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A Single Dose of Caffeine Ingestion Improves Physical and Cognitive Performance During A 1500-M Run Competition

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A B S T R A C T

Caffeine is a psychoactive world widely used substance to improve physical and cognitive athletes' performance. However, its relative impact during outdoor competitions is not well investigated. The present investigation aimed to assess the impacts of a single moderate dose of caffeine ingestion on physical and cognitive performance following a 1500-m running competition. Methods: Fifteen recreational runners performed two test sessions in a randomized order at 09:00 a.m. after ingesting 5 mg.kg-1 caffeine or a placebo. At each session, participants realized the competition of 1500-m running in a field setting. Before and after the race, they performed the correct detection and reaction-time tasks. Compared to placebo, caffeine ingestion improved 1500-m performance time (1.5%, $p < .01$), increased correct detections (10.6%, $p < .01$), and decreased reaction time (6.3%, $p < .001$) following the race. Caffeine consumption is an effective strategy to enhance athletes' physical and cognitive performances during such running distances.

Keywords: *Caffeine, Endurance exercise, Performance, Physical state, Cognitive function.*

1. Introduction

Caffeine is a prevalent psychoactive substance that is naturally present in different dietary products such as coffee, tea, chocolate, and soda (1). This drug is recognized to be frequently used by athletes before exercise to improve physical and cognitive performance (2). The ability of caffeine to enhance physical state and cognitive function seems to be dose-dependent. Doses of 3 to 7 $mg.kg^{-1}$ consumed about one hour before exercise have been reported to enhance physical performance, whereas doses of approximately 0.5 to 4.0 $mg.kg^{-1}$ have been reported to improve cognitive function. Moreover, the relative caffeine impact on exercise performance is generally greater for aerobic in comparison with anaerobic exercise (3). Accordingly, previous studies have demonstrated that caffeine administration markedly improved endurance running performance such as 3 km (4) 5 km (5), and 8 km (6) races. The main mechanism by which this substance improves physical and cognitive states is the antagonism of adenosine receptors in the central nervous system that indirectly promote the stimulatory effects of dopamine on these states (7).

Due to the difficulty of controlling field studies, ecologically valid approaches simulating outdoor running competitions were barely used as compared to laboratory studies (8). Furthermore, only a few studies examined the impact of this substance on short-term endurance distance (4). In particular, to our knowledge, this is the first investigation that simulated a 1500-m running competition to assess the physical and cognitive impacts of caffeine intake at such a running distance.

Accordingly, this study aimed to determine the effect of a single moderate dose of caffeine on the performance time of 1500-m running competition and cognitive function (i.e. reaction time and digit cancellation tests) for fifteen young recreational runners.

2. Methods and Materials

2.1. Study Design and Participants

A double-blinded study of supplementation with caffeine was performed. The trials consist of two randomized test sessions performed by each participant with an interval of 7 days to ensure good recovery. During test sessions, participants came at 07:00 a.m. to the field. An external researcher was responsible for giving caffeine or placebo to the two groups (caffeine group (i.e. CAF) or placebo (sucrose) (i.e. control group; CONT)) that were offered in opaque capsules of equal size, color, and taste, to blind participants to treatments. An hour later, cognitive tests (i.e. digit cancellation and reaction time) were carried out. At 09:00 am, participants performed the 1500-m running test around the 400m track. During the run, athletes were encouraged and supplemented with water. Just after the exercise, performances were recorded and cognitive tests were repeated.

Fifteen healthy male recreational runners, being physical education students, participated in the present study. Their mean (± S.D) physical characteristics were as follows: age 21.6 (± 1.2) years, weight 66.71 (± 8.7) kg, height 1.75 (± 0.09) m, BMI 21.4 (±1.7) kg/m^2, VO_{2max} 54.2 (± 5.4) ml/kg/min. Students were well informed concerning the study protocol and the probable risks and benefits produced before they gave written consent to participate in the study. The investigation was conducted under the Declaration of Helsinki for research on human subjects. The protocol was approved by the local Institutional Review Board (CPP SUD N° 0197/28) and was fully approved by the University Ethics Committee before starting the evaluations. Participants had almost the same waking-up times (07:00 ± 00:30 a.m.) and bedtimes (11:00 ± 00:30 p.m.) and reported no sleep disorder. They affirmed being non-habitual consumers of caffeine (average intake of 26.5±8.8 mg/day), non-consumers of alcoholic beverages, and non-smokers.

