 750 m swim, 20 km bike, and 5 km run. PT1 athletes complete the latter two disciplines in a recumbent handcycle and a racing wheelchair over a duration of ~1 h. Previous leg cycling research suggests that 3-6 $mg \cdot kg^{-1}$ caffeine is advantageous for 1 h TT events where ~6% improvement in performance has been reported (Kovacs et al., 1998 (3-4 $mg \cdot kg^{-1}$); McNaughton et al., 2008 (6 $mg \cdot kg^{-1}$)). However, there is currently limited evidence to support its use during UBE and by athletes with a physical impairment.

As part of the nutritional support package for a PT1 Para-triathlete, the authors explored the use of caffeine as a supplement. The handcycle section of a Para-triathlon comprises more than half the total time (~00:36 in a ~01:02 h:min performance) and hence this section was chosen as part of a laboratory controlled testing protocol. The aim of the current case study was therefore to investigate the effects of caffeine supplementation (2, 4 and 6 $mg \cdot kg^{-1}$) on 20 km handcycling TT performance.

Presentation of the athlete

One male Para-triathlete with paraplegia (T7, ASIA A) (age 46 y, body mass 76.9 kg, body fat 25.4%, handcycling $\dot{V}O_{2\ peak}$ 3.45 $l \cdot min^{-1}$ and habitual caffeine intake 160 $mg \cdot d^{-1}$) provided written informed consent to take part. All procedures were approved by the University's Ethical Advisory Committee.

As part of the athlete's sport science support the authors were provided with the results from a $\dot{V}O_{2\ peak}$ test (3 weeks prior to visit 1) and a dual energy x-ray absorptiometry (DXA) scan (Lunar iDXA, GE Healthcare, Buckinghamshire, UK) (during the study) to enable greater understanding of the athlete's training status. The athlete completes a 20 km handcycling TT in the laboratory every three months and consequently was familiar with the testing procedures and the rating of perceived exertion (RPE) scale (Borg, 1998). Hence no specific familiarization was deemed necessary as it would have impacted on the athlete's training programme. The participant was however familiarised with the Felt Arousal scale (a measure of perceived arousal) (Svebak & Murgatroyd, 1985) during visit 1.

Presentation of intervention

The athlete visited the laboratory on five separate occasions. Previous evidence has suggested that individuals with paraplegia can display variable appearance rates following caffeine consumption (Graham-Paulson et al., 2016a) and hence this was determined during visit 1. During visits 2-5 the athlete performed four 20 km handcycling TTs following the randomised consumption of placebo (PLA), 2, 4 or 6 $mg \cdot kg^{-1}$ caffeine (CAF). The athlete had previously used 4 $mg \cdot kg^{-1}$ caffeine with no adverse effects and a subjective improvement in performance but he was unsure whether it was the correct dose. The maximum dose was set at 6 $mg \cdot kg^{-1}$ as higher doses have been linked to side effects such as jitters, increased heart rate and impaired performance (Graham & Spriet, 1995). The visits followed a single-blind, placebo controlled, randomised, repeated measures design and were separated by at least five days. The TTs were conducted at the same time of day (10:15 am) to avoid any influence of circadian rhythm (Drust et al., 2005). The athlete performed each TT in their own handcycle to ensure the configuration and set-up matched that used in training and competition. This was standardised across visits. The handcycle was mounted on a Cyclus II ergometer (Avantronic Richter, Leipzig, Germany).

Visit 1

The athlete arrived at the laboratory 1.5 h post-ingestion of a self-selected meal (1891 kJ: 64% carbohydrate, 18% protein, 18% fat). Lying in a semi-supine position, a cannula (Venflon, Becton Dickinson, Helsinborg, Sweden) was inserted into an antecubital vein for subsequent venous sampling. The cannula was kept patent using 5-10 ml sodium chloride (0.9%) after each blood sample.

