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EXERCISE AND ACADEMIC ACHIEVEMENT IN CHILDREN: EFFECTS OF ACUTE CLASS-BASED CIRCUIT TRAINING

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ABSTRACT
Purpose. For schools, the increasingly imposed requirement to achieve well in academic tests puts increasing emphasis on improving academic achievement. While treadmill exercise has been shown to have beneficial effects on cognitive function and cycling ergometers produce stronger effect sizes than treadmill running, it is impractical for schools to use these on a whole-class basis. There is a need to examine if more ecologically valid modes of exercise might have a similar impact on academic achievement. Circuit training is one such modality shown to benefit cognitive function and recall ability and is easily operationalised within schools. **Methods.** In a repeated measures design, twenty-six children (17 boys, 8 girls) aged 10–11 years (mean age 10.3; *SD* ± 0.46 years) completed the Wide Range Achievement Test (WRAT 4) at rest and following 30 minutes of exercise. **Results.** Standardised scores for word reading were significantly higher post exercise ($F(1,18) = 49.9$, $p = 0.0001$) compared to rest. In contrast, standardised scores for sentence comprehension ($F(1,18) = 0.078$, $p = 0.783$), spelling ($F(1,18) = 4.07$, $p = 0.06$) mathematics ($F(1,18) = 1.257$, $p = 0.277$), and reading ($F(1,18) = 2.09$, $p = 0.165$) were not significantly different between rest and exercise conditions. **Conclusions.** The results of the current study suggest acute bouts of circuit based exercise enhances word reading but not other areas of academic ability in 10–11 year old children. These findings support prior research that indicates acute bouts of exercise can selectively improve cognition in children.

Key words: acute exercise, academic achievement, children

Introduction

Physical activity and physical education within schools is comprehensively researched and the health benefits of exercise for cardiovascular fitness and general health is widely acknowledged. Research has shown acute exercise to have beneficial effects on cognition and subsequently academic achievement. It has been suggested that children gain cognitive benefits from physical activity [1, 2] with greatest improvements seen in complex mental processing [3]. Standardised achievement in maths and reading [4] as well as increased performance in core academic classes has been reported for children who participate in vigorous physical activity outside of school [5].

For schools the increasingly imposed requirement to achieve well in academic tests puts more emphasis on methods of improving academic achievement. These increased demands place an importance on academic testing and as a result, many schools have responded with a decrease in time dedicated to non-academic subjects [4]. From this perspective, participation in moderate activity of boys and girls aged 2 to 14 has since fallen between 2008 and 2014 [6]. Minutes spent taking part in PE has also fallen [7].

Within schools, children generally engage with whole-class physical education and so it is important to review the exercise modality used in studies of this nature. Treadmill exercise has been shown to have beneficial effects on cognitive function [8], while cycling ergometer use produced stronger effect sizes than treadmill running [9]. This study argued that cycling uses less metabolic energy compared with running and that running resulted in greater 'neural interference' and more cognitive demands for movement. Duncan and Johnson [10] also used cycle ergometer training at differing intensities and found that spelling and reading were improved, arithmetic impaired and sentence comprehension unaffected. While the potential for acute exercise to enhance academic achievement is attractive for educational practitioners/teachers, it is impractical for schools to use cycle ergometers or treadmills on a whole class basis. Thus, there is a need to examine whether different, more ecologically valid modes of exercise might have a similar impact on academic achievement. Immediate recall scores were higher following submaximal intensity lessons involving both team games and aerobic training. This can be attributed to exercise-induced increases in physiological arousal and the cognitive activation induced by the exercise demands. Circuit training is one such modality which has shown benefit cognitive function and recall ability [11] and is easily operationalised in the school setting. No studies appear to have examined whether the changes seen in the aforementioned laboratory studies [8–10] can translate to the school setting in a practical way.

The current study sought to address this gap by examining the effects of class-based exercise on preadolescent academic performance.

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Material and methods

Participants

Twenty-six children (17 boys, 8 girls) aged 10–11 years (mean age 10.3; *SD* ± 0.46 years) from the town of Warrington, UK, participated in the study following institutional ethics approval and informed parent and child and school consent. A pre-exercise Physical Activity Readiness Questionnaire was also used to confirm that the children did not have any pre-existing condition that would be exacerbated by physical exercise. None of the children included in the study had a recognised special educational need (e.g. dyslexia) or behavioural problem and nor were they classified as 'gifted and talented' according to school records. Children were all drawn from one school representing an area in the mid-range of socio-economic status within the town. Children were not given any inducement to participate and were recruited voluntarily following a presentation given by the researchers to children and parents attending the school concerned.

Procedures

This study employed repeated measures design whereby participants completed an academic test, comprising measures of reading, spelling, arithmetic and sentence comprehension, as a control result. This was followed 1 week later by a 30-minute circuit style class exercise session followed by a re-sit of the academic test. Both sessions occurred on the same weekday and time of day one week apart.

