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Review

Caffeine: benefits and drawbacks for technical performance

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Abstract

Surgical and minimally-invasive procedures, including cardiac and radiological, have high-stake patient outcomes. Working pressures, altering shift rotas, and ever-increasing demands have led to worsening sleep patterns for surgeons and allied professionals. Sleep deprivation alone has harmful consequences in relation to clinical outcomes and the physical and mental health of the surgeon, and to offset fatigue, some surgeons use legal stimulants such as caffeine and energy drinks. This stimulant use, however, may come at the cost of negative effects on cognitive and physical function. We aimed to explore evidence behind the use of caffeine, and its consequences on technical performance and clinical outcomes.

Keywords: Human factors; Wellbeing; Performance; Patient care; Caffeine

Introduction

Sleep deprivation and sleep cycle disturbances are widespread issues within the healthcare system.[1] Sleep deprivation has been shown to have adverse effects on cognitive performance, attention, and psychomotor vigilance.[2,3] Haluza et al showed that following two consecutive 12-hour night shifts, clinical staff would need at least three days off work to avoid prolonged fatigue.[2] However, with service demands and problems with understaffing this is difficult to achieve. Some surgeons regularly use stimulants such as caffeine and "energy drinks" to offset fatigue and the concentration problems caused by poor or inadequate sleep.

Commercial stimulants play a significant role in the workplace, with coffee being one of the most commonly consumed beverages worldwide (Fig. 1).[4] Caffeine's function as a psychostimulant has been recognised in The Queensland Health Fatigue Management Strategy, which states that the use of 400 mg caffeine induces wakefulness.[5] Caffeine, however, does not only affect the state of wakefulness, but can also influence psychomotor performance. High doses can impair dexterity, whereas moderate doses can reduce the time taken to complete motor tasks,[6,7] and it is difficult to achieve the balance of caffeine intake that works entirely in one's favour without experiencing unwanted side effects. Some surgeons individually consume varying quantities of caffeine to combat inadequate sleep and fatigue, and there is little uniformity in their intake levels. Besides, caffeine, most commonly in the form of coffee and tea, is undoubtedly enjoyed independent of any stimulant effect.

There is ubiquitous use of caffeine by European health professionals, with 84% purchasing a daily coffee.[8] Some surgeons (orthopaedic and general surgeons) have been shown to consume greater amounts of coffee when compared with other specialists.[8] Significant evidence exists on the effects of coffee on wakefulness in other workers, such as truck-drivers, and studies have shown that after coffee, night-time performance is similar to that of daytime in 75%.[9] These data may be extrapolated to provide

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Fig. 1. Coffee beans contain a high level of caffeine.

information regarding the impact of caffeine on a surgeon's ability to work effectively whilst sleep deprived.

Over the last two decades the use of an increasing range of caffeinated energy drinks has emerged.[10,11] These drinks can deliver caffeine in a concentrated form and are produced to taste attractive, but they can easily add to caffeine consumption, used alone or in addition to other caffeine intake. They may also contain other stimulants such as taurine and there are health concerns about them, for example, related to the cardiovascular, neurological, and renal systems.[10] Evidence shows that high doses of caffeine can improve endurance performance over that of lower doses,[12] but not without the risk of side effects.

Caffeine is also available in other forms with various uses, and tablets (designed to deliver it at concentrated levels) to increase wakefulness have doses of up to 100 mg/tablet. At levels of 180 mg/capsule, caffeine is found in some weight loss, "fat burner" products, and it sometimes forms part of the ingredients of commonly used cold and flu preparations at amounts between 25 mg and 50 mg/dose.

Caffeine is effective for inducing wakefulness and restoring cognitive performance in sleep-deprived individuals

Caffeine is the most widely consumed neuro-stimulant in the world, and caffeinated drinks are consumed in a quantity second only to water.[4] Three mechanisms of action are suggested for caffeine, with the neuro-cognitive effects most widely associated with its antagonistic action on adenosine. By inhibiting adenosine, it indirectly increases activity in the locus coeruleus, basal forebrain, and hypothalamus, and in turn induces wakefulness. The critical centre of activity responsible for this effect has been proposed to be the brainstem via the basal forebrain.[13] The overall cognitive effects of caffeine, however, go beyond inducing wakefulness.

