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Sprint-based exercise and cognitive function in adolescents

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ABSTRACT

Moderate intensity exercise has been shown to enhance cognition in an adolescent population, yet the effect of high-intensity sprint-based exercise remains unknown and was therefore examined in the present study. Following ethical approval and familiarisation, 44 adolescents (12.6 ± 0.6 y) completed an exercise (E) and resting (R) trial in a counter-balanced, randomised crossover design. The exercise trial comprised of 10 × 10 s running sprints, interspersed by 50 s active recovery (walking). A battery of cognitive function tests (Stroop, Digit Symbol Substitution (DSST) and Corsi blocks tests) were completed 30 min pre-exercise, immediately post-exercise and 45 min post-exercise. Data were analysed using mixed effect models with repeated measures. Response times on the simple level of the Stroop test were significantly quicker 45 min following sprint-based exercise (R: 818 ± 33 ms, E: 772 ± 26 ms; $p = 0.027$) and response times on the complex level of the Stroop test were quicker immediately following the sprint-based exercise (R: 1095 ± 36 ms, E: 1043 ± 37 ms; $p = 0.038$), while accuracy was maintained. Sprint-based exercise had no immediate or delayed effects on the number of items recalled on the Corsi blocks test ($p = 0.289$) or substitutions made during the DSST ($p = 0.689$). The effect of high intensity sprint-based exercise on adolescents' cognitive function was dependant on the component of cognitive function examined. Executive function was enhanced following exercise, demonstrated by improved response times on the Stroop test, whilst visuo-spatial memory and general psycho-motor speed were unaffected. These data support the inclusion of high-intensity sprint-based exercise for adolescents during the school day to enhance cognition.

1. Introduction

There is a substantial body of literature suggesting that exercise has beneficial effects upon cognitive function in adult populations (Chang et al., 2012; Lambourne and Tomporowski, 2010). Although less work has been conducted in adolescents, there is some evidence to suggest that exercise is also beneficial for cognitive function in this population (Best, 2010; Cooper et al., 2012b; Ellemberg and St-Louis-Deschênes, 2010; Hillman et al., 2009; Stroth et al., 2009) where it is of particular importance for academic achievement (Morales et al., 2011; Tomporowski et al., 2015). The viewpoint that exercise is beneficial for cognition in young people is also supported by an effect size of 0.32 in the meta-analysis of Sibley and Etnier (2003).

However, the literature surrounding the effects of exercise on cognitive function can be difficult to interpret due to the many moderating variables in the exercise-cognition relationship, including the intensity, duration and modality of the exercise, as well as the component of cognitive function examined (Chang et al., 2012). Of particular interest in young people is the effect of high intensity intermittent activities, given that this is the mode of exercise that young people most frequently engage in (Armstrong and Welsman, 2006; Bailey et al., 1995; Howe et al., 2010). Specifically, it has been suggested that 95% of young people's 'bouts' of physical activity are less than 15 s in duration (Bailey et al., 1995) and evidence has shown that young people's activity patterns are sporadic and very rarely consist of sustained moderate or vigorous intensity activity (Armstrong and Welsman, 2006). Despite this the studies examining the effect of exercise on young people's cognitive function have focussed upon more continuous exercise models such as walking (Hillman et al., 2009), running (Cooper et al., 2012b) and cycling (Ellemberg and St-Louis-Deschênes, 2010), with no studies to date examining the effects of high intensity intermittent exercise.

In adults (27 males), one study has compared the effects of high intensity exercise (2 × 3 min running sprints) and moderate intensity exercise (40 min running) on learning performance (Winter et al.,

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2007). Interestingly, the findings suggest that high intensity exercise was the most beneficial for immediate learning performance, indicative of enhanced cognitive function (Winter et al., 2007). The authors go on to suggest that these effects may be influenced by higher brain-derived neurotrophic factor (BDNF) and catecholamine concentrations following the high intensity exercise (Winter et al., 2007). However, this study was conducted in an adult population and meta-analyses have suggested that age is a moderating variable in the exercise-cognition relationship (Chang et al., 2012; Sibley and Etnier, 2003), potentially due to the fact that young people have a larger brain weight relative to their body weight and a greater metabolic rate per unit of brain weight (Hoyland et al., 2009).

