第一页为封面页

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论文题目：**Efficacy of acute caffeine consumption on visual attention and short-term memory in Chinese high school students: a randomized controlled trial**

第二页为论文摘要（包括论文选题背景的简要介绍、在选题上和研究上的亮点等）

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摘要：

Abstract

Objectives The study aimed to evaluate the efficacy of acute caffeine consumption on visual attention and short-term memory in Chinese high school students.

Methods This study was a randomized, double-blind, controlled trial, in which 44 healthy high school students (20 males and 24 females), 16-18 years of age, were randomly assigned to the intervention group (24 cases) and the control group (20 cases). Participants in the intervention group received 2 g of caffeinated coffee (containing 60mg caffeine) while the control group received 2 g of decaffeinated coffee. Visual attention, short-term memory, blood pressure and heart rates were measured at baseline and 45 min post-coffee consumption.

Results There was a significant decrease in visual attention scores both in caffeinated coffee group and decaffeinated coffee group after intervention. Visual attention scores of the caffeinated coffee group decreased more than the decaffeinated coffee group (-16.33 ± 10.31 *vs* -10.35 ± 12.42, $p<0.05$). The short-term memory scores were increased both in the two groups after intervention while the change was not significantly different between the two groups (7.04 ± 6.49 *vs* 6.95 ± 7.33, $p>0.05$). There was no statistically significant difference as for changes in blood pressure and heart rates, whether before and after intervention or between the two groups.

Discussion Acute caffeine consumption was associated with improved visual attention performance in adolescent populations. The relationship between acute caffeine consumption and short-term memory performance is still worthy of further research.

Key-words

Caffeine, visual attention, short-term memory, adolescent, randomized controlled trial

第三页为论文英文摘要（如果是中文论文，此页为英文摘要。否则，留空白。）

Title:

Abstract

第四页为创新性申明

本参赛团队声明所提交的论文是在指导老师下进行的研究工作和取得的研究成果。尽本团队所知，除了文中特别加以标注和致谢中所罗列的内容以外，论文中不包含其他人或本团队已经发表或撰写过的研究成果。若有不实之处，本人愿意承担一切相关责任。

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日 期：

此处开始为论文的主体部分……

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Introduction

Caffeine (1, 3, 7-trimethylxanthine) is the most commonly consumed dietary ingredient throughout the world and approximately 80% of the world's population consumes caffeine-containing products, with coffee and tea being the two most prominent sources [1]. The history of caffeine may date from 2737 BC, when Chinese legend describes Emperor Shen Nung's discovered tea can produce vigor of body, contentment of mind, and determination of purpose [2]. Caffeine is a widely used psychoactive stimulant as caffeine can easily cross the blood–brain barrier and acts primarily by blocking adenosine A1 and A2A receptors, leading to centrally stimulating effects [3]. Acute caffeine consumption can also activate the sympathetic nervous system [4] and increase galvanic skin response [5]. These stimulant properties may explain the beneficial effects of acute caffeine intake on attention, memory and cardiovascular functions.

A substantial body of evidence demonstrated that caffeine consumption can improve attention [6]. *Andrew P Smith* et al conducted a trial in the adult population and found that caffeine intake was associated with faster reaction time, fewer long responses, greater detection of targets in the cognitive vigilance task, and faster encoding of new information [7]. A double-blind, placebo-controlled study in young adults concluded that acute habitual doses of caffeine can improve simple and sustained attention and executive updating [8]. Caffeine was also considered as a potential therapeutic approach in treatment of attention-deficit hyperactivity disorder (ADHD) [9]. A growing number of animal experiments found that caffeine can improve memory performance and prevent memory impairment [10-13]. Nevertheless, the beneficial effects of caffeine on human's memory performance are still unclear [14].

In China, more and more teenagers begin drinking caffeine-containing products to refresh themselves due to heavy study stress. However, few studies have investigated the potential effects of acute caffeine consumption on teenagers' cognitive abilities such as attention and memory so far. The present trial was conducted to study the relationship between acute caffeine consumption with visual attention, short-term memory performance and cardiovascular function in Chinese high school students.

The study protocol was approved by the ethics committee, high school affiliated to Renmin University of China. All the participants provided written informed consent prior to participation. The trial was conducted and reported according to the principles contained in the CONSORT statement 2010 [15].