After a minimum of 15 min rest, a baseline venous blood sample (5 ml) was taken. The athlete then consumed 4 $mg \cdot kg^{-1}$ caffeine (MyProtein, Northwich, UK). The 4 $mg \cdot kg^{-1}$ caffeine dose was selected because it was the median experimental dose. Absolute caffeine concentration [CAF] may differ between doses but the data gathered provided an indication of the time-course of caffeine appearance as this is not affected to the same extent (Graham

& Spriet, 1995). The athlete remained rested for 120 min during which a further eight (5 ml) samples were collected (15, 30, 45, 60, 70, 80, 90 and 120 min). All blood sampling and analysis procedures to assess [CAF] were performed as described by Graham-Paulson et al. (2016a).

Visits 2-5

Prior to visiting the laboratory, the athlete maintained normal dietary and activity patterns. These were standardised across trials using a 24 h food (5319 kJ: 55% carbohydrate, 34% protein, 11% fat) and training log which was replicated prior to each visit. The same standardised meal as visit 1 was consumed 1.5 h prior to arrival at the laboratory. The athlete abstained from caffeine consumption in the 24 h preceding all visits.

The athlete consumed either 2, 4 or 6 $mg \cdot kg^{-1}$ CAF, or a dextrose PLA 45 min prior to the commencement of each TT. The timing recommendation was based on preliminary testing results. The athlete was instructed to complete the 20 km TT in the shortest time possible. Motivation was provided upon the completion of each kilometre and throughout the final 3 km. The only in-test feedback provided was cumulative distance covered. Blood glucose [GLU] and lactate [Bla] concentrations were determined using a Biosen C-Line (EKF Diagnostic GmbH, Barleben, Germany) via earlobe capillary blood samples. Heart rate (HR) was monitored continuously (Polar RS400, Polar, Kempele, Finland). The 6-20 differentiated RPE scale (Borg, 1998; Pandolf et al., 1984) was used and the athlete reported Felt Arousal scores. See Figure 1 for the testing protocol. Environmental conditions were mean(SD) temperature 19.4(0.6)°C and humidity 51(5)%.

Outcome of the intervention

The participant's [CAF] peaked 45 min post-ingestion (43.2 µM) followed by a gradual decline (Figure 2). Ingestion of 2, 4 and 6 $mg \cdot kg^{-1}$ resulted in 20 km TT performance times of 36:56, 37:06 and 36:39 min:sec, which were 2, 1.5 and 2.7% faster than PLA (37:40 min:sec). Importantly, the percentage improvements are greater than those that have previously separated athletes at the Paralympic Games (0.3-0.6%) (Perret, 2015). Figure 3a

indicates distinctly different pacing strategies employed following the ingestion of 2 and 6 mg·kg^{-1} (two fastest TTs). Following 2 mg·kg^{-1} the athlete produced a steady power output (PO) throughout the TT followed by an end spurt. Whereas, the ingestion of 6 mg·kg^{-1} resulted in a higher initial PO, a gradual decline and a similar end spurt. This may be linked to the athlete's high pre-TT arousal score following 6 mg·kg^{-1} and because this continued to increase throughout the TT (Figure 4). This positive pacing strategy must be considered in relation to the para-triathlon event as a whole but previous research suggests that such a strategy (decreasing from 92 to 73% maximal 750 m swim TT time) earlier during the swim section is not detrimental to performance compared to both even and negative pacing (Wu et al., 2016). Different baseline arousal responses, which can be influenced by a wide range of external factors, may explain the lack of a dose response to caffeine.

The athlete's RPE responses were similar across trials (Table 1) but given the improved TT times this indicates an increased PO for a given RPE, which has been reported previously (Astorino et al., 2012). Subjectively the athlete reported feeling more 'focused', with an improved ability to 'refocus' following the consumption of 2 and 6 mg·kg^{-1}. The athlete was not accurate in predicting which dose had been consumed.

