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Department of Sport and Recreation

BRAIN BOOST

how sport and physical activity enhance children's learning

what the research is telling us

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PHYSICAL ACTIVITY AND ACADEMIC SUCCESS

IT'S A WIN-WIN

Research tells us that there's a positive link between children being active and playing sport and their ability to get better marks at school.

SPORT AND PHYSICAL ACTIVITY participation are generally promoted for their positive impacts on children's physical and mental health.

However, the overall picture is better than that. Researchers believe that, with children, increased participation in sport and other forms of physical activity also enhances cognitive functioning (information processing), memory, concentration, behaviour and academic achievement.

In other words, research is telling us that there's a positive link between children being active and playing sport and their ability to get better marks at school.

But the opposite can also be true. Inactivity in children can negatively impact brain health and aspects of cognition known as executive control (also called cognitive control in adults).

These negative impacts can involve inhibition (the ability to resist distractions and maintain focus), working memory (mentally holding and manipulating information) and cognitive flexibility (multi-tasking) – which are considered vital to success at school, at work and in life *(Hillman et al., 2014)*.

For reasons such as these, the link between physical activity and academic achievement in children is of increasing interest in the fields of education and sport.

This publication is an update on research on the relationship between physical activity, sport, learning and academic success, Brain boost: Sport and physical activity enhance children's learning *(Martin, 2010)*.

It details findings from Australian and international research published in peer-reviewed journals and it provides summaries of intervention and longitudinal research (Table 1), correlational studies (Table 2), and research reviews (Table 3).

The research might be newer but the message is the same: the links between physical activity and learning in children are positive and can be long-lasting.

Unfortunately, with increasing pressure on schools to ensure children achieve academic success, physical activity classes (such as physical education and sport) are increasingly being pushed down the curriculum priority list.

DECLINING

A concern pointed out by several researchers is that the time spent on physical activity in schools has been steadily declining *(Donnelly & Lambourne, 2011; Hardman K & Marshall J, 2000; Lowry, Wechsler, Kann, & Collins, 2009; Salmon J, Timperio A, Cleland V, & Venn A, 2005)*.

In some schools, the average amount of time spent on moderate to vigorous physical activity in class has been reported as being less than 10 minutes a day.

Another concern is that research indicates that removing or reducing physical activity classes at school may be detrimental to children's physical and mental health *(Ahn & Fedewa, 2011)*. That's because physical activity at school is associated with the total daily physical activity of children *(Dale D, Corbin CB, & Dale S, 2000; Myers, Strikmiller, Webber, & Berenson, 1996; Sallis JF et al., 2003)*.

While some people believe more sport will leave less time for children to achieve better marks, this is not the case.

The vast majority of research indicates that replacing academic learning sessions with physical activity does not have a detrimental impact on school grades. Indeed, some intervention research indicates that increased participation in physical activity leads to enhanced learning and better grades *(de Greeff et al., 2014; Hollar et al.; Shephard RJ, Lavallee H, Volle M, La Barre R, & C, 1994)*.

Evidence also suggests that achieving a threshold amount of physical activity may be necessary to acquire learning benefits *(Davis et al., 2007; Ericsson & Karlsson, 2014).*

As well as that, there's also evidence that participation in vigorous physical activity may further enhance learning *(Coe, Pivarnik, Womack, Reeves, & Malina, 2006; de Greeff et al., 2014; Hillman et al., 2014; Howie & Pate, 2012)*.

ORGANISED

Children have been found to be receptive to additional daily physical activity, especially when it offers high time-on-task, is fun, and reflects their interests *(Macdonald, Abbott, lisahunter, Hay, & McCuaig, 2014)*.

However, there is evidence that there has been a reduction over the years in children's participation in physical activity and organised community sport *(Dollman, Norton, & Norton, 2005; Donnelly & Lambourne, 2011)*.

Evidence also suggests that achieving a threshold amount of physical activity may be necessary to acquire learning benefits.

WHAT DOES THE EVIDENCE TELL US?

What is the relationship between physical activity, fitness and academic achievement?

The large majority of university-based, internationally published research in this field has found a positive association between children's physical activity participation and academic achievement.