2.2. Measures

2.2.1. The 1500-m Running Test

The 1500-m race was carried out as an official outdoor competition. Athletes competed against each other to finish with the best performance. It took place on an outdoor athletics track (i.e. 400-m track) under almost the same conditions of temperature (21 to 26 °C), humidity (36 to 38%), atmospheric pressure (1011 to 1027 mbar), and wind (13 to 18 km/h). Participants were encouraged to produce their maximal capacities during the race. Their performance times were recorded manually using a stopwatch to the nearest second. The recorded times were documented and were not discussed with runners until the end of the experiments.

2.2.2. Digit Cancellation (Attention Task)

The digit cancellation test is a pencil and paper test evaluating constant attention performance. Participants perform the test by deleting given target numbers arranged in random order on a sheet of paper. The test is composed of four different forms. Each form contains 600 numbers arranged in 36 lines on a sheet. Each number consists of one digit (e.g. 7) to five digits (e.g. 36274). The score was calculated in terms of the sum of all 3-digit numbers correctly identified (9).

2.3. Reaction Time (Alertness Task)

The test of reaction time is an index of cognitive performance measuring general alertness and motor performance. It was performed by the software MILLISECOND (INQUIST, Ver.5). During the test, participants had to press the space bar of a microcomputer as soon as possible when a visual stimulus appeared 10 times in a row. Then, a script measures the average, faster, and lower time to react to the stimulus (10).

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2.4. Data Analysis

Statistical tests were processed using STATISTICA Software. The results were expressed as Means ± SD. The normality of the population was checked by the Shapiro-Wilk test. The Student t-test was used to analyze the performance time data. The cognitive data was analyzed using a two-way ANOVA (2 [Time] × 2 [Caffeine]) with repeated measures on both factors. Statistical significance found was followed by paired t-tests with Bonferroni correction. Values of $p < 0.05$ were considered as significant.

3. Findings and Results

3.1. Performance

The statistical analysis showed a significant effect of Caffeine ($t = 3.82$; $p = 0.002$; $d = 0.54$). A significantly lower duration to complete the 1500-m run (i.e. faster) was observed in the caffeine compared to the placebo group (5.11 ± 0.14 min versus 5.03 ± 0.18 min, respectively) (Δ (%) = 1.5%; $p < 0.01$).

3.2. Cognitive parameters

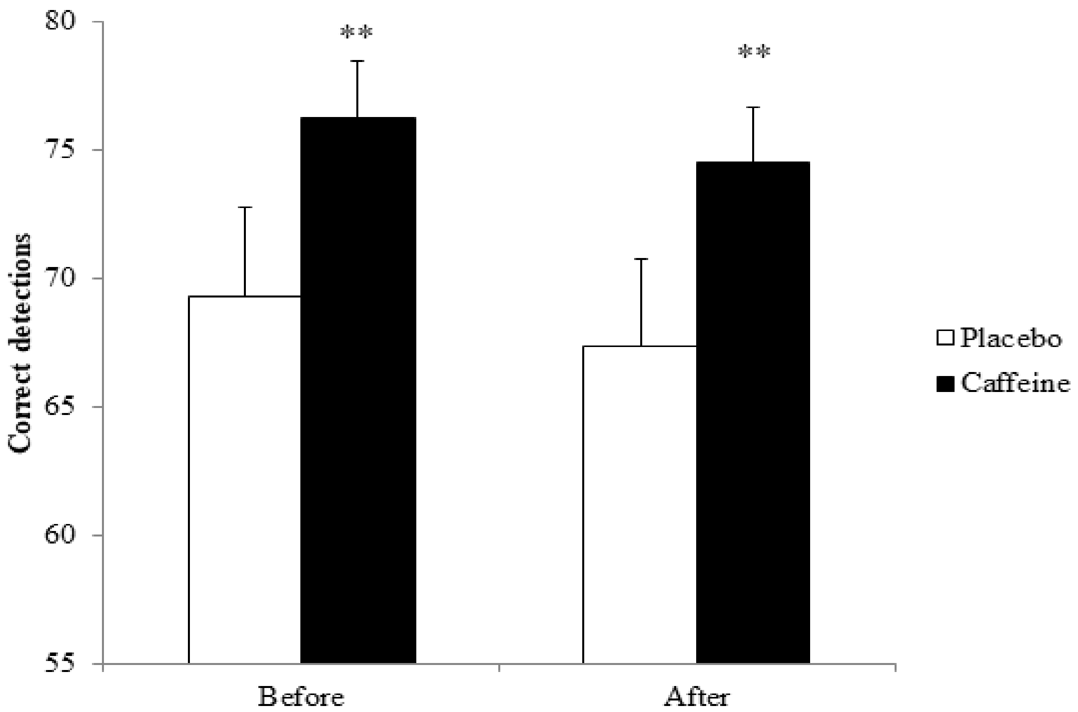
3.2.1. Digit cancellation (i.e. correct detections)