The athlete reported symptoms of spasticity following 2 and 4 mg·kg^{-1} but he did not believe this affected his performance. Such symptoms were reported by Graham-Paulson et al. (2015b) and anecdotally by athletes with a spinal cord injury (SCI). The triathlete has a complete SCI which interrupts all signals coming from or going to higher levels of the nervous system, but spinal reflexes can be preserved below the lesion level if spinal nerves remain undamaged (Jacobs & Nash, 2004). Therefore, a sensory stimulus, such as pain in this instance may have led to the muscle spasms. The athlete has experienced similar episodes during normal training sessions and it is apparent that these are linked to periods of maximal effort such as during a TT.

The participant's [Bla] increased throughout each TT but was greater at 10, 15 and 20 km following the ingestion of 6 mg·kg^{-1} (Figure 3b). This has been reported previously in the literature (Bell & McLellan, 2002; Graham-Paulson et al., 2016b) and is understandable

given this trial resulted in the fastest TT. There was no change in [GLU] during any trial (Figure 3c). The athlete's mean TT HR was slightly increased during CAF (169, 168 and 172 beats·min^{-1} following 2, 4 and 6 mg·kg^{-1}) compared to PLA (163 beats·min^{-1}) but this was eliminated post-TT (180, 174 and 181 beats·min^{-1} following 2, 4 and 6 mg·kg^{-1}) compared to PLA (180 beats·min^{-1}).

The current triathlete's DXA results (25.4%) are similar to those reported for British male wheelchair athletes (25.0%; (Goosey-Tolfrey et al., 2016). His 20 km TT time (~36-37 min) was relatively faster than those reported by trained handcyclists with a SCI (T2-8) over 22 km (~45 min) (Fischer et al., 2015). In conjunction with a $\dot{V}O_{2\ peak}$ of 3.45 l·min^{-1} this reinforces his highly trained status. Graham-Paulson et al. (2016b) suggested that an individual's training status may be linked to caffeine's ability to impact performance. The current case study supports this notion and may be related to changes in muscle fibre type (type I appear to be more sensitive to caffeine (Mitsumoto et al., 1990)) and oxidative capacity as a consequence of the daily endurance training this Para-triathlete completes (Schantz et al., 1997). It may also be as simple as the athlete's ability to motivate themselves during maximal exercise to benefit from the ergogenic effect of caffeine (Burke, 2008). The mechanism of action has not been investigated in this case study but at physiological concentrations such as these it is likely the same as during lower/whole-body exercise and hence related to adenosine receptor antagonism (Graham 2001).

Reflections

The positive impact of this case study was threefold: i) it allowed the athlete to feel valued as a member of the Para-triathlon team while the ambulant members performed winter training in a velodrome, ii) it provided athlete-specific evidence for the use of caffeine as an ergogenic aid, and iii) it increased contact time between the athlete and nutritionist thereby improving their working relationship. Following the case study results and discussions with his coach, the triathlete practiced using 4 mg·kg^{-1} caffeine 45 min prior to select prolonged training sessions to ensure no side-effects were experienced.

Unfortunately, a Para-triathlon race (swim, bike and run) does not lend itself to controlled laboratory testing however, the successful use of caffeine during the case study, prior to select training sessions and race simulations gave both the nutritionist and the athlete confidence in the supplement. For this reason the athlete now includes caffeine in his pre-race strategy. Having taken the athlete's warm-up time into account the athlete now consumes caffeine 20-30 min prior to the race/swim start time. Anecdotally the athlete has reported feeling more focused during races, even when things have not gone to plan e.g. transition errors not under his control. He continues using caffeine in capsule form prior to racing and plans to trial a caffeinated isotonic sports drink to help tailor his plan further.

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274 **Figure legends**
275
276 **Figure 1.** Schematic of the 20 km time trial protocol. PLA=placebo, RPE=rating of perceived
277 exertion, TT=time trial.

278 **Figure 2.** Plasma caffeine concentration following the ingestion of 4 $mg \cdot kg^{-1}$ caffeine.