For instance, intervention and longitudinal studies have concluded that:

- **Short bouts of exercise benefit executive control/function** *(Chen, Yan, Yin, Pan, & Chang, 2014; Niemann et al., 2013; Tine & Butler, 2012).*

- **Greater vigorous physical activity out of school results in higher test scores** *(Coe et al., 2006; Niemann et al., 2013).*

- **The average academic achievement of children who received extra physical education is significantly higher than children who were in a control group which did not receive extra physical education** *(Ardoy et al., 2014; Shephard RJ et al., 1994).*

- **Reading comprehension improves** *(Hillman et al., 2009; Stevens, To, Stevenson, & Lochbaum, 2008).*

- **Physical activity intervention leads to significant improvements in children's maths scores** *(Gao, Hannan, Xiang, Stodden, & Valdez, 2013; Hollar et al.; Riley, Lubans, Morgan, & Young, 2014; Stevens et al., 2008) and motor skills (Ericsson & Karlsson, 2014)*.

- **Cognitive benefits are maintained over time** *(Koivusilta, Nupponen, & Rimpela, 2012; Stevens et al., 2008; Wittberg, Northrup, & Cottrell, 2012)*.

The large majority of internationally published research has found a positive association between children's physical activity participation and academic achievement.

Studies exploring the relationship between physical activity or fitness and academic achievement among children and adolescents have been carried out around the world, and are summarised in Tables 1 (**page 20**), 2 (**page 38**) and 3 (**page 54)**.

Research shows children can spend less time on academic learning, and more time being physically active during the school day, without affecting their academic success or progress.

On top of that, correlation studies (which explore the relationship between sport, physical activity or fitness and academic achievement retrospectively) have found:

- **A linear relationship between academic performance and physical activity with sport/physical activity a significant positive predictor of academic achievement with higher physical fitness, physical capacity and physical activity being associated with higher school ratings of scholastic ability** *(Dexter T, 1999; Dwyer T, Sallis JF, Blizzard L, Lazarus R, & Dean K, 2001; Kwak et al., 2009; Sigfusdottir, Kristjansson, & Allegrante, 2006).*

- **Students who reported a greater level of exercise spent more time in sport and achieved higher grade point averages** *(Dexter T, 1999; Field T, Diego M, & Sanders CE, 2001; Fox, Barr-Anderson, Neumark-Sztainer, & Wall, 2010; Lidner KJ, 1999; Morales et al., 2011).*

- **Greater physical activity level was associated with positive achievement orientation** *(Ardoy et al., 2014; Sallis, Prochaska, & Taylor, 2000).*

- **Boys who were in the Healthy Fitness Zone (HFZ) for aerobic fitness or muscular endurance were found to be 2.5 to 3 times more likely to pass maths/reading exams. Girls who were in the Healthy Fitness Zone (HFZ) for aerobic fitness were 2 to 4 times as likely to meet or exceed reading and maths standards** *(Bass et al., 2013).*

SUPERIOR LEARNING

In addition to these findings, research shows children can spend less time in academic learning, and more time being physically active during the school day, without it affecting their academic success or progress. *(Ahamed et al., 2007; Coe et al., 2006; Dollman J, Boshoff K, & Dodd G, 2006; Donnelly & Lambourne, 2011; Dwyer T, Coonan WE, Worsley LA, & Leitch DR, 1979; Sallis JF et al., 1999; Shephard, 1997.)*

Superior learning therefore occurs with greater physical activity participation *(Gao et al., 2013; Shephard, 1996)*, supporting the theory that increasing physical activity has a positive impact on learning *(Dwyer T, Blizzard L, & Dean K, 1996; Lambourne et al., 2013)*.

However, some studies have failed to find a relationship between physical activity and learning *(Fisher, Juszczak, & Friedman, 1996; LeBlanc et al., 2012; Tomporowski PD, 1986), and other studies identified the relationship for girls only (Carlson et al., 2008; Shachaf, Katz, & Shoval, 2013)*.

There tends to be an overwhelming amount of literature indicating physical activity is related to academic performance *(Jonker, Elferink-Gemser, Toering, Lyons, & Visscher, 2010; Jonker, Elferink-Gemser, & Visscher, 2009; Kristjánsson, Sigfúsdóttir, Allegrante, & Helgason, 2009; Kwak et al., 2009; Lambourne et al., 2013)*.

Findings that consider the intensity of exercise have shown that undertaking physical activity at vigorous to moderate intensity is related to better cognitive performance *(Morales et al., 2011)*.

