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Breakfast glycaemic index and exercise: Combined effects on adolescents' cognition

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HIGHLIGHTS

- First to study combined effects of breakfast GI and exercise on cognitive function.
- Both low GI breakfast and mid-morning bout of exercise enhanced cognitive function.
- Beneficial effects of low GI breakfast and exercise are combined for Stroop test.

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ABSTRACT

The aim of the present study was to examine the combined effects of breakfast glycaemic index (GI) and a mid-morning bout of exercise on adolescents' cognitive function.
Participants were randomly allocated to a high or low GI breakfast group in a mixed research design, where each participant completed two experimental trials (exercise and resting). Forty-two adolescents (12.4 ± 0.5 years old), undertook a bout of exercise (ten repeats of level one of the multi-stage fitness test; exercise trial) or continued to rest (resting trial) following consumption of either a high or low GI breakfast. A battery of cognitive function tests (visual search test, Stroop test and Sternberg paradigm) was completed 30 min before and 45 min following the exercise.
Average heart rate during exercise was 170 ± 15 beats·min^{-1}. On the complex level of the Stroop test, response times improved across the morning following the low GI breakfast on both the exercise and resting trials, though the improvement was greatest on the exercise trial. However, response times only improved on the resting trial following the high GI breakfast ($p = 0.012$). On the 5 letter level of the Sternberg paradigm, response times improved across the morning following the low GI breakfast (regardless of exercise) and only on the exercise trial following the high GI breakfast ($p = 0.019$).
The findings of the present study suggest that the combined effects of breakfast GI and exercise in adolescents depend upon the component of cognitive function examined. A low GI breakfast and mid-morning bout of exercise were individually beneficial for response times on the Sternberg paradigm, whereas they conferred additional benefits for response times on the Stroop test.

1. Introduction

There is consensus in the literature that breakfast consumption, when compared to breakfast omission, is beneficial for cognitive function in adolescents [7,13,35]. However, it appears that breakfast composition also has a role to play in determining adolescents' cognitive function, with particular interest surrounding the glycaemic index (GI) of breakfast. GI provides a measure of the quality of a carbohydrate by classifying foods according to their effect on postprandial glycaemia [15]. Per gramme of carbohydrate, consumption of a high GI food results in a higher peak blood glucose concentration and a greater overall glycaemic response, when compared to low GI foods. The related concept of glycaemic load (GL) refers to both the quality and quantity of the carbohydrate, and is calculated by multiplying the GI by the amount of available carbohydrate, then dividing by 100 [25].

Previous research suggests that a low GI breakfast is beneficial for cognitive function in a range of populations, including young children [14,17] and adults [2]. In adolescent populations, the weight of available evidence suggests that a low GI breakfast is the most beneficial for

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cognitive function, especially later in the morning [8,20,34]. In contrast some studies have indicated that a high GI breakfast is most beneficial for adolescents' cognitive function [19,26]. However, such studies have often used high and low GI breakfasts which are not matched on key variables such as energy and carbohydrate content, and have measured only limited components of cognitive function. Whilst the exact mechanisms for the beneficial effect of a low GI breakfast on cognitive function is unknown, a recent review suggests this effect may be due to a more stable supply of fuel (glucose) to nerve cells and/or favourable modulation of hormones (primarily insulin and cortisol) and neurotransmitters following a low GI breakfast [21].

Whilst the nutritional effects on cognitive function in adolescents are well documented, the acute effects of a single bout of exercise are less well known. There is some evidence to suggest that exercise has a beneficial effect on adolescents' cognitive function [5,18,31,37]. However, a recent meta-analysis suggests that comparisons between studies are difficult to make due to numerous factors moderating the relationship between exercise and cognition, including exercise duration, exercise intensity and component of cognitive function examined [6]. More recently, it has been shown that a 10 minute mid-morning bout of exercise enhanced subsequent cognitive function in an adolescent population, as evidenced by faster responses on a test of working memory 45 min following exercise [9].

One previous study has examined the combined effects of breakfast and exercise on cognitive function in adults [33]. The findings of the study suggest that breakfast consumption alone had a negative impact on performance on two attention demanding tasks (Stroop test and rapid visual information processing (RVIP) task), but that these negative effects were reversed following a mid-morning bout of exercise [33]. Whilst these findings are of interest to the present study, they must be interpreted cautiously as a post-breakfast impairment of cognitive function is not reported elsewhere in the literature. Furthermore cognitive function was assessed after participants had consumed a mid-morning snack and an ad libitum lunch, both of which have previously been demonstrated to affect cognitive function [1,3,16]. Thus, the exact effects of breakfast, exercise and their interaction are difficult to determine.