Firstly, to establish baseline academic performance, the Wide Ranging Achievement Task [12] was administered. WRAT 4 is the updated version of the academic achievement test employed by Hillman et al. [8] and in addition to measures of word reading, spelling and arithmetic, now includes an assessment of sentence comprehension. Word reading is a measure of the number of words correctly pronounced aloud and spelling is a measure of the number of words correctly spelt. The reading test comprised 55 words ranging from three-letter words such as 'see' and 'red', to more complex words such as 'ubiquitous' and 'regicidal' with children asked to read these aloud to the tester. In the spelling test, children read a series of 42 words in isolation and then in context (e.g. 'go. The children want to go home') and asked to spell these words in written form. The words range from two-letter (e.g. 'go') to nine-letter (e.g. 'assiduous') words. The arithmetic score is a measure of the number of mathematical problems correctly solved. In the assessment of sentence comprehension children were asked to provide the missing word in a given sentence e.g. 'Dee is having a birthday party for her brother. He will be seven ___ old' to measure the ability to comprehend information contained in a sentence. This paper and pencil assessment was administrated in silence in the children's normal classroom and lasted approximately 20 minutes. The WRAT was also administered in the order prescribed by the test guidelines, i.e. (1) word and letter reading, (2) sentence comprehension, (3) spelling and (4) math computation.

A within-subjects repeated measures design was employed whereby, one week after the initial WRAT4 test, the children participated in 30 minutes of class-based circuit training. Participants' heights (cm) and body masses (kg) were assessed using a Seca Stadiometre and weighing scales (Seca Instruments, Frankfurt, Germany). Heart rate monitors were used to measure the intensity of the session for 6 students selected at random and are accepted as a valid measure of assessment of intensity and have demonstrated reliability in test-retest studies [13]. The Polar RS400 (Polar Electro, Kuopio, Finland) were used in the instance. Resting heart rate was recorded for all participants after a 5-minute rest period in a supine position.

A 30-minute circuit-based exercise session was conducted with a full school class and consisted of exercise stations of requiring 30 seconds exercising followed by 30 seconds rest. The children were instructed to complete as many repetitions of the selected body-weight based exercises as they could during the 30 seconds. The exercises selected were body weight focused, compound, whole body exercises, chosen as the children were familiar with the exercises from previous PE lessons and designed to use large muscle groups. The circuit stations were Star Jumps, Squat Thrusts, Burpees, Speed Bounces, Modified press ups, Tuck jumps, 5 m shuttle runs, 'Mountain Climbers', press ups, sit ups, body weight squats, Bean Bag raises and Stork balance. In order to establish exercise intensity post testing, heart rate was recorded every 5 minutes immediately after an exercise interval on a station.

On completion of the exercise session, the children repeated the full WRAT test procedure. The blue and green WRAT4 forms, considered to be equivalent versions, were administered as part of the experimental design to eliminate the potential for practice effects [12].

Statistical analysis

For the purpose of analysis, standardised scores on WRAT 4 were employed. Data was screened for normality (Shapiro–Wilk, $p > 0.05$) and met the assumption. A repeated measures MANOVA was then employed to examine any differences in components of the WRAT, post control and post exercise conditions, wherein the independent variable was time (control vs. exercise) and the dependent variables were standardised WRAT scores for mathematics, reading, spelling, and sentence comprehension. Gender was used as a between subjects factor. Partial eta squared ($P\eta^2$) was also used as a measure of effect size. The Statistical Package for Social Sciences (SPSS, Version 20, Chicago, Il, USA) was used for all analyses.

Results

There was a significant multivariate effect for the intervention condition, $F(4,15) = 5.54$, $p = 0.006$, *Wilks' Lambda* = 0.403, $\eta_p^2 = 0.597$. Gender was not significant ($p > 0.05$) in any of the analyses and is therefore not discussed further. Analysis of each individual dependent variable, with Bonferroni correction, indicated that standardised scores for word reading were significantly higher post exercise ($F(1,18) = 49.9$, $p = 0.0001$, $\eta_p^2 = 0.735$) compared to control. In contrast, standardised scores for sentence comprehension ($F(1,18) = 0.078$, $p = 0.783$, $\eta_p^2 = 0.004$), spelling ($F(1,18) = 4.07$, $p = 0.06$, $\eta_p^2 = 0.185$), mathematics ($F(1,18) = 1.257$, $p = 0.277$, $\eta_p^2 = 0.065$), and reading ($F(1,18) = 2.09$, $p = 0.165$, $\eta_p^2 = 0.104$) were not significantly different in control and exercise conditions. Mean ± *SD* of standardised WRAT scores in control and exercise conditions are shown in Figure 1.

Discussion

The present study investigated the effect of an acute bout of exercise (30 minutes of circuit based exercise) compared to rest on academic performance (WRAT 4). The findings of the present study, that only word reading scores were significantly different between rest and exercise, matches similar studies using the WRAT test exercise that found improved reading comprehension but not spelling or arithmetic [8] or improved spelling and reading scores [10]. These positive benefits could be attributed to the cognitive benefits resulting from physical activity [1, 2] particularly immediate and delayed recall [11]. The results also support those of [8, 10] in that acute bouts of class based exercise have an adverse effect on arithmetic.