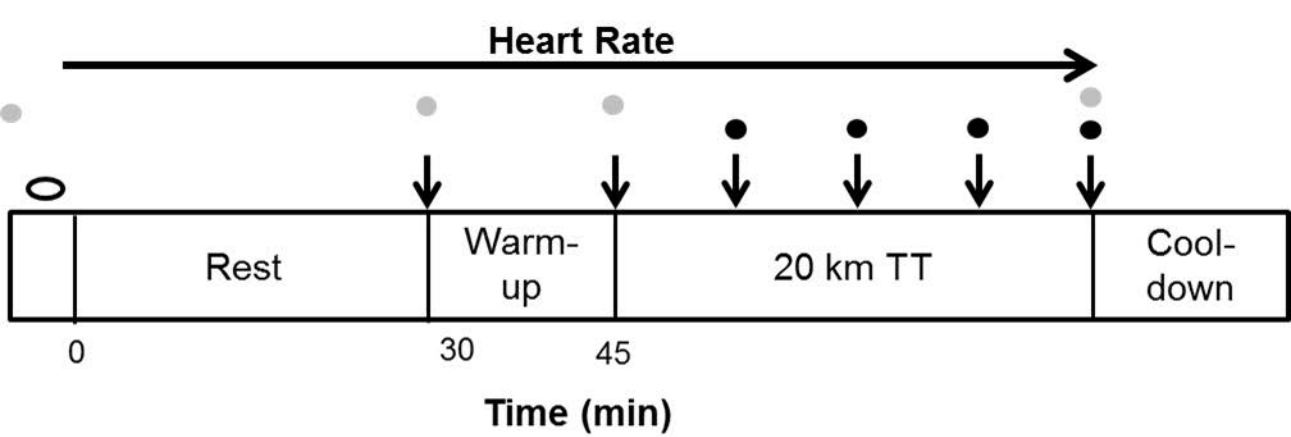
279 **Figure 3.** (a) Average power output, (b) blood lactate and (c) glucose concentrations during
280 the 20 km time trial following the consumption of placebo (PLA), 2, 4 and 6 $mg \cdot kg^{-1}$ caffeine.

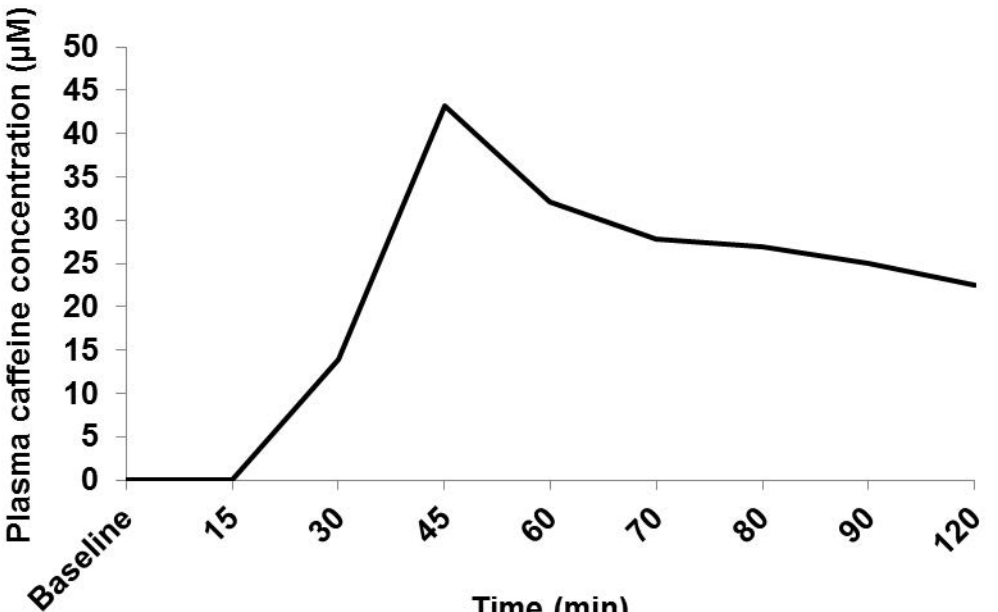
281 **Figure 4.** Felt arousal responses following the consumption of placebo (PLA), 2, 4 and 6
282 $mg \cdot kg^{-1}$ caffeine. TT=time trial.