In addition to the above differences in the BDNF and catecholamine response to high intensity intermittent activity (compared to the more commonly assessed moderate intensity activity), psychological mechanisms such as exercise-induced arousal and mood may also moderate the exercise-cognition relationship. The increase in arousal during and following exercise has been suggested to affect cognitive function (McMorris, 2009), with exercise intensity affecting subsequent changes in arousal (Kamijo et al., 2004). Furthermore, mood has been suggested to affect cognitive function and exercise of differing intensities has been shown to differentially affect mood (Kennedy and Newton, 1997). Therefore, despite clear scientific rationale, the effect of high intensity exercise on cognition in adolescents has not yet been examined.

It is also important that a number of domains of cognitive function are examined due to evidence suggesting that exercise differentially affects different domains of cognitive function (Chang et al., 2012). For example, in the meta-analysis of Chang et al. (2012) exercise was shown to enhance executive function but have no effect on memory. Furthermore, it is also important for studies to examine the time-course of the changes in cognitive function following exercise, with much of the literature to date only examining cognitive function immediately following exercise (Ellemberg and St-Louis-Deschênes, 2010; Stroth et al., 2009). However, whilst the immediate effects are of interest, the delayed effects (for example, 45–60 min post-exercise) are perhaps of greater importance because this is when the young people will be in their next academic lesson following a Physical Education lesson and/or break/recess, and where cognitive function will influence their learning. Interestingly, it has been suggested using a meta-analysis approach that similar effects are seen immediately following exercise and after a delay (Chang et al., 2012), but no study to date has examined both the immediate and delayed effects of exercise in young people in the same study.

Therefore, the aim of the present study was to test the hypothesis that a 10 min bout of repeated (~10 s) high intensity sprint-based running exercise would enhance cognitive function in an adolescent population, both immediately and following a delay. This novel study is important not only because high intensity intermittent activity is commonplace in young people, but also should beneficial effects be demonstrated, this could form the basis of future interventions aimed at increasing both physical activity levels and cognitive function/academic achievement in young people.

2. Methods

2.1. Participant characteristics

Forty-seven schoolchildren aged 12.6 (±0.6) years were recruited to participate in the study. However, 3 participants failed to complete the study because they were absent from school for one of the experimental trials, thus 44 participants (21 male, 23 female) completed the study. 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 participant's anthropometric characteristics were (mean ± SD): height 154.9 ± 8.3 cm; body mass: 45.5 ± 9.0 kg; body mass index: 18.9 ± 3.2 kg/m^2 (51.4 ± 29.3 percentile); waist circumference: 65.3 ± 7.5 cm.

2.2. Study design

The study was approved by the institution's ethical advisory committee. 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 to ensure all participants were in good health. In addition, participants indicated their assent to take part in the study.

Each participant undertook a familiarisation session, which preceded the first of two experimental trials by seven days. During familiarisation, the protocol of the study was explained and participants were provided with an opportunity to familiarise themselves with the methods involved, which included completing the battery of cognitive function tests. In addition, participants were provided with an opportunity to ask questions and clarify any part of the tests they did not fully understand.

The study employed a randomised crossover design, with participants blind until arrival at school on each day of testing. The experimental trials consisted of an exercise trial and a resting trial, thus participants acted as their own controls. During the exercise trial, participants completed 10 × 10 s sprints followed by 50 s active recovery 60 min following breakfast consumption. On the resting trial, participants remained seated in a classroom and continued to rest during this time. Trials were scheduled seven days apart and participants reported to school at the normal time. The experimental protocol is shown in Fig. 1.

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.

Following the overnight fast, participants reported to school at the normal time and completed the mood questionnaire. Due to the well documented effect of breakfast consumption (Cooper et al., 2011) and breakfast composition (Cooper et al., 2012a) on adolescents' cognitive function, participants were provided with a standardised breakfast, identical to that used in previous research (Cooper et al., 2012a). The breakfast consisted of cornflakes, milk, white bread (toasted) and margarine, and provided 1.5 g carbohydrate per kg body mass. As an example, the breakfast for a participant with a body mass of 50 kg consisted of 55 g cornflakes (Kelloggs, UK), 216 g 1% fat milk (Sainsbury's, UK), 42 g Kingsmill thick slice white bread (Kingsmill, UK) and 6 g margarine (Flora original, Flora, UK), providing a total energy content of 422 kcal and a macronutrient profile of 75 g carbohydrate (71% of energy intake), 14.3 g protein (14% of energy intake) and 7.2 g fat (15% of energy intake).