Caffeine

Pubmed (Medline) and SPORTDiscus were searched for all human studies published in peer reviewed journals in the last 9 years. The terms searched were “caffeine AND exercise” and “caffeine AND sport”. Sixteen articles were retrieved and reference lists searched for any additional papers that were relevant to the development of this document and the history of caffeine in sport, especially regarding landmark papers involving the use of caffeine in sport prior to 2004. The background information in this document regarding the use of caffeine in sport was obtained from review papers.

Inclusion criteria
- Human studies published in English
- Healthy subjects
- Original investigations assessing the use of caffeine and exercise
- Incorporated the use of an indistinguishable placebo

Exclusion Criteria
- Studies assessing caffeine in combination with another supplement i.e. creatine
- Qualitative studies assessing supplement use in both the general and athletic population

Introduction

Caffeine is a stimulant that is consumed by a vast majority of the adult population (Burke et al. 2008, McNaughton et al. 2008). It can be found in many foods such as tea, coffee, cola, energy drinks and chocolate, in a wide range of sports drinks, gels and powders, or purchased over the counter as tablets or capsules.

Caffeine as a supplement has wide ranging physiological effects on the body, which may or may not enhance performance. However there is extensive evidence that its is effective in enhancing sports performance in trained athletes when used in moderate doses. (Goldstein 2010)

On January first 2004, caffeine was removed from the World Anti-Doping Agency’s (WADA) prohibited list. This means athletes can consume caffeine as part of their usual diet and during competition for performance benefits without breaching WADA regulations. Caffeine use is monitored by WADA, but athletes are free to use it without any limit or sanction (Woolf et al. 2008, Australian Institute of Sport, 2009).

Caffeine acts on the central nervous system to reduce fatigue and increase alertness (McNaughton et al. 2008, Hogervorst et al. 2008, Tarnopolsky 2008). It is thought that the potential performance-enhancing effects of caffeine are due to a combined effect on the central and peripheral systems. It is possible that caffeine acts on the central nervous system and may also have an effect on substrate metabolism and neuromuscular function (Goldstein et al. 2010). A review by Tarnopolsky (2008) discusses the mechanisms by which caffeine could exert its ergogenic effects. Caffeine may therefore have an important role in all types of exercise in which concentration, reaction time, and technical/tactical skills have a major influence on both physical and mental performance.

Many scientific articles have reviewed the hundreds of studies assessing the ergogenic effects of caffeine. The most recent being the position statement of caffeine usage by Goldstein et al. 2010, and two systematic review by Glade et al. (2010) and Burke (2008). Table 1 summaries some of the key studies published since the publication of Burke. For a comprehensive review of studies across all sports prior to and including June 2008 see Burke (2008).

**Proposed benefits of caffeine consumption among athletes**

Caffeine has been subjected to hundreds of studies with summaries of performance benefits identified in Burke (2008), Ganio et al. (2009) and Glade et al 2010 and Goldstein et al (2010). In summary, caffeine has been demonstrated to have the following benefits:

- It has ergogenic effects in prolonged and acute exercise performance
• It attenuated fatigue during repeated high intensity sprints in competitive cyclists (Paton 2010)
• It can prolong time to fatigue and reduce the overall time to complete a fixed task when consumed before and during endurance exercise (Cox et al. 2002, McNaughton et al. 2008, Jenkins et al. 2008)
• It can reduce an athlete’s perceived exertion or pain experienced during exercise (Ahrens et al. 2007, Gliottoni et al. 2008, Gliottoni et al. 2009)
• It can improve mood states, simple reaction time and muscle power and vigour in martial arts and resistance exercise. (Souissi et al. 2011, Duncan et al 2011)
• It enhances cognitive ability (Hogervorst et al. 2008)
• It may increase the force of a muscle contraction when consumed before and during exercise (Woolf et al. 2008, Duncan et al. 2009)
• It can promote wakefulness, which may be of benefit in multi-day ultra endurance events due to its effect on the central nervous system (Tarnopolsky 2008).
• It can attenuate the reduction in skills associated with sleep deprivation (Cook et al 2011).
**Recommended dosage**

Based on current literature, caffeine ingestion of 2–3 mg kg$^{-1}$ approximately 60 minutes before exercise may enhance performance. There does not seem to be a performance advantage of consuming more than 3-6 mg.kg. (Cook et. Al 2011, Desbrow et al. 2011). For athletes contesting endurance events, caffeine intake can be timed closer to the start of competition or throughout the event itself (Burke et al. 2008, Australian Institute of Sport, 2009). Caffeine ingestion should be from a source in which caffeine content is identifiable and consistent, with the anhydrous form of caffeine being the most effective, such as gels, capsules, tablets and gum (Goldstein 2010). Caffeine must be ingested, as mouthrinse have been show to be ineffective in improving performance (Doering et al 2013). As the caffeine content varies significantly in items such as tea and coffee, these sources should not be used as a reliable source of caffeine.

