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Research Article

Effects of Repeated Low-dose Caffeine Ingestion During a Night of Total Sleep Deprivation on Physical Performance and Psychological State in Young Recreational Runners

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Abstract

Background: Caffeine is frequently consumed by athletes to maintain alertness in conditions of sleep loss. However, the effect of caffeine ingestion during total sleep deprivation during aerobic exercise remains questionable.
Objectives: The present study aimed to assess the effects of repeated intake of low-dose caffeine during a night of total sleep deprivation on endurance performance and psychological states.
Methods: Twelve recreational runners performed four test sessions in a double-blind randomized order after a placebo or 6 mg/kg of caffeine ingestion after a baseline night (BN) or three doses of 2 mg/kg of caffeine during a night of total sleep deprivation (TSD). At each session, they completed an exhaustive run around a 400 m athletics track and performed the Feeling Scale test. ANOVA with repeated measures followed by paired t-tests was used to analyze the data.
Results: In comparison with BN, the TSD condition significantly impaired running performance ($P < 0.001$). On the contrary, caffeine administration improved endurance running performance ($P < 0.001$) and increased feeling of well-being ($P < 0.05$) after TSD night as compared to placebo.
Conclusions: Repeated ingestion of low-dose caffeine is an effective way to mitigate the negative effects of total sleep deprivation on endurance performance and mood states.

Keywords: Caffeine, Endurance, Physical Performance, Mood, Sleep Deprivation

1. Background

Sufficient regular sleep (about six to eight hours per night) is of major importance for the cognitive and physical performance of athletes (1). However, professional athletic competition requires more travel across time zones, leading to disruption of circadian rhythm and mood impairment. The negative sleep loss effects are more pronounced when prolonged up to 24 hours, resulting in total sleep deprivation (TSD) (2).

Many pharmacological auxiliaries are used to counter the harmful effects of sleep deprivation, in particular caffeine. Since it is the most popular psychoactive substance in the world, it is frequently consumed by athletes in order to maintain alertness in conditions of sleep loss, which could enhance psychomotor performance (3).

2. Objectives

Our study aimed to determine the effect of ingesting three doses of 2 mg/kg caffeine every 3 hours during a night of sleep deprivation on the performance of an exhaustive run at 75% of VO_{2max} and psychological state in young recreational runners.

3. Methods

Twelve healthy physical education students [age: 21.7 (± 0.9) years; weight: 64.4 (± 9.4) kg; height 1.75 (±

0.08) m; VO_{2max}: 50.9 (± 6.1) mL/kg/min] participated in the study. They had the same wake-up times (06:30 ± 00:30 h) and the same bedtimes (23:00 ± 00:30 h). In addition, they reported no sleep disorders and affirmed being non-habitual consumers of caffeine (average intake of 26.1 ± 10.2 mg/day), non-smokers, and non-consumers of alcoholic beverages. Participants performed four randomized test sessions after ingestion of 6 mg/kg caffeine or placebo following a baseline night (BN), or ingestion of 3 repeated doses of 2 mg/kg caffeine or placebo each 3 hours during the total sleep deprivation (TSD) night.

Running performance was recorded right after exercise. Before and after running, psychological test was assessed using the well-being Feeling Scale (FS) index (4). This test is based on the subjective assessment of the participants' mood during the realization of the experimental trials. Response to each "item" ranges from +5 to -5; +5 indicate "very good", and -5 indicate "very bad".

4. Results

Figure 1 illustrates the performance-time of running at 75% of VO_{2max} to exhaustion recorded in the placebo and caffeine trials following BN and TSD nights. Post hoc tests revealed that after TSD, time to exhaustion was faster compared to that of BN for both groups [placebo: Δ (%) = 17.5% ($P < 0.001$); caffeine: Δ (%) = 9.9% ($P < 0.001$)]. On the other hand, following BN, the exhaustion time was significantly higher after caffeine ingestion (Δ (%) = 9.8%; $P < 0.001$) (44.7 ± 4.5 min versus 40.7 ± 5.6 min) as well as after TSD (Δ (%) = 20%; $p < 0.001$) (40.3 ± 4.6 min versus 33.6 ± 3 min) compared to the placebo group.