Caffeine has long been known to induce a state of wakefulness, which improves both alertness and mood, even at low doses.[14,15] Most studies on its effects look at individuals with controlled sleep deprivation followed by the administration of caffeine. Subjective and objective wakefulness are then measured. Study aims have been to induce wakefulness to that of rested individuals, [9,14] and doses as low as 12.5-32 mg have been shown to be sufficient to achieve this, with higher doses of 200 mg restoring daytime peak performance.[9,14,16] These effects will vary amongst individuals, with key influences including the amount of sleep deprivation, the delivery method/dose of caffeine, and numerous metabolic factors.[17]

Low doses of caffeine have been shown to significantly improve cognitive performance by increasing response times and visual information processing.[16] Multiple studies demonstrate that low doses (from 0.18 mg/kg) are sufficient to achieve these benefits, and cognitive responses often follow a flat dose-response curve thereafter.[2,16] The fact that chronic users exhibit diminished or even absent cognitive responses suggests the concept of caffeine tolerance with long-term use.[18]

High doses of caffeine affect error rate and may lead to worse clinical outcomes

Caffeine has a positive impact on motor function through its stimulant metabolic effects,[19] and energy drinks are often advertised to promote this, focusing on the performance-enhancing effects of their contents.[20] Studies investigating the impact of caffeine on sports people have shown a positive effect on muscle endurance and strength.[21] These qualities are desirable in a physically demanding role, but translating these effects into the surgical or interventional field would have limitations, as fine motor function can be diminished by caffeine. Whilst refined motor control may not be important in many sports, it is to the surgeon.

Caffeine's negative effect on dexterity is dose-dependent. A moderate intake of 2.5 mg/kg may induce fine hand tremor, while 5 mg/kg leads to worsened dexterity.[14] These effects, however, could be partially mitigated through tolerance, so caffeine has a mixed effect on psychomotor performance and may increase speed at the expense of dexterity.

Aggarwal et al studied the effects of sleep deprivation and caffeine on the ability of subjects to perform tasks with a laparoscopic simulator. The performance parameters measured included time taken to complete the task, economy of movement, and reaction time.[6] Caffeine given to sleep-deprived individuals successfully restored the time taken to complete the task to the baseline value (measured whilst rested), but had no significant effect on the higher error rate of sleep-deprived individuals.[6] This may lead sleep-deprived individuals consuming caffeine to have false confidence to perform procedures safely.

Moderate-to-high doses of caffeine can lead to deleterious effects on function and wellbeing

Caffeine is used worldwide, and in most countries there are few regulations as to how it is advertised, marketed, and sold. Doses of more than 4 mg/kg often lead to nervousness, irri-

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tability, anxiety, insomnia, tremor, tachycardia, and palpitations.[12,20]

Popular energy drinks contain between 75 and 160 mg of caffeine.[20] A person weighing 70 kg can receive a moderate intake of caffeine from just one energy drink and can show demonstrable psychomotor side effects.[14] One can receive a high dose by consuming anything over a single energy drink or by combining energy drinks with coffee or tea. Using other preparations containing caffeine, for example, some cold remedies and weight-loss products, may lead to the inadvertent ingestion of high levels, especially if combined with caffeine-containing drinks.

Energy drinks have been shown to have a higher risk of adverse side effects when with more traditional methods of caffeine consumption.[17] Their use has been noted to have a negative association with wellbeing and has been shown to increase damaging health behaviours such as smoking and increased alcohol consumption.[22] Regular users of caffeine may develop a dependence that can result in withdrawal symptoms if the intake is lowered or stopped; cognitive performance has been posited to be adversely affected by acute caffeine withdrawal.[20,23] In these cases, where apparent, caffeine can be used to prevent further deterioration. This method of amelioration is described by the withdrawal-symptom reversal theory.[24–26] Doctors often miss breaks and opportunities to drink their usual caffeine drink during a long and busy shift, leading to caffeine withdrawal symptoms.