Figure 1 shows the mean changes of the correct detections (CD) observed in the digit cancellation test. Repeated measures ANOVA revealed a significant main effect of Caffeine ($F = 12.79$; $p < .01$; η2p = 0.52). Post-hoc tests showed that, following caffeine ingestion, CD was significantly higher at rest (placebo: 69,31 ± 7,86; caffeine:76,23 ± 8,03) (Δ (%) = 10%; $p < .01$) and after the run (placebo:67,38 ± 9,32; caffeine:74,54 ± 7,61) (Δ (%) = 10.6%; $p < .01$), in comparison with placebo.

Figure 1

Scores of the correctly crossed numbers in the digit cancellation task recorded before and after exercise in placebo and caffeine groups

*(Values are mean ± SD (n = 15). *: p < 0.05; **: p < 0.01; ***: p < 0.001: significant difference from placebo)*



3.2.2. Reaction time

Figure 2 shows the reaction time (RT) variations in the simple reaction time task. Statistical analysis revealed a significant main effect of Caffeine ($F = 24.03$; $p < .001$; η2p = 0.66). The pairwise posthoc tests showed that, after caffeine supplementation, the RT was significantly lower (i.e. faster) at rest (placebo:254,62 ± 27,87ms; caffeine:234,92 ± 27,98ms) (Δ (%) = 7.7%; $p < .001$) and after exercise (placebo:259,08 ± 26,84ms; caffeine:242,69

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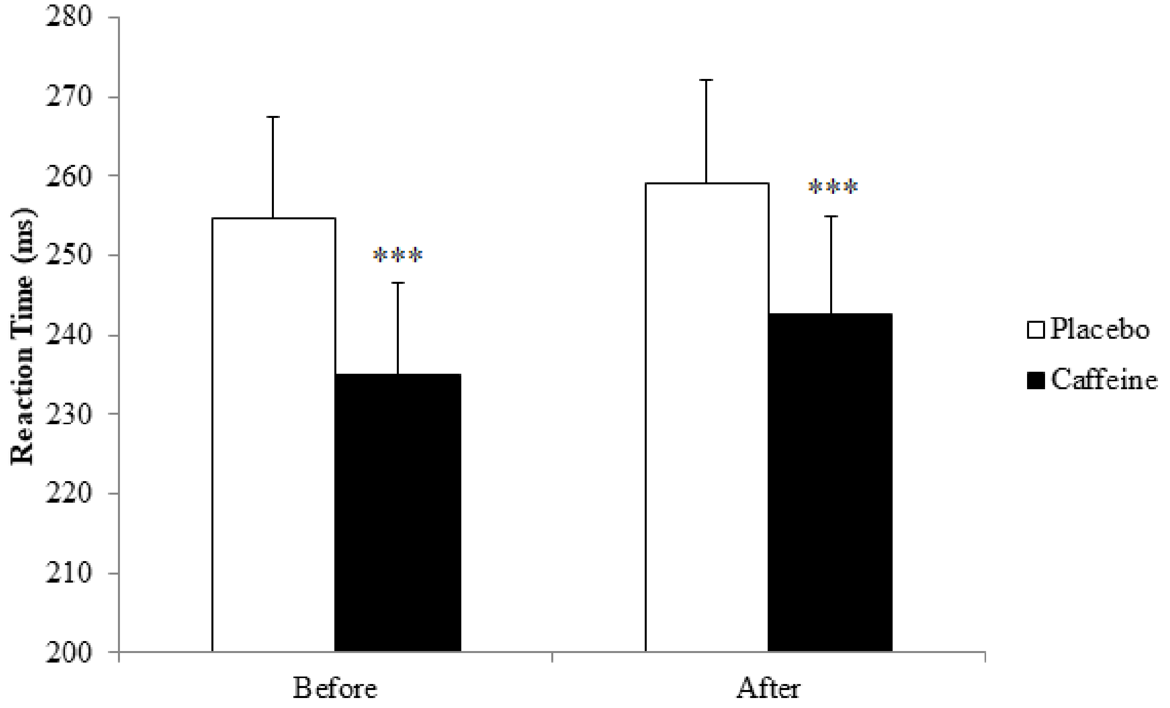
± 25,47ms) (Δ (%) = 6.3%; $p < .001$), as compared to placebo.