**Concerns with caffeine use**

Caffeine can increase heart rate and alter fine motor control, which may negatively affect sports that involve precise movements and techniques. Caffeine can cause over-arousal, which may negatively affect race preparation, recovery and sleep (Burke et al. 2008, Ganio et al. 2009).

Different athletes respond to caffeine ingestion in different ways. Some athletes may experience a benefit from caffeine consumption, others may not. Research is still emerging regarding the interactions between caffeine and other supplements, for example creatine (Hoffman et al. 2008). It is possible a negative performance outcome may arise from the combination of different supplements.
<table>
<thead>
<tr>
<th>Reference</th>
<th>Subjects</th>
<th>Caffeine Dosage</th>
<th>Sport / Exercise Protocol</th>
<th>Enhanced Performance</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duncan et al. 2013</td>
<td>11 resistance trained athletes (9 men and 2 women)</td>
<td>Caffeine 5mg.kg BW or placebo, 60 min prior to test</td>
<td>Resistance exercise test to failure at 60% 1 repetition maximum</td>
<td>Yes</td>
<td>Participants completed significantly greater repetitions to failure, irrespective of exercise, in the presence of caffeine. Acute caffeine ingestion enhances resistance exercise performance to failure and reduces perception of exertion and muscle pain.</td>
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<td>Pitchford et al. 2013</td>
<td>9 well trained male cyclists</td>
<td>Caffeine (3mg.kg-1 BW) or placebo 90min prior to test, in a double blind, crossover study</td>
<td>simulated cycling time-trials in environmental conditions of 35°C and 25% RH.</td>
<td>Yes</td>
<td>Caffeine supplementation at 3mg.kg-1 BW resulted in a worthwhile improvement in cycling time-trial performance in the heat.</td>
</tr>
<tr>
<td>Doering et al. 2013</td>
<td>10 well trained male cyclists</td>
<td>Mouthrinse of 35mg held for 10 seconds in buccal cavity on 8 occasions during time trial.</td>
<td>Time trial – 75% peak aerobic power for 60 mins</td>
<td>No</td>
<td>Eight exposures of a 35mg dose of caffeine in the buccal cavity for 10 seconds does not significantly enhance endurance cycling time-trial performance, nor does it elevate plasma caffeine</td>
</tr>
<tr>
<td>Study</td>
<td>Participants</td>
<td>Conditions</td>
<td>Interventions</td>
<td>Results</td>
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<tr>
<td>Duncan et al. 2011</td>
<td>13 moderately trained men</td>
<td>5mg.kg caffeine or placebo 60 minutes prior to trial</td>
<td>Bench press exercise to failure and the mood state response pre to post exercise.</td>
<td>Participants completed significantly more repetitions to failure and lifted significantly greater weight in the caffeine condition compared to the placebo condition. Mood state scores for vigor were greater (p = 0.001) and fatigue scores lower (p = 0.04) in the presence of caffeine.</td>
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<tr>
<td>Souissi et al. 2012</td>
<td>12 elite judoists</td>
<td>5mg.kg caffeine or placebo</td>
<td>Mood states, simple reaction time, and muscle power during the Wingate test were measured during two test sessions at 07:00 h and after placebo or caffeine ingestion</td>
<td>Results revealed an increase of the anxiety and the vigor, a reduction of the simple reaction time and an improvement of the peak and mean powers during the Wingate test in the caffeine condition compared to the placebo condition. The fatigue index during this test was unaffected by the caffeine ingestion.</td>
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<tr>
<td>Desbrow 2011</td>
<td>16 well trained cyclists</td>
<td>Placebo, 3mg.kg or 6mg.kg 90</td>
<td>Three time trials in randomised order under</td>
<td>Exercise performance was significantly improved with both caffeine treatments as</td>
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January 2014
minutes prior to exercise | double blind conditions. Time trials represented a set amount of work equivalent to 75% of peak sustainable power output for 60 mins. | compared to placebo. A caffeine dose of 3 mg.kg body mass appears to improve cycling performance in well-trained and familiarized athletes. A dose of 6 mg.kg body mass does not confer any additional improvements in performance.