In everyday situations breakfast and exercise do not exist as separate entities and it is likely that a young person will consume breakfast and then exercise either before school, at morning break or during a physical education class. Whilst the individual effects of breakfast glycaemic index (GI) and a mid-morning bout of exercise on adolescents' cognitive function are well documented, the combined effects of breakfast and exercise have not been previously examined in young people. Thus, the combined effects of these variables on cognitive function in adolescents are of particular interest, not only due to their previously unexplored nature, but also due to the importance of cognitive function for scholastic achievement.

Therefore, the aim of the present study is to examine the combined effects of a high or low GI breakfast and 10 min of mid-morning exercise or continuing to rest on cognitive function in an adolescent population. Based on the literature to date we hypothesise that both a low GI breakfast and mid-morning bout of exercise will enhance cognitive function in adolescents. However, the combined effects of breakfast GI and exercise are novel to this study and thus this aspect of the study is exploratory.

2. Methodology

2.1. Participant characteristics

Fifty two adolescents (aged 11 to 13 years) were recruited to participate in the study. However, 10 participants failed to complete the study because they were either absent from school for one of the experimental trials (n = 7) or failed to comply with the dietary control conditions (n = 3). During familiarisation, simple measures of height, body mass and waist circumference were taken. Height was measured using a Leicester Height Measure (Seca, Hamburg, Germany), accurate to 0.1 cm. Body mass was measured using a Seca 770 digital scale (Seca, Hamburg, Germany), accurate to 0.1 kg. These measures allowed the determination of Body Mass Index (BMI), calculated by dividing body mass [kg] by the square of the height [m^2]. Waist circumference was measured at the narrowest point of the torso between the xiphoid process of the sternum and the iliac crest, to the nearest 0.1 cm. For descriptive purposes, the anthropometric characteristics of the participants who completed the study (n = 42) and a comparison between the high and low GI breakfast groups are provided in Table 1.

2.2. Study design

The study was approved by the institutions' ethical advisory committee (approval number R14-P9). Participants were recruited from a local secondary school and in accordance with the ethical guidelines of the British Education Research Authority for school based research, school level consent was obtained from head teachers. In addition, written parental informed consent was obtained and a health screen questionnaire completed (covering any medical issues relating to the child) to ensure all participants were in good health. Finally, participants signed an assent form on each day of testing, to indicate they were willing to participate in the study.

Each participant undertook a familiarisation session followed by two experimental trials. During familiarisation, which preceded the first experimental trial by 7 days, the protocol of the study was explained to participants and they were provided with an opportunity to familiarise themselves with the methods involved. Participants were allowed to repeat the cognitive function tests until they felt comfortable with them, to negate any potential learning effects.

The study employed a mixed research design, with participants randomly allocated to a high or low glycaemic index (GI) breakfast group. Within each group, participants completed an exercise and resting trial, in a randomised, order balanced crossover design. The experimental (exercise and resting) trials were scheduled 7 days apart and participants reported to school at the usual time. Fig. 1 shows the experimental protocol.

Upon arrival at school, participants rested for 10 min in a seated position, then a capillary blood sample was taken and the mood questionnaire completed. The protocol commenced as participants started breakfast, which they were given 15 min to consume. The monitoring period was selected based upon the period of time after which it is suggested the effects of breakfast GI [8,19,34] and a mid-morning bout of exercise [6,9] on cognitive function will become apparent in young people.

2.3. Dietary control

Participants were asked to consume a meal of their choice the evening before their first experimental trial and repeated this meal for the subsequent trial. Following this meal, participants fasted from 10 pm. In order to maintain euhydration, participants were allowed to drink water ad libitum during this time. In addition, participants avoided any unusually vigorous exercise for 24 h prior to each experimental trial. Prior to each experimental trial a telephone call was made to participants to remind them of this information. Upon arrival at school, participants were asked to indicate if they had followed the above requirements. Participants who had not followed these requirements were removed from the study (n = 3).

2.4. Mood questionnaire

The mood questionnaire was a modified version of the 'Activation–Deactivation Check List' (AD ACL) short form, which has previously been shown as both a valid and reliable measure of mood [30]. The mood questionnaire was completed upon arrival at school (0 min),