The consumption of caffeine should be monitored to achieve optimal effects, but there are multiple barriers to achieving this

Serum concentrations of caffeine peak 20-180 minutes after ingestion, and in healthy adults caffeine has a half-life of three to seven hours.[17] Therefore there is a wide variability in serum peak times and in the metabolic removal of caffeine. The daily limit of intake should be <400 mg. Serious side effects are apparent at 1 g intake/day.[20] The effect of caffeine extends beyond that of neuro-stimulation and includes the inhibition of phosphodiesterase enzymes to increase cyclic adenosine monophosphate (cAMP), the mobilisation of intracellular calcium, and antagonism of benzodiazepine receptors.[13,27] At very high doses it is these mechanisms that have been proposed to be the cause of its toxic and rarely fatal effects.

Optimal consumption is difficult to predict due to the wide range of the plasma mean half-life of caffeine and the varying time to reach peak serum levels. The half-life depends on variations amongst individuals and factors that affect metabolism, for example, smoking, body mass index (BMI), and oral contraceptives.[27]

To receive the optimal effects and avoid the unwanted and potentially dangerous ones, surgeons and colleagues who undertake minimally-invasive procedures should aim to monitor their caffeine intake. There is a multitude of considerations to achieve this, for example, the extent of sleep deprivation, delivery method/dose of caffeine, and metabolic, health, and environmental factors.[17,28] The varying amounts of caffeine in different brands of coffee, tea, and energy drinks also make it difficult to accurately estimate the caffeine content that is consumed.[18]

Conclusion

Caffeine may have a role in restoring a degree of cognitive function to that of rested levels, but there is little evidence to support its regular use to improve a clinician's performance. Regular caffeine consumption is concerning due to its long-term effects on the user's health and wellbeing. Caffeine tolerance may also occur, leading to overall increased consumption, and there is also a risk of withdrawal symptoms. The outcomes of surgical and invasive procedures may suffer, as evidence shows that caffeine quickens surgical tasks but diminishes dexterity, and has no positive impact on error rate.

Caffeine may be perceived as attractive in a competitive environment like surgery where the expectations of patients, health organisations, and "self" are high. Possible risks to the caffeine consumer may add to the already high rates of anxiety, depression, and burnout amongst clinicians,[19] so it should not be a replacement for sleep, rest, and recuperation.

Ethics statement/confirmation of patients permission

N/A

Conflict of interest

We have no conflicts of interest.

References

1. NHS Digital. Health Survey for England - 2013 - NHS Digital. Available from URL: https://digital.nhs.uk/data-and-information/publications/statistical/health-survey-for-england/health-survey-for-england-2013 (last accessed 22 February 2023).
2. Haluza D, Schmidt V-M, Blasche G. Time course of recovery after two successive night shifts: a diary study among Austrian nurses. *J Nurs Manag* 2019;**27**:190–196.
3. Killgore WD. Effects of sleep deprivation on cognition. *Prog Brain Res* 2010;**185**:105–129.
4. Lieberman HR, Wurtman RJ, Emde GG, et al. The effects of low doses of caffeine on human performance and mood. *Psychopharmacology* 1987;**92**:308–312.
5. Hunter New England Local Health District. JMO handbook - shift work, fatigue and wellbeing. 2019. Available from URL: https://www.calvarycare.org.au/public-hospital-mater-newcastle/wp-content/uploads/sites/6/2021/03/JMO-Handbook-for-Shiftwork-Fatigue-Wellbeing.pdf (last accessed 23 February 2023).
6. Aggarwal R, Mishra A, Crochet P, et al. Effect of caffeine and taurine on simulated laparoscopy performed following sleep deprivation. *Br J Surg* 2011;**98**:1666–1672.
7. Fargen KM, Turner RD, Spiotta AM. Factors that affect physiologic tremor and dexterity during surgery: a primer for neurosurgeons. *World Neurosurg* 2016;**86**:384–389.

