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Move more, Learn more? Exercise and Cognitive Function in Adolescents

The beneficial effects of exercise on health are well documented, including in adolescents and specifically concern the development of cardio-metabolic risk factors, including high blood pressure, hyperglycaemia and low grade chronic inflammation (Cooper *et al.,* 2016b). However, this article will focus on one of the lesser-known benefits of exercise; the acute effects of a single bout of exercise on cognitive function.

Cognitive function is defined as a great variety of brain mediated functions and processes, which allow us to perceive, evaluate, store, manipulate and use information (Schmitt *et al.,* 2005). Due to the heterogeneous nature of cognitive function, it is commonly sub-divided into six domains; memory, attention, executive function, perception, psychomotor functions and language skills; which are sometimes sub-divided even further (e.g. verbal, spatial, visual and auditory memory). Given this definition, it is unsurprising, that cognitive function has serious implications for academic achievement and scholastic performance, particularly the domains of attention, memory and executive function. Academic achievement is not only given great priority by school policy makers but also students themselves, given grades can be a key determinant of future life opportunities. Therefore, factors such as exercise that may be able to enhance cognitive function are of great interest and here we will focus on the acute effects of a single bout of exercise on cognitive function in adolescents.

The Evidence

The literature suggests that a single bout of exercise has a small beneficial effect on subsequent cognitive function across the lifespan, including in children (Sibley and Etnier, 2003) and adults Chang *et al.,* 2012). However, generalisations to adolescents must be made cautiously given the rapid changes in growth and metabolism that occur during this time, where cognitive function and academic achievement are of upmost importance, with adolescents sitting various school examinations. Encouragingly, recently there has also been a review focussing on the exercise – cognition relationship in adolescents, also suggesting exercise has an acute beneficial effect on cognitive function and academic performance (Li *et al.,* 2017). However, they remain cautious in drawing firm conclusions due to the equivocal nature of the evidence, which they attribute to many differences between the studies; primarily differences in the intensity, duration and modality of exercise sessions employed.

The majority of the literature to date has examined the effects of continuous exercise models such as cycling (Hogan *et al.,* 2013; Stroth *et al.,* 2009), walking (Soga *et al.,* 2015) or running (Budde *et al.,* 2010; Cooper *et al.,* 2012a). One example from our own research group involved an exercise session consisting of 10 repetitions of stage 1 of the Multistage Fitness Test (Bleep test), with each one minute repetition interspersed with 30 seconds rest (Cooper *et al.,* 2012a). Various cognitive domains were assessed 60 minutes post-exercise and results showed favourable effects for perception and working memory (in charge of simultaneously storing and processing of information). Activities as diverse as (for example) reading comprehension (Daneman and Carpenter, 1980), reasoning (Kyllonen and Christal, 1990) and complex learning (Kyllonen and Stephens, 1990) are significantly associated with working memory, thus

it is unsurprising that working memory capacity is closely associated with academic achievement (Blankenship *et al.,* 2015). Therefore Cooper *et al.* (2012a) provide evidence that indicates benefits for cognitive function and academic performance after a short bout of exercise, which could easily be incorporated in a school morning.

However, the endurance-type exercises most commonly utilized in studies do not reflect the activity patterns typically observed in young people. It has been suggested that activity patterns in young people are high intensity and intermittent in nature (Armstrong and Welsman, 2006), with 95% of physical activity bouts in young people lasting less than 15 seconds (Bailey *et al.*, 1995). Consequently, it is important that the effects of this more ecologically valid mode of exercise on cognitive function be examined. In this regard, we recently investigated the impact of 10 x 10 second sprints, each followed by 50 seconds active recovery (walking), on cognitive function in adolescents. The sprint-based exercise enhanced the speed of executive function both immediately and 45 minutes post-exercise, but had no effect on general psychomotor speed or visuo-spatial working memory. This suggest that the effects of exercise may be specific to more complex cognitive domains such as executive function. However, the effects on executive function are of great interest given that executive function is crucial for decision making and more complex cognitive tasks, which have been shown to be essential for reading ability (Savage *et al.,* 2006) as well as academic performance (Duckworth and Seligman, 2005). Therefore, this work clearly demonstrates that exercise that replicates adolescent's everyday activity patterns has the potential to positively influence cognitive function.

A number of other studies have also examined types of exercises that reflect adolescents' activity patterns more closely. Pesce *et al.* (2009) contrasted aerobic circuit training, team games and a resting control trial and found that memory performance was enhanced following exercise, with a larger effect seen after engaging in team games, which require cognitive input (in the form of decision making) in addition to physical exertion. Budde *et al.* (2008) similarly reported coordinative exercise to have beneficial effects on attention when compared to normal PE Lessons. These effects suggest that the combination of physical activity and cognitive activation is particularly advantageous for subsequent cognitive function in adolescents. Therefore, games-based activity, incorporating both high intensity intermittent exercise and cognitive decision-making, might be especially beneficial for cognitive function and academic achievement; in addition to being a very attractive exercise model for young people.

The above benefits of exercise must be interpreted with respect to the alarmingly low physical activity levels seen in young people. Only 21% of boys and 16% of girls (aged 5 to 15 years) currently meet the recommended guidelines of 60 minutes of moderate to vigorous physical activity per day (British Heart Foundation, 2015). This is not only implicated in the high prevalence of obesity in young people (29% of people aged 2 – 15 in the UK are classified as obese) (Health and Social Care Information Centre, 2015), but might also mean that these young people are missing out on the potential cognitive benefits of exercise.

Conclusions and Recommendations

Having reviewed the evidence above, we believe that an acute bout of exercise has a beneficial effect on subsequent cognitive function in adolescents. Predominantly, the domains of executive function, working memory and attention are enhanced following exercise, hence the potential for exercise to improve academic achievement. Furthermore, high intensity intermittent exercise appears to be a particularly advantageous type of exercise, with emerging evidence that games-based activity (combining physical and cognitive exertion) could be an especially effective method to enhance cognition in adolescents. However, many aspects of the exercise-cognition relationship remain unclear, with various inconsistencies in the literature requiring further investigation. Future research should especially focus on: the optimal duration of exercise; the differential effects on various cognitive domains; and how long the benefits can be seen after exercise. It is also important to explore the interaction between exercise and nutrition for cognitive function, as we have shown that breakfast consumption (Cooper *et al.,* 2011) and breakfast composition (Cooper *et al.,* 2012b) affect cognition in adolescents, alongside potential synergistic effects of breakfast and exercise (Cooper *et al.,* 2015).

Nevertheless, despite the need for further research, the current evidence suggesting an acute

bout of exercise has beneficial effects on cognitive function paired with the well documented health (Cooper *et al.,* 2016b), social and emotional (Ramstetter *et al.,* 2010) benefits of exercise strongly supports incorporating more opportunities for physical activity into the school day for adolescents. Possible examples include: active travel to and from school; opportunities for physical activity during break times (e.g. games-based activities); active lessons combining physical and cognitive exertion; and ensuring the inclusion of regular physical education lessons in the curriculum.

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