Methods

Setting and Participants

This study was conducted in high school affiliated to Renmin University of China. Participants were recruited from grade 10 and grade 11 in the school. To be eligible for the study, participants had to be healthy high school students, nonsmokers with normal or corrected-to-normal vision, 6 to 8 hours sleep during weekdays without any sleeping problems.

Each participant's general information including name, sex, age, height and weight was recorded. Their habits of drinking coffee were defined as three categories: never drink (with no history of drinking coffee), drink occasionally (drinking coffee at least once a week but not every day) and drink a lot (drinking coffee frequently or daily).

Study design and treatment

This study was a randomized, double-blind, controlled trial. Participants were randomly assigned to two groups using table of random number: caffeinated coffee group (intervention group) and decaffeinated coffee group (control group). In this trial, randomization with allocation concealment by opaque sequentially numbered sealed envelopes was conducted. ### generated the random allocation sequence. ### and ### enrolled participants and assigned them to interventions. The researchers and participants were blind to the caffeinated or decaffeinated coffee given. As there was no previous study on which to base a sample size calculation, this study was initiated as an exploratory trial, not powered to be definitive but to provide the basis for sample size calculation for any future trial. Participants in the caffeinated coffee group received 2 g of caffeinated coffee (Dormans®, containing 60mg caffeine) dissolved in 200 ml hot water. Participants in the decaffeinated coffee group received 2 g of decaffeinated coffee (Kenco) also dissolved in 200 ml hot water.

Outcomes and measurement

Visual attention

A Schulte table from a previous similar study [16] was modified in this trial to assess the ability of visual attention. During the experimental sessions, participants were seated in a bright classroom and faced a piece of paper on a desk. A black ball pen, a timer, and a quiz paper were placed on each desk. Natural numbers 00 to 99 (00, 01, 02, 03, 04, 05…, 99) were randomly presented in a 10*10 square frame. The participants were asked to find any 15 continuous natural numbers in the square frame as fast as possible. The time participants spent to complete the task was recorded by the timer. The visual attention scores, presented in second, was a time measurement for the time participants completing the test, and hence the shorter time indicated the better visual attention performance. An example of visual attention test questionnaires was shown in Fig. 1.

I. Visual Attention Test

Instruction: Natural numbers from 00 and 99 are randomly placed below, please find 15 serial numbers. For instance, from 1 to 15, 2 to 16 or 30 to 44 and etc., and record the time taken.

1233 40 97 94 57 22 19 49 60
27 98 79 08 70 13 61 06 80 99
05 41 95 14 76 81 59 48 93 28
20 96 34 62 50 03 68 16 78 39
86 0742 11 82 85 38 87 24 47
63 32 77 51 71 21 52 04 09 69
35 58 18 43 26 75 30 67 46 88
17 46 53 01 72 15 54 10 37 23
83 73 84 90 44 89 66 91 74 92
25 36 55 65 31 0045 29 5602

Time Taken：_____ seconds

Figure 1 Visual attention test questionnaire

Short-term Memory

The short-term memory test contains terms (in Chinese character) memorizing and numbers memorizing in order to prevent the effects made from special tendency or interest towards Chinese characters or numbers. This test contains 20 terms (2 terms with one character each and 18 terms with 2 characters each). The participants were asked to memorize as many as

possible in 30 second and turn over the paper and write down what they memorized. Each correct term worth one mark and the total mark of the terms memorized was recorded as T1. Numbers memorizing contains a number sequence with 30 numbers set randomly (from 0 to 9, no same number were next to each other). The participants were asked to memorize as many as possible in 40 seconds in correct order of the sequence from the starting number and turn over the paper to write down what they memorized. N for the nth correct term the participant successfully memorized in the sequence was the mark of the numbers memorizing part and was recorded as T2. The total scores were calculated by T1+T2. The short-term memory scores, was a measurement for terms participants remember correctly, and hence the more scores indicated the better short-term memory performance. An example of short-term memory test questionnaires was shown in Fig. 2.

II. Short-term Memory Test

1. Chinese Characters Test: (Please take 30 seconds to memorize the following words)

树　鹅　板凳　汽车　手套手枪　镰刀　麻花　球拍　蛋糕

筷子　婴儿　医生　钥匙　月饼衣扣　拐杖　衣架　药酒　按铃

Note: Each word is worth one mark, the number of words memorize in 30 second is the number of marks you earn, your mark is: _____ points.