On the other hand, repeated measure ANOVA revealed that there was no significant effect of Time nor significant interaction of Time × Caffeine in cognitive parameters.

Figure 2

*Reaction time recorded in the simple visual reaction time task before and after exercise in placebo and caffeine groups (Values are mean ± SD (n = 15). *: p < 0.05; **: p < 0.01; ***: p < 0.001: significant difference from placebo)*



As observed in **Error! Reference source not found.**, the effectiveness of schema therapy on health anxiety among individuals attending neurological and psychiatric centers for differences between groups (control and experimental) after adjusting the means of both groups based on the pretest score is statistically significant. Therefore, it can be concluded that schema therapy is effective in reducing health anxiety. Also, the means of the two groups indicate that the scores of the subjects in the experimental group have decreased in the posttest compared to the control group. Therefore, it can be concluded that schema therapy has been effective in reducing health anxiety among individuals attending neurological and psychiatric clinics.

As seen in **Error! Reference source not found.**, the effectiveness of schema therapy on health resilience among individuals attending neurological and psychiatric centers for differences between groups (control and experimental) after adjusting the means of both groups based on the pretest score is statistically significant. Therefore, it can be concluded that schema therapy is effective in enhancing health resilience. Also, the means of the two groups show that the scores of the subjects in the experimental group have increased in the posttest compared to the control group. Therefore, it can be concluded that schema therapy has been effective in enhancing health resilience among individuals attending neurological and psychiatric clinics.

4. Discussion and Conclusion

In this paper, we examined the effects of caffeine ingestion on 1500-m running performance and cognitive function. The main findings suggested that consuming a moderate dose of caffeine (i.e. 5 mg.kg-1 of body weight) markedly improved young recreational runners' physical and cognitive states.

The data obtained in the current study is broadly consistent with the major trends showing that caffeine ingestion enhanced both physical and cognitive performance during prolonged exercise (3). Such results

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will provide athletes with helpful information about the relative impact of caffeine (i.e. in every similar tested distance) in improving performance under similar conditions.

Regarding the physical state, our results demonstrated that caffeine intake significantly enhanced the performance of the 1500-m running competition. Caffeine intake led to a 1.5% enhancement as compared to the control, which corresponds to an average amelioration of 4.5 s. Similarly, Matthew et al. (5) reported that five $mg.kg^{-1}$ improved 5-km running performance for both well-trained and recreational runners by 1.1% and 1.0% respectively. In the same line, Khcharem et al. (6) reported that consuming 5 $mg.kg^{-1}$ caffeine enhanced absolute 8-km run performance by 2.8% for recreational runners. Such findings may recapitulate that caffeine administration could contribute to a slight but significant amelioration in short and long-term endurance performances for trained and recreational runners. This beneficial performance enhancement is mainly mediated by the stimulation of the central nervous system through the blockade of A1 and A2a adenosine receptors and the increase of dopamine levels. In this way, caffeine stimulates energy production and improves blood flow to the heart and muscles, which improves physical performance (11).

Relative to the cognitive state, the current data showed that five $mg.kg^{-1}$ caffeine consumption led to a faster response in the reaction time task and better attention in the digit cancellation test. In the same context, a large consensus in the literature reviews agreed that this substance improves alertness, reaction time, and attention regardless of sex, age, and normal levels of daily caffeine consumption (12). These cognitive beneficial effects are probably mediated via the antagonism of adenosine receptors that have been identified in many brain regions, including the hippocampus, cerebral cortex, and thalamus (13).

Additionally, some limitations should be taken into account when considering the findings of the present study. Firstly, plasma caffeine concentration was not measured. Moreover, the sample size was small (i.e. fifteen recreational runners), which could make the findings non-transferable to a large number of physically active subjects.

We concluded from this study that the consumption of five $mg.kg^{-1}$ caffeine enhanced the 1500-m running performance time and improved the reaction time and attention of young recreational runners. Thus, consuming a single moderate dose of caffeine, one hour before performing a short-term endurance exercise, could be an effective strategy to enhance physical and cognitive states.

Authors' Contributions

All authors contributed to the study's conception and design. K. A., M. L., and S. Z. performed material preparation, data collection, and analysis. K. A. wrote the first draft of the manuscript and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data availability De-identified data available upon reasonable request to the authors.

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Declaration of Interest

The authors report no conflict of interest.

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Ethics Considerations

Informed consent was obtained from all individual participants included in the study. All procedures performed in studies involving human participants were under the ethical standards of the Faculty of Medicine's research committee, University of Sfax, Tunisia. The protocol was approved by the local Institutional Review Board (CPP SUD N° 0197/28) and by the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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