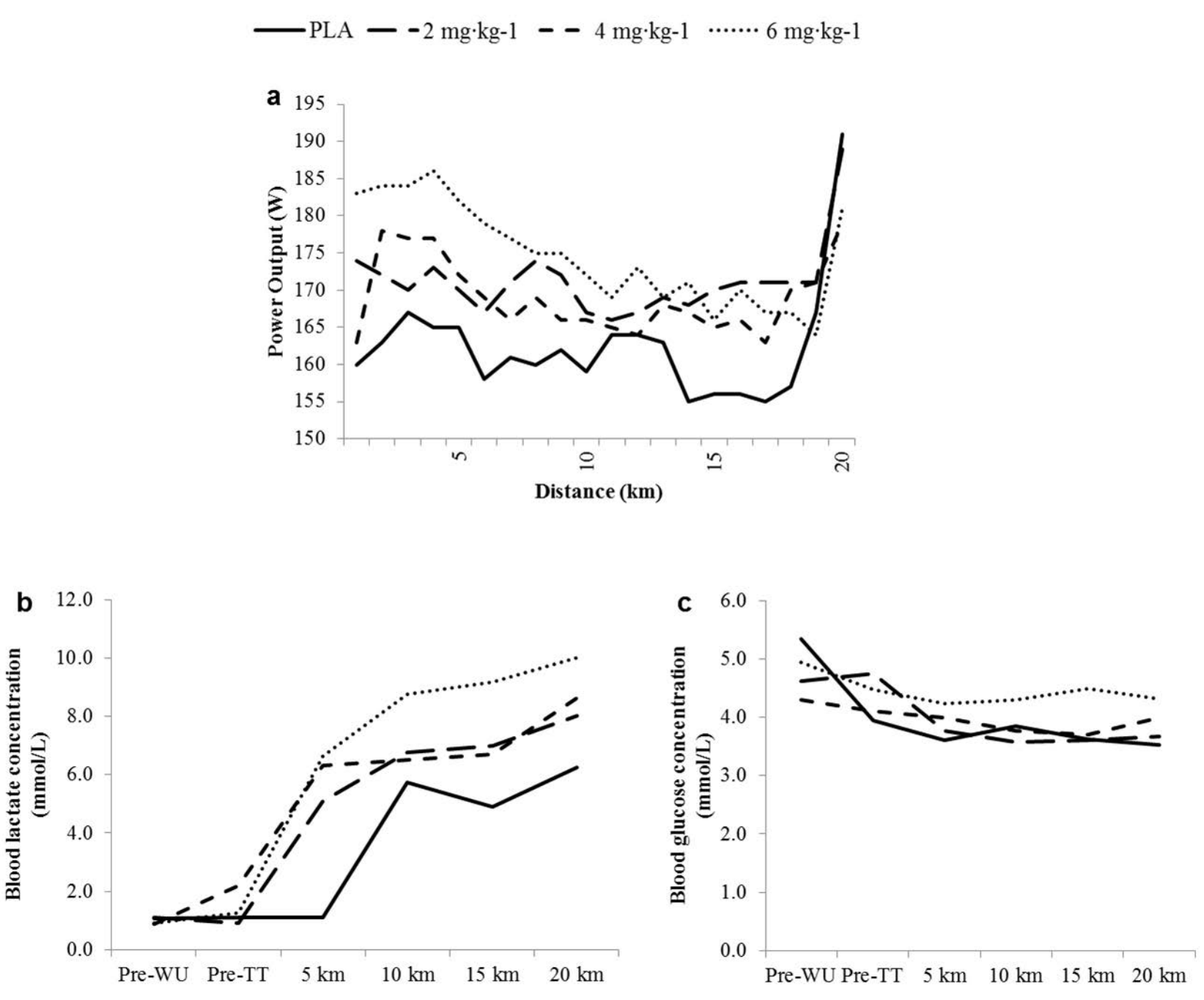
283 **Table 1.** Differentiated (local, central and overall) ratings of perceived exertion (RPE) during the 20
284 km time trial (TT) following the consumption of placebo (PLA), 2, 4 and 6 mg·kg^{-1} caffeine.