Figure 2 shows the variation in subjective mood scores (feeling of well-being) in the "feeling scale" test. Statistical analysis revealed a significant effect of sleep ($F = 10.94$; $P < 0.05$). After the TSD, the feeling of well-being decreased in both groups before exercise [placebo: 533% ($P < 0.05$), caffeine: 233% ($P < 0.05$)] and also after exercise [placebo: 111% ($P < 0.05$), caffeine: 86% ($P < 0.05$)] as compared to BN. ANOVA also showed a significant effect of exercise ($F = 23.01$; $P < 0.01$). Moreover, the ANOVA showed a significant effect of caffeine ($F = 6.05$; $P < 0.05$). After caffeine ingestion, the feeling of well-being increased by 31.6% after exercise ($P < 0.05$) following the night of TSD compared to the placebo group.

5. Discussion

The results of the present study concluded that a dose of 6 mg/kg of caffeine (3 × 2 mg/kg) improved the performance of exhaustive endurance exercise (at 75% of VO_{2max}) following the BN and the TSD nights. Indeed, the time to exhaustion was improved after BN by 9.8% after caffeine ingestion compared to the control group. In the same context, Doherty and Smith (5) concluded that the ergogenic effect of caffeine is observed more markedly when performance is measured with an exhaustive protocol with a fixed intensity during endurance exercise. Other authors (6, 7) have shown that the ingestion of 3 to 6 mg/kg of caffeine produces significant improvements in endurance capacity measured by time to exhaustion at submaximal workload ranging from 75 to 85% of maximal oxygen consumption. On the other hand, our results showed that the exhaustion time after the night of TSD was improved by 20% after the ingestion of three repeated doses of 2 mg/kg of caffeine compared to the placebo group. According to McLellan et al. (8, 9), repeated doses of 100 - 300 mg of caffeine enhanced exhaustion time by 25% after running on a treadmill at 85% of VO_{2max} until exhaustion, and improved 6.3 km runnig times by 1.2 ± 1.8 min for military special forces after a night of TSD. Additionally, recent research showed that caffeine intake enhanced athletes' physical performance following TSD (10-12).

These findings suggest that the intake of caffeine may produce a significant improvement in submaximal-load exhaustive endurance exercise after normal sleep as well as after total sleep deprivation.

In addition, the results of our study showed that consuming repeated doses of caffeine during TSD significantly improved feelings of well-being by 31.6% after exhaustive running exercise. Along the same lines, there is considerable evidence to suggest that low and moderate caffeine consumption improves psychological state following sleep restriction (13-15). Additionally, studies on military forces have reported that consuming repeated doses of caffeine (100 - 300 mg) during the night of sleep deprivation improves soldiers' mood (8, 9, 16).

Some limitations should be taken into account with regard to the study findings. The sleep quality was not recorded using devices during the conditions of BN and TSD, which could limit study conclusions. In addition, the sample size was small (i.e. 12 male students), which could make the findings non-transferable to a large number of physically active individuals.

5.1. Conclusion

We concluded from the current study that consuming three doses of 2 mg/kg body mass of caffeine every 3 hours