2. Number test: (Please memorize as many numbers as possible in order in 40 seconds)

7 9 8 4 6 5 2 3 1 3 4 9 6 7 5 5 1 3 8 7 2 7 9 4 8 2 6 1 3 6

Note: Each number is worth one mark, the nth number you memorized is the points you earn.
Your mark is: _____points.

Total marks: _____ points.

Figure 2 Short-term memory test questionnaire

Blood pressure and heart rates

The differences between the baseline and post-intervention arterial blood pressure (BP) and heart rates (HR) were observed to evaluate the short-term effect of caffeine on cardiovascular function. BP and HR were measured using a well-validated electronic sphygmomanometer (HEM-8102A) both before and at 45 min after coffee consumption. Two measurements were taken at 1-2 min intervals, and the average was recorded as the BP value. BP was presented in mmHg and HR was presented in number of beats per minute (bpm).

Procedures

The participants were asked to abstain from caffeine-containing beverages such as coffee, tea and soft drinks for at least 48 hours prior to the trial. All the tests took place in the morning at a consistent time among participants. At the beginning of the trial, the general information, BP and HR were measured and collected at the same time. Then, visual attention and memory tests were conducted. Participants were instructed to try their best to complete the questionnaire papers and were not allowed to talk or disturb any other participant in the laboratory. Then, the participants received 2 g of decaffeinated coffee or caffeinated coffee from the same brand dissolved in 200 ml hot water. Approximately 45 minutes after the participants took coffee, when peak plasma caffeine levels were reached [17], BP and HR were measured again. Meanwhile, another similar visual attention and short-term memory tests using questionnaire papers with different but same structured questions were performed again.

Statistical Analysis

Continuous variables were presented as mean values ± standard deviation (SD) and categorical variables were presented as absolute numbers and percentages. The independent-samples t-test was used to test differences between the two groups and the paired-samples t-test was used to test differences before and after treatment if the variables were normally distributed, or else, the Mann-Whitney U test was used. The categorical variables were analyzed by $\chi 2$ test. All P-values were 2-sided and P-values<0.05 was regarded as statistically significant difference. All the analyses were performed by SPSS17.0 software.

Results

Participant flow and baseline data

44 healthy high school students, 20 males and 24 females, between 16 to 18 years of age, with different habits of drinking coffee (8 drink a lot, 26 drink occasionally, and 10 never drink any) were enrolled and randomly assigned (24 to caffeinated coffee group and 20 to decaffeinated coffee group). Participant flow through the trial was shown in Fig. 3.

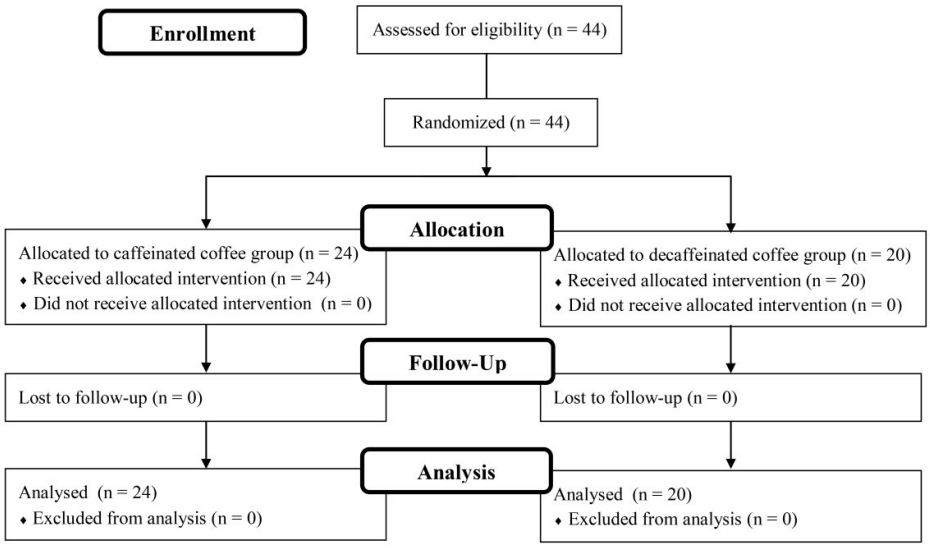

Figure 3 CONSORT 2010 diagram for participant flow through the trial

There were no significant differences in gender, height and weight between the two groups. There were statistical differences on age (17.04 ± 0.55 vs 16.30 ± 0.47, P<0.01), nevertheless, this difference had little clinical significance. The habits of drinking coffee also showed statistical differences (P<0.01). The baseline data of the participants were shown in table 1.