The findings of the current study could also be interpreted in another way. The Word reading test is the first

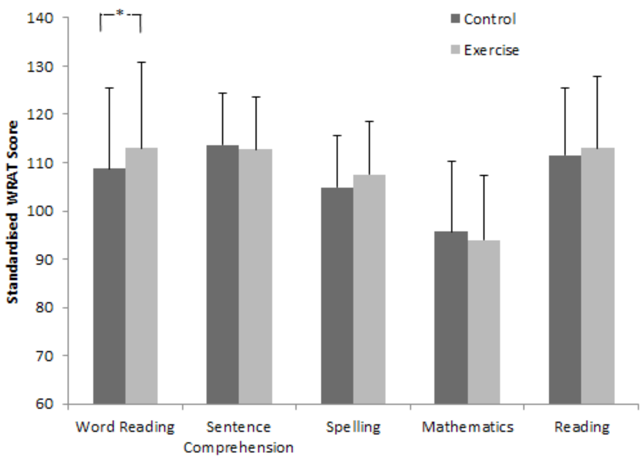

Figure 1. Mean ± *SD* of standardised WRAT scores in control and exercise conditions (*$p = 0.001$)

in the WRAT schedule and will occur within 20 minutes of the cessation of the exercise bout. The significance of results in only this test may be attributed to acute exercise-induced increases in memory storage and physiological arousal leading to temporary cognitive activation that are possibly time limited. This would be supported by higher immediate recall scores following submaximal intensity lessons involving both team games and aerobic training. If this were the case, however, increased scores should be realistically expected for all the tests. It is certainly important to acknowledge that the order of testing required in the WRAT battery may indirectly affect the findings of studies with prolonged testing batteries post exercise and would be an area for further clarification in studies of this nature. Future alterations to the order of administration of the WRAT are limited by the test procedure itself. The order of administration of the tests in the present study followed guidance on use of the WRAT [12] and the way prior studies using this test have employed it [8, 10]. Firstly, Word Reading was administered, then Sentence Comprehension, Spelling and lastly Math Computation. There is the option for the four subtests to be given separately or in combination of two or more at one sitting; however, they emphasize the Word Reading subtest should be given before the Sentence Completion subtest. Thus, in the context of the current procedure, it may be that the temporal effects of the bout of exercise employed only lasted for around 20–25 minutes, to coincide with the post exercise period and the first part of the WRAT. This point is however speculative and further research would be needed to better understand any temporal effects of exercise on cognitive performance in children.

Exercise intensity was determined from the measurement taken from the heart rate monitors. Mean HR was 142 bpm which, when age adjusted, equates to 68% MHR, indicating moderate intensity (categorised as 65–74% of MHR). This intensity has been found to elicit improvements in reading [10], reading comprehension [8] and general improvement in cognitive processing speed [14]. However, in future work more stringent control of exercise intensity may be a factor for consideration. Despite this, the method of exercise employed in the present study is arguably more ecologically valid and practical for class based interventions as compared to either Duncan and Johnson [10] who used a cycle ergometer, or Hillman et al. [8] who employed treadmill based exercise.

Physiologically, the acute bout of exercise could have induced increased cerebral blood flow to the brain, with vigorous leg, arm and hand movements evoking marked focal increases in cortical blood flow of the contralateral hemisphere [15], stimulating areas of memory function and brain-derived neurotrophic factor [16]. These changes in cortical blood flow are similar to those induced by memory tasks and visual stimulation [15] and this may be the mechanism whereby cognitive performance is increased. Endurance exercise, such as circuit style exercise and running, has been proposed to produce a deregulation of the highest level of consciousness associated with the prefrontal cortex and an adverse effect on executive control during exercise [17]. This hypothesis also proposes that all motor cortex activation will cease, and functioning restored, immediately as soon as the altered state, such as that produced by exercise, has ended. Standardised scores achieved could, therefore, possibly be affected not only by timing, and order of the WRAT protocol, but also by efficiency of physical recovery of the individual children. If this is the case, and with reference to the 'neural interference' and more cognitive demands for movement reported by Lambourne and Tomporowski [9] it would be advantageous in future research to ascertain the fitness of the children prior to the session. The reporting of positive relations between fitness and standardised achievement test performance [4] and increased performance in core academic classes in children who were able to engage in more vigorous physical activity [5] may imply that fitter children can cope with more neural interference before it affects cognitive function after exercise.

In summary, the present study provides no strong evidence that exercise intensity moderates the improvement in pre-adolescent post-exercise academic ability. Exercise was found to improve word reading independent of intensity. Exercise did not improve sentence comprehension, arithmetic, spelling or reading, with the relationship with exercise intensity requiring further investigation.

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