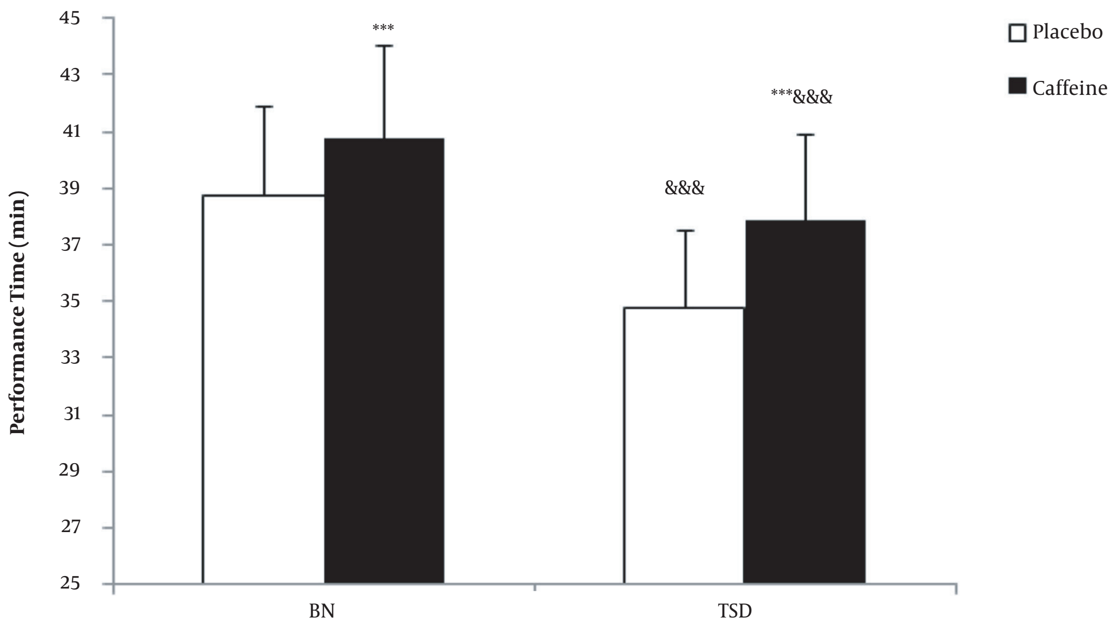

Figure 1. Performance time recorded in the exhaustive run for placebo and caffeine groups after baseline night (BN) and total sleep deprivation (TSD). Values are mean ± SD (n = 12) (***: P < 0.001: indicates significant difference from placebo; &&&: P < 0.001: indicates significant difference from BN).

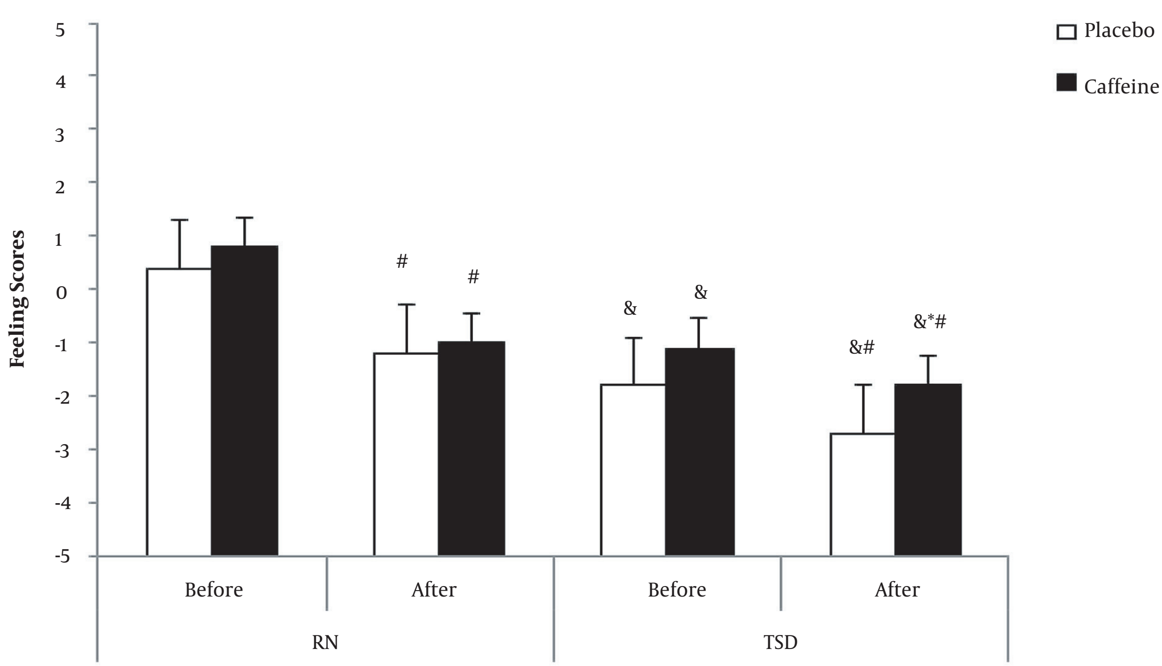

Figure 2. Subjective feeling of well-being scores in the Feeling Scale test (from +5 "very good" to -5 "very bad") recorded before and after exercise in placebo and caffeine groups following reference night (RN) and total sleep deprivation (TSD) (values are mean ± SD (n = 12);&: P < 0.05, P < 0.001: significant difference from RN; *: P < 0.05: significant difference from before; #: P < 0.05: significant difference from Placebo).

during the night of TSD enhanced the exhaustive running performance time at levels comparable to the control state, and considerably improved the psychological state of young recreational runners. Thus, the repeated ingestion of low doses of caffeine during TSD night could be an effective strategy to counteract endurance performance decline and mood impairment associated with sleep loss.

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Footnotes

Authors' Contribution: A.K developed the original idea and the protocol, abstracted and analyzed the data, wrote the manuscript. M.S and Z.S contributed to the development of the protocol and the final preparation of the manuscript.

Conflict of Interests: No conflict of interest exists.

Clinical Trial Registration Code: CPP-05/21.

Ethical Approval: The study conducted according to the Declaration of Helsinki (2013), was approved by the Sfax University ethics committee (Subjects gave their written informed consent to participate in the research. CPP-05/21).

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Informed Consent: All Subjects gave their written informed consent to participate in this research.

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