Table 1 Comparison of Baseline Data between the Two Groups

Characteristic	Caffeine group (24 cases)	Decaffeinate group (20 cases)	P-value
Age (year, x±s)	17.04±0.55	16.30±0.47	0.001
Height (cm, x±s)	171.42±6.96	171.90±6.98	0.82
Weight (kg, x±s)	62.08±9.16	63.80±12.85	0.62
Male (case, %)	14, 58.0%	10, 50.0%	0.58
Habits (case, %)			
never drink	8, 33.3%	2, 10.0%	
drink occasionally	9, 37.5%	17, 85.0%	0.006

drink a lot	7, 29.2%	1, 5.0%

Outcomes and estimation

Visual attention Scores and Short-term Memory Scores

At baseline, there was no significant difference both in visual attention scores and short-term memory scores between the two groups. After intervention, there was a significant decrease in visual attention scores both in caffeinated coffee group and decaffeinated coffee group. Visual attention scores of the caffeinated coffee group decreased more than the decaffeinated coffee group (-16.33 ± 10.31 vs -10.35 ± 12.42, $p<0.05$). The short-term memory scores were increased both in the two groups after intervention. However, the difference was not statistical significant between the two groups (7.04 ± 6.49 vs 6.95 ± 7.33, $p>0.05$). The results were shown in table 2 and Fig. 4.

Table 2 Comparisons of Visual Attention Scores and Short-term Memory Scores in Two Groups before and after Intervention (Score, x±s)

Outcome	Group	Before intervention	After intervention	Difference
Visual attention	Caffeine (24 cases)	60.25±14.71	43.92±13.37▲	-16.33±10.31△
	Decaffeinate (20 cases)	63.70±26.14	53.35±20.44▲	-10.35±12.42
Short-term memory	Caffeine (24 cases)	18.58±8.02	25.63±7.94▲	7.04±6.49
	Decaffeinate (20 cases)	22.65±8.18	29.60±8.05▲	6.95±7.33

Notes: ▲P<0.05, compared with before intervention; △P<0.05, compared with the decaffeinate group at the same time

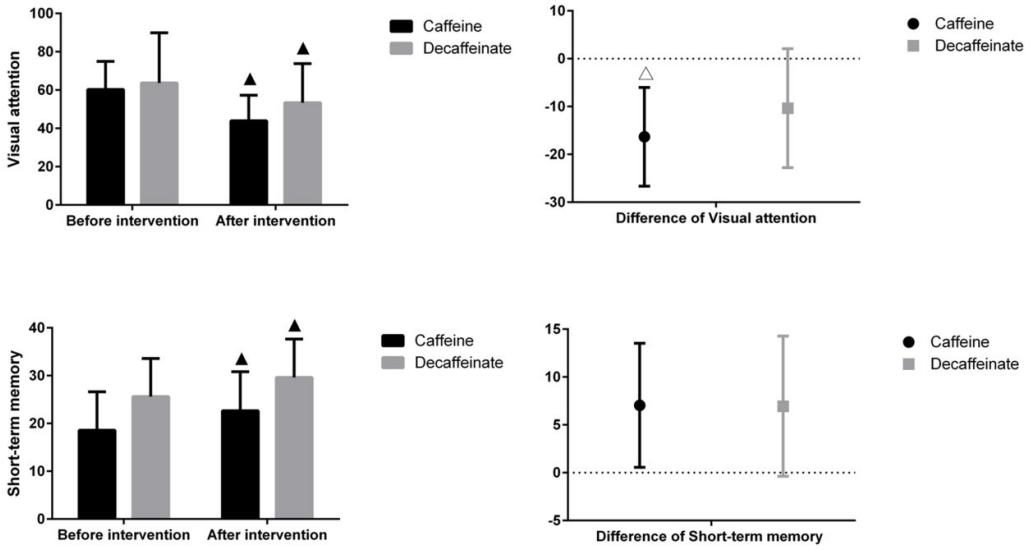

Figure 4 Comparisons of Visual Attention Scores and Short-term Memory Scores in Two Groups before and after Intervention (Score, x±s)

Notes: ▲P<0.05, compared with before intervention; △P<0.05, compared with the decaffeinate group at the same time

Blood pressure and heart rates

At baseline, there were no significant differences both in systolic BP (SBP) and diastolic BP (DBP) level between the two groups. After intervention, the changes in SBP, DBP and HR were all not statistically significant. The results of BP were shown in table 3 and Fig. 5. The results of HR were shown in table 4 and Fig. 6.

