Caffeine and exercise: a systematic review on performance and physiological mechanisms of action

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Abstract

Background: Caffeine (1,3,7-trimethylxanthine) is the most widely used psychoactive drug in the world, with the average Canadian consuming approximately 210-238 mg/d. At average consumption levels, caffeine's main mechanism of action is through the inhibition of adenosine receptors, namely A_1R and $A_{2A}R$. Through the inhibition of $A_{2A}R$, caffeine reduces Ca^{2+} release, reducing pain and discomfort. As well, upon consumption, caffeine reduces levels of prostaglandin, an inflammatory mediator associated with pain. The reported reduction in RPE during exercise, through these mechanisms, may explain the ergogenic effects of caffeine in resistance and aerobic exercise.
Methods: Pubmed and Google Scholar were searched through to March 7, 2016 using the search terms "Caffeine AND aerobic exercise" and "Caffeine AND resistance exercise".
Results: The effects of caffeine on resistance exercise are equivocal, however studies suggest that it is through the rating of perceived exertion (RPE) and fatigue-reducing mechanisms that caffeine consumption leads to better performance. In aerobic exercise, caffeine improves peak and mean power output and reduces the time-to-trial in trained, but not necessarily in untrained subjects.
Conclusions: Caffeine may be used as an ergogenic aid during aerobic and resistance exercise at low and medium doses, respectively. Future research needs to investigate the effect of caffeine on resistance exercise with consistent methodology, in order to reach a consensus.

Introduction

- Caffeine stimulates the central nervous system through competitive inhibition of the adenosine A_1 and A_{2A} receptors (1).
- Caffeine dosage can be categorized into low (1-3 mg/kg), medium (4-6 mg/kg) and high (>6 mg/kg) (2).

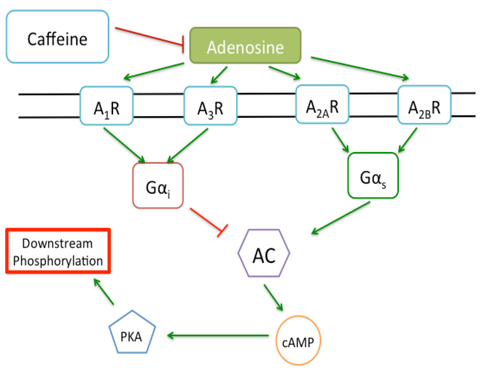

Figure 1. Caffeine's main mechanism of increasing exercise performance is through antagonizing the adenosine A_1 and A_{2A} receptors. PKA activation is associated with decreased pain (3).

Research Question

At what dose and through which mechanism does caffeine affect performance during aerobic and resistance exercise?

Caffeine and Aerobic Exercise

- Caffeine increases performance in aerobic exercise, with the greatest ergogenic effect at low doses.

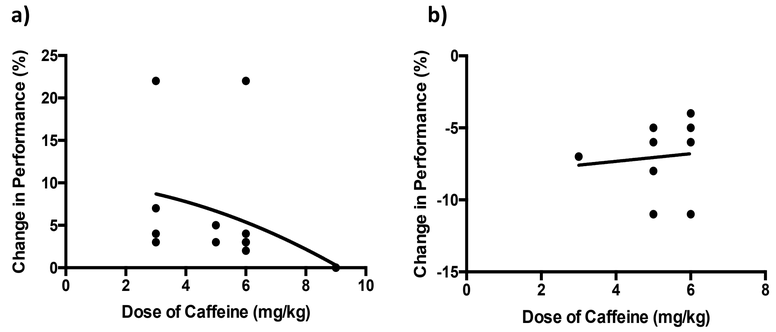

Figure 2. Different dosages of caffeine on a) overall aerobic performance and b) rating of perceived exertion (4-18).

Caffeine and Resistance Exercise

- Caffeine has no effect on 1-RM.
- Caffeine is most ergogenic at a medium dosage during number of repetitions to failure exercises