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8. Giesinger K, Hamilton DF, Erschbamer M, et al. Black medicine: an observational study of doctors' coffee purchasing patterns at work. *BMJ* 2015;**351** h6446.
9. Philip P, Taillard J, Moore N, et al. The effects of coffee and napping on nighttime highway driving: a randomized trial. *Ann Intern Med* 2006;**144**:785–791.
10. Alsunni AA. Energy drink consumption: beneficial and adverse health effects. *Int J Health Sci (Qassim)* 2015;**9**:468–474.
11. Vercammen KA, Koma JW, Bleich SN. Trends in energy drink consumption among U.S. adolescents and adults, 2003–2016. *Am J Prev Med* 2019;**56**:827–833.
12. Mora-Rodriguez R, Pallarés JG. Performance outcomes and unwanted side effects associated with energy drinks. *Nutr Rev* 2014;**72**(Suppl 1):108–120.
13. Penetar D, McCann U, Thorne D, et al. Caffeine reversal of sleep deprivation effects on alertness and mood. *Psychopharmacology* 1993;**112**:359–365.
14. Temple JL, Bernard C, Lipshultz SE, et al. The safety of ingested caffeine: a comprehensive review. *Front Psychiatry* 2017;**8**: 80.
15. Alhaider IA, Aleisa AM, Tran TT, et al. Chronic caffeine treatment prevents sleep deprivation-induced impairment of cognitive function and synaptic plasticity. *Sleep* 2010;**33**:437–444.
16. Smit HJ, Rogers PJ. Effects of low doses of caffeine on cognitive performance, mood and thirst in low and higher caffeine consumers. *Psychopharmacology* 2000;**152**:167–173.
17. Rogers PJ, Heatherley SV, Mullings EL, et al. Faster but not smarter: effects of caffeine and caffeine withdrawal on alertness and performance. *Psychopharmacology* 2013;**226**:229–240.
18. Judelson DA, Armstrong LE, Sökmen B, et al. Effect of chronic caffeine intake on choice reaction time, mood, and visual vigilance. *Physiol Behav* 2005;**85**:629–634.
19. Souza DB, Del Coso J, Casonatto J, et al. Acute effects of caffeine-containing energy drinks on physical performance: a systematic review and meta-analysis. *Eur J Nutr* 2017;**56**:13–27.
20. Reissig CJ, Strain EC, Griffiths RR. Caffeinated energy drinks- a growing problem. *Drug Alcohol Depend* 2009;**99**:1–10.
21. Mielgo-Ayuso J, Calleja-Gonzalez J, Del Coso J, et al. Caffeine supplementation and physical performance, muscle damage and perception of fatigue in soccer players: a systematic review. *Nutrients* 2019;**11**:440.
22. Ágoston C, Urbán R, Rigó A, et al. Morningness-eveningness and caffeine consumption: a largescale path-analysis study. *Chronobiol Int* 2019;**36**:1301–1309.
23. Richardson NJ, Rogers PJ, Elliman NA, et al. Mood and performance effects of caffeine in relation to acute and chronic caffeine deprivation. *Pharmacol Biochem Behav* 1995;**52**:313–320.
24. Seifert SM, Schaechter JL, Hershorin ER, et al. Health effects of energy drinks on children, adolescents, and young adults. *Pediatrics* 2011;**127**:511–528.
25. van Duinen H, Lorist MM, Zijdewind I. The effect of caffeine on cognitive task performance and motor fatigue. *Psychopharmacology* 2005;**180**:539–547.
26. Cappelletti S, Daria P, Sani G, et al. Caffeine: cognitive and physical performance enhancer or psychoactive drug? *Curr Neuropharmacol* 2015;**13**:71–88.
27. Institute of Medicine (US) Committee on Military Nutrition Research. *Pharmacology of caffeine - caffeine for the sustainment of mental task performance.* National Academies Press (US), 2001. Available from URL: https://www.ncbi.nlm.nih.gov/books/NBK223808/ (last accessed 23 February 2023).
28. Cornelis MC, El-Sohemy A, Campos H. Genetic polymorphism of the adenosine A2A receptor is associated with habitual caffeine consumption. *Am J Clin Nutr* 2007;**86**:240–244.

Please cite this article as: Parry, D., Iqbal, S., Harrap, I. et al. Caffeine: benefits and drawbacks for technical performance, *British Journal of Oral and Maxillofacial Surgery*, https://doi.org/10.1016/j.bjoms.2023.01.007