Table 3 Comparisons of BP in Two Groups before and after Intervention (mmHg, x±s)

Outcome	Group	Before intervention	After intervention	Difference
Systolic BP	Caffeine (24 cases)	114.38±13.01	113.42±14.19	-0.96±7.57
	Decaffeinate (20 cases)	113.35±11.31	112.40±17.02	-0.95±11.23
Diastolic BP	Caffeine (24 cases)	69.42±10.65	71.54±10.23	2.13±7.80

	Decaffeinate (20 cases)	66.20±9.36	72.95±19.55	6.75±18.44

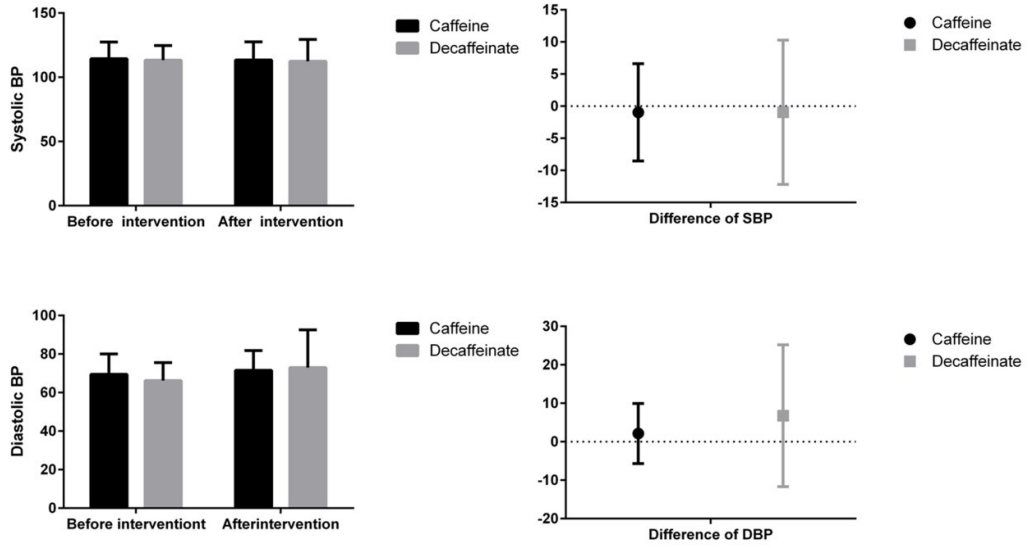

Figure 5 Comparisons of BP in Two Groups before and after Intervention (mmHg, x±s)

Table 4 Comparisons of HR in Two Groups before and after Intervention (bpm, x±s)

Outcome	Group	Before intervention	After intervention	Difference
Heart rates	Caffeine (24 cases)	83.17±10.27	80.71±10.96	-2.46±9.73
	Decaffeinate (20 cases)	75.80±13.52	78.25±11.27	2.45±8.91

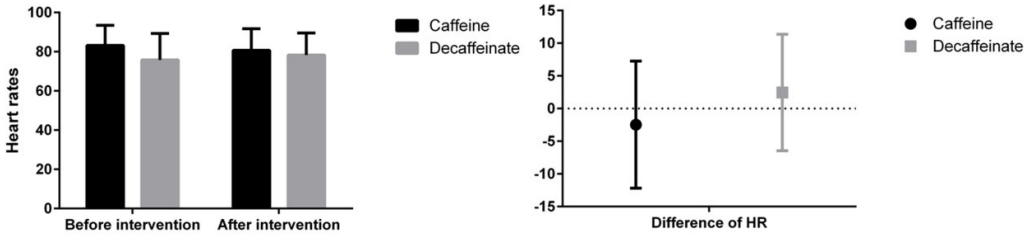

Figure 6 Comparisons of HR in Two Groups before and after Intervention (bpm, x±s)

Discussion

Summary of main findings

In this study, acute caffeine consumption was found to be associated with teenagers' visual attention performance as caffeinated coffee can better improve an individuals' visual attention than decaffeinated coffee. However, acute caffeine consumption was not significantly associated with short-term memory performance and cardiovascular function in this trial.