Cook et al. 2011 | 10 elite male rugby players | 1 or 5 mg.kg caffeine or placebo | Rugby passing skill test following either 7-9hrs sleep or 3-5 hrs. sleep | Yes | Sleep deprivation with placebo application resulted in a significant fall in skill performance accuracy on both the dominant and non-dominant passing sides. No fall in skill performance was seen with caffeine doses of 1 or 5 mg/kg, and the two doses were not significantly different in effect.

Paton et al. 2010 | 9 male competitive cyclists | 240mg caffeine gum acutely ingested | 4 sets of 30s sprints, 5 sprints per set | Yes | Acute ingestion of caffeine via gum attenuated fatigue during repeated high intensity sprints in competitive cyclists.

Gliottoni et al. 2009 | 24 college aged males who were either low Caffeine consumers | 5 mg·kg⁻¹ of caffeine or placebo 1 hour prior to | 30 min of cycle ergometry at 75–77% of peak oxygen | Yes | Caffeine was associated with a reduction in muscle pain in both habitual users and nonusers of caffeine.
<table>
<thead>
<tr>
<th>Study</th>
<th>Participants</th>
<th>Intake</th>
<th>Protocol</th>
<th>Outcome</th>
<th>Comments</th>
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</thead>
<tbody>
<tr>
<td>Duncan et al. 2009</td>
<td>12 males with resistance training experience</td>
<td>3 mg kg(^{-1}) caffeine or placebo 1 hour prior to exercise</td>
<td>Unilateral leg extensions to failure at 60% of pre-determined 1-RM</td>
<td>Yes</td>
<td>Though Caffeine ingestion enhanced performance, those subjects consuming a placebo who believed they were consuming caffeine also increased the number of reps to failure.</td>
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<tr>
<td>Ivy et al. 2009</td>
<td>6 male and 6 female trained cyclists</td>
<td>500 ml of either flavoured placebo or Red Bull Energy Drink (160 mg caffeine) 40 min before exercise</td>
<td>Simulated cycling time trial</td>
<td>Yes</td>
<td>Consuming an energy drink can improve cycling time trial performance, but does not decrease RPE. As Red Bull contains carbohydrate and other vitamins and minerals, this increased performance may not be due to caffeine alone.</td>
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<tr>
<td>Share et al. 2009</td>
<td>7 elite male clay target shooters</td>
<td>2 mg kg(^{-1}) caffeine or 4 mg kg(^{-1}) caffeine or placebo</td>
<td>3 trials 4 rounds per trial of 50 targets per round</td>
<td>No</td>
<td>Caffeine ingestion of ≤4 mg kg(^{-1}) does not enhance clay target shooting in elite shooters.</td>
</tr>
<tr>
<td>Carr et al. 2008</td>
<td>10 team sport players</td>
<td>6 mg kg(^{-1}) caffeine or placebo</td>
<td>Repeated sprint running</td>
<td>Yes</td>
<td>Caffeine enhanced repeated sprint performance and was</td>
</tr>
<tr>
<td>Authors</td>
<td>Participants</td>
<td>Intervention</td>
<td>Outcome Measures</td>
<td>Results</td>
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<tr>
<td>McNaughton et al. 2008</td>
<td>8 healthy males</td>
<td>placebo 60 min before exercise</td>
<td>performance (5 sets of 6 x 20m)</td>
<td>not detrimental to reaction times.</td>
<td></td>
</tr>
<tr>
<td>Beck et al. 2008</td>
<td>31 untrained to moderately trained males</td>
<td>6 mg·kg(^{-1}) caffeine or placebo 60 min before exercise</td>
<td>3 x 1 hour cycling time trial performances</td>
<td>Performance was improved, potentially through increased free fatty acid metabolism</td>
<td></td>
</tr>
<tr>
<td>Woolf et al. 2008</td>
<td>18 male athletes</td>
<td>5 mg·kg(^{-1}) caffeine or placebo 60 min before exercise</td>
<td>Leg press, chest press and 30-sec Wingate test.</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>
References


Cook Christian J, Crewther Blair T, Kilduff Liam P, Drawer Scott, Gaviglio Chris M. Skill execution and sleep deprivation: effects of acute caffeine or creatine supplementation – a randomized placebo-controlled trial. Journal of the International Society of Sports Nutrition 2011, 8:2


January 2014