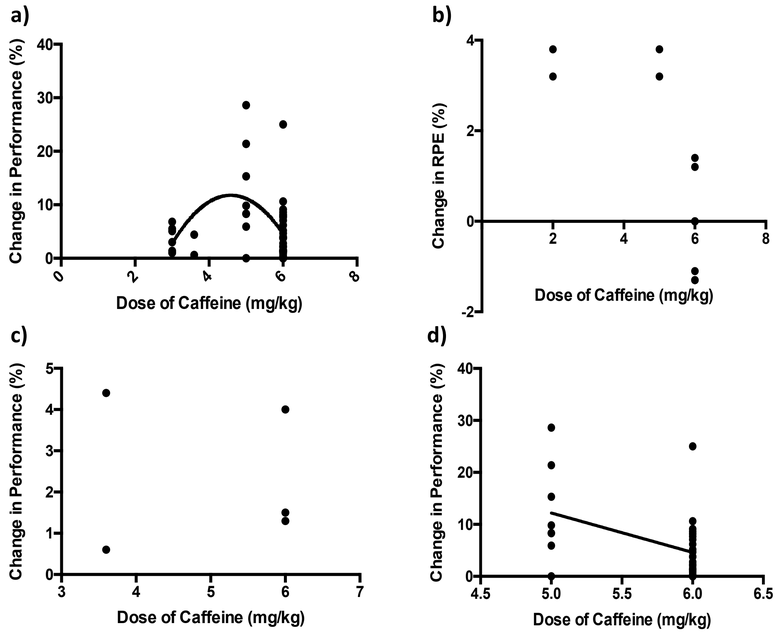

Figure 3. Different dosages of caffeine on a) overall resistance performance, b) rating of perceived exertion, c) 1-rep maximum performance, and d) number of repetitions to failure (19-29).

Caffeine Tolerance

- Body compensates for adenosine's inhibition by increasing amount of A_1-adenosine receptors (30).
- Higher amounts of caffeine are required to achieve the same ergogenic effect.

Mechanisms of Action

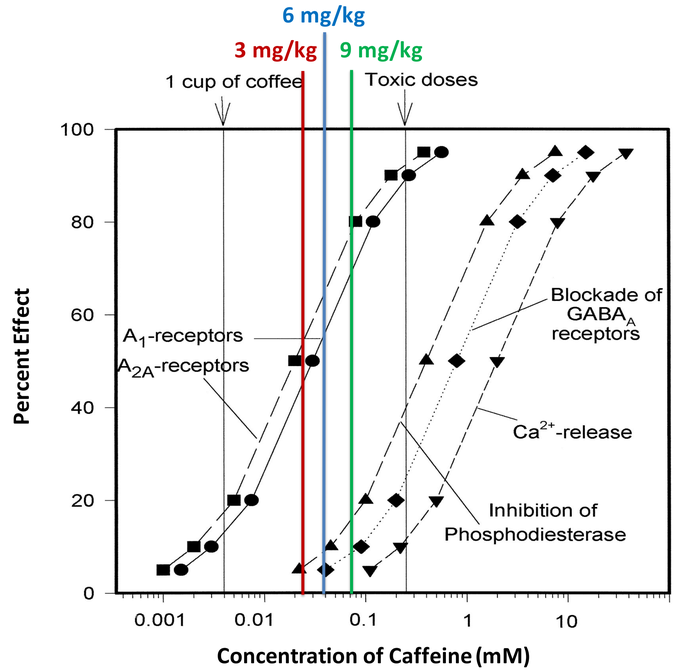

Figure 4. Caffeine's main mechanisms of action at different concentrations and doses (31).

Discussion

- At low doses, caffeine significantly increases performance during aerobic exercise. At medium doses, caffeine improves number of repetitions to failure. These ergogenic effects are due to RPE-reducing mechanisms (32,33).
- Caffeine has no effect on 1-repetition maximum performance.
- Continuous intake of caffeine leads to tolerance.

References

1. Dias et al, Trends Neurosci 2013
2. Cappelletti et al, Curr Neuropharmacol 2015
3. Kolahdouzan and Hamadeh, CNS Neurosci Ther 2017
4. Miller et al, Eur J Appl Physiol 2014
5. Acker-Hewitt et al, Appl Physiol Nutr Metab 2012
6. Kovacs et al, J Appl Physiol 1998
7. Lane et al, Med Sci Sports Exerc 2013
8. Wiles et al, J Sports Sci 2006
9. Pitchford et al, J Sports Sci Med 2013
10. Irwin et al, J Sports Sci 2011
11. Stadheim et al, Med Sci Sports Exerc 2013
12. Hendrix et al, J Strength Cond Res 2010
13. Womack et al, J Int Soc Sports Nutr 2012
14. McLellan et al, Aviat Space Environ Med 2004
15. Hodgson et al, PLOS ONE 2014
16. Pataky et al, Scand J Med Sci Sports 2015
17. Noragerer et al, J Appl Physiol 2005
18. Graham and Spriet, J Appl Physiol 1995
19. Trexler et al, Eur J Sport Sci 2015
20. Green et al, Int J Sports Physiol Perform 2007
21. Goldstein et al, J Int Soc Sports Nutr 2010
22. Astorino et al, Eur J Appl Physiol 2008
23. Duncan and Oxford, J Strength Cond Res 2011
24. Richardson and Clarke, J Strength Cond Res 2016
25. Duncan et al, Muscle Nerve 2013
26. Astorino et al, J Strength Cond Res 2011
27. Mora-Rodriguez et al, J Sci Med Sport 2015
28. Duncan et al, Muscle Nerve 2014
29. Mora-Rodriguez et al, PLOS ONE 2012
30. Chou et al, Life Sci 1985
31. Fredholm et al, Pharmacol Rev 1999
32. Sawynok J, Neuroscience 2016
33. Kamp and Hell, Circ Res 2000