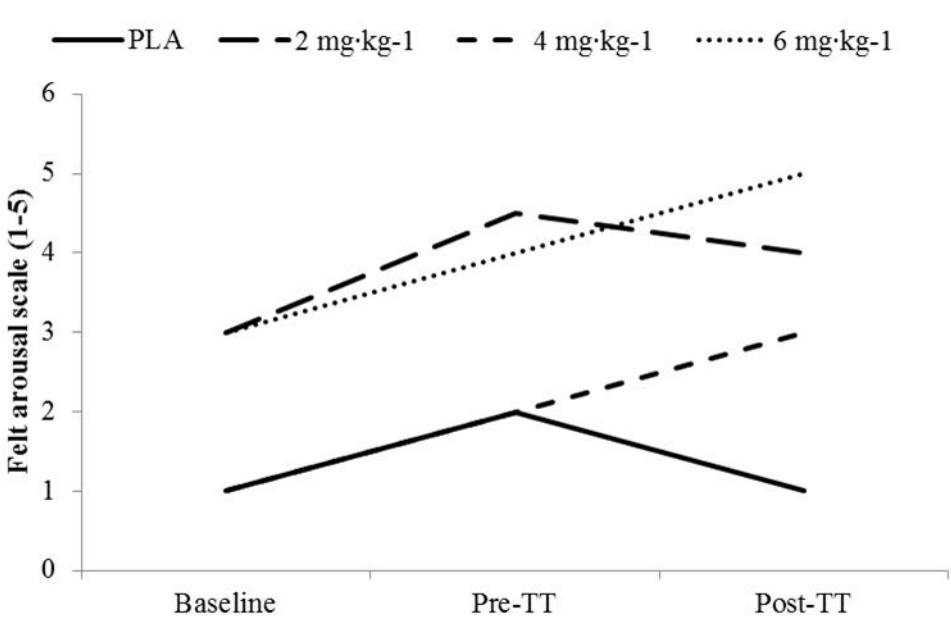
		5 km	10 km	15 km	Post-TT
Overall RPE	PLA	15	16	16	20
	2 mg·kg^{-1}	15	15	15	19
	4 mg·kg^{-1}	15	17	17	19
	6 mg·kg^{-1}	15	16	17	20
Central RPE	PLA	16	16	16	19
	2 mg·kg^{-1}	16	14	15	19
	4 mg·kg^{-1}	16	17	16	19
	6 mg·kg^{-1}	16	17	16	20
Peripheral RPE	PLA	15	16	17	20
	2 mg·kg^{-1}	16	15	17	20
	4 mg·kg^{-1}	16	16	17	19
	6 mg·kg^{-1}	16	16	17	20

285


Heart Rate
Rest
Warm-up
20 km TT
Cool-down
0
30
45
Time (min)
Capsule = PLA, 2, 4 or 6 mg·kg-1 caffeine
Capillary blood sample
RPE
Felt arousal scale (1-5)


Plasma caffeine concentration (µM)
50
45
40
35
30
25
20
15
10
5
0
Baseline
15
30
45
60
70
80
90
120
Time (min)


PLA
2 mg·kg-1
4 mg·kg-1
6 mg·kg-1
a
Power Output (W)
195
190
185
180
175
170
165
160
155
150
5
10
15
20
Distance (km)
b
Blood lactate concentration (mmol/L)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Pre-WU
Pre-TT
5 km
10 km
15 km
20 km
c
Blood glucose concentration (mmol/L)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Pre-WU
Pre-TT
5 km
10 km
15 km
20 km


PLA
2 mg·kg-1
4 mg·kg-1
6 mg·kg-1
Felt arousal scale (1-5)
0
1
2
3
4
5
6
Baseline
Pre-TT
Post-TT