Interpretations

This trial showed that caffeine may be a preferable visual attention enhancer for high school students, which provide new evidence of caffeine for teenagers' visual attention. A previous systematic review concluded caffeine can improve performance on simple and complex attention tasks in healthy adult volunteers [6]. One trial showed that in habitual consumers high doses of caffeine can produce beneficial changes in visual attention and suggested that caffeine can interact with adenosine and dopamine in brain regions mediating visual attention [19]. A high dose of caffeine can also improve the visual attention in non-habitual caffeine consumers [20]. Releasing the pre- and post-synaptic brakes that adenosine imposes on dopaminergic neurotransmission by acting on different adenosine receptor heteromers localized in different elements of the stratal spine module may be a critical mechanism of the psychostimulant effects of caffeine [21]. An experiment also hypothesized caffeine might be useful to manage the attention deficit during the prepubertal period of attention deficit hyperactivity disorder (ADHD) as caffeine can improve the attention deficit of the 6-hydroxy-dopamine (6-OHDA) lesioned rats [22].

In accordance with former studies [23, 24], this trial found no significant effect of caffeine on short-term memory behavioral performance. However, other studies reported that caffeine can enhance working memory [25, 26]. These discrepancies might be resulted from different traits of participants, differences in the methods of test or different dosage of caffeine intake. Moreover, the insignificant effect may result from low statistical power due to the small sample size of participants investigated.

In the present study, acute caffeine consumption was founded to have no effect on cardiovascular functions in adolescent as the BP and HR showed no significant change in the

caffeinate group. A meta-analysis of randomized controlled trials showed that chronic intake of caffeine increased BP though the effect was small [27]. Chronic caffeine intake can also increase the HR [28] and acute caffeine intake can increase HR in mice [29]. However, there is still no agreement on the actual effect of acute caffeine consumption on peripheral BP and HR. Previous trials found that acute caffeine intake significantly increased central BP but had no effect on peripheral BP in healthy adults and the effects of caffeine on BP may be significantly underestimated by measurement of BP at the brachial artery [30, 31]. In this trial, only measuring BP at the brachial artery may also underestimate the actual effects of caffeine on BP and more in-depth study should be conducted in the future to give a conclusion of this issue.

Strengths and limitations

Compared with previous studies, this trial has its characteristics in the sample resources and outcome measurement method. While most previous studies were carried out in the adult populations, this trial enrolled 16 to 18 years old high school students as study populations. Moreover, this trial adopted a relatively traditional method—testing on papers, to assess the effect of caffeine on attention and memory. In the past studies, electronic screen [19], multi-sync monitor [33] and electronic portable device [8] were often used as measurement tools. However, for high school students in China, taking quiz and examinations on papers was a relatively more common form in their daily study, so testing their cognitive abilities on papers in this trial may be a more appropriate method.

There were, however, some limitations should be carefully considered. Firstly, due to time and distance restrictions, this trial only enrolled forty-four participants from one high school. Therefore, it may be argued people from other areas, racial background or different ages might have different cognitive abilities. In addition, the sample size was not large enough to draw the fairest conclusion. Secondly, we failed to find a satisfactory placebo. We used caffeinated and decaffeinated coffee from the same brand, but these two drinks may differ in other unknown ways. Thirdly, even though we randomised the participants, age and habits at baseline still had statistical differences as the sample size was too small to randomise completely fair. Nevertheless, the further sub-group analysis did not shown the influence of habits on the results of visual attention and short-term memory in this trial. Lastly, despite

that we controlled the amount of caffeine consumption, we did not control the daily routine dietary which may also influence the effects.

Implications for future research

In summary, there was a relationship between acute caffeine consumption and teenagers' visual attention performance. The present trial provided evidence suggesting that caffeine consumption can improve visual attention in adolescent populations. The relationship between acute caffeine consumption and short-term memory performance and cardiovascular function in adolescent is still worthy of further research. Future studies with well-design and large sample size needed to be carried out to further evaluate the effects of caffeine on teenagers' cognitive ability and experimental studies should be conducted to explore the mechanisms underlying the effects.

Acknowledgements

We would like to sincerely thank ### for offering us constructive suggestions and our schoolmates for their active participations.

Declaration of interest

The authors report no declarations of interest.

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如果有必要，最后可以列出团队成员和指导老师的简历。

注：本文作者经与组委会邮件协商沟通后，经其同意，将会将此文投稿给若干杂志社，特此注明，谢谢！