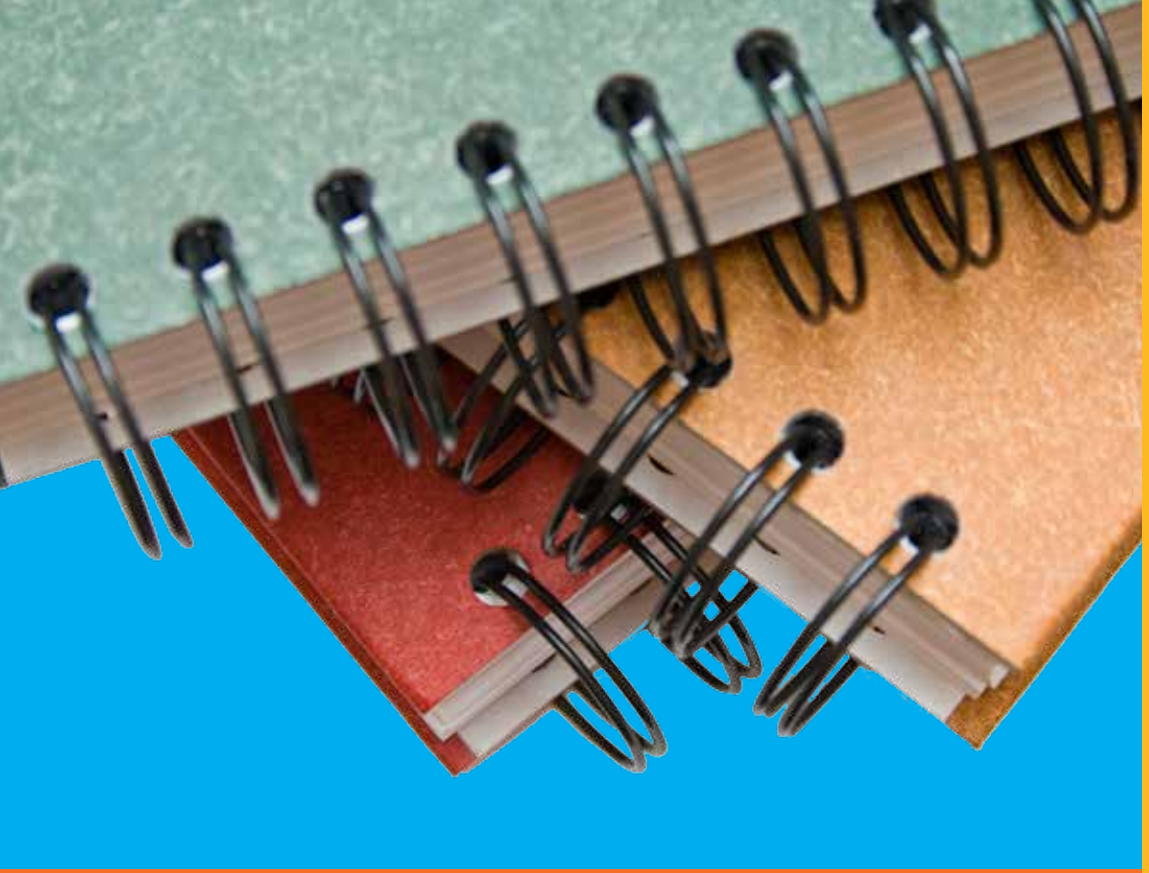
SCHOOL SUCCESS

With evidence that children who are involved in more organised, community sports or recreation are likely to perform better academically, the benefits from implementing strategies to increase children's involvement in community sports seem to extend to school success.

A limitation of cross-sectional studies is that they do not explain the direction of observed relationships; in this instance, children who perform well academically may be more likely to be involved in sport and greater physical activity.

However, results from intervention studies *(Ardoy et al., 2014; Chen et al., 2014; Hillman et al., 2014; Macdonald et al., 2014; Niemann et al., 2013; Sallis JF et al., 1999; Shachaf et al., 2013; Shephard RJ et al., 1994; Tine & Butler, 2012)* provide some evidence that gains in academic achievement are achieved following greater physical activity participation, suggesting that physical activity is impacting on learning.

Superior learning therefore occurs with greater physical activity participation, supporting the theory that increasing physical activity has a positive impact on learning.



How can physical activity and sport improve learning?

Learning can be examined in different ways and is often measured via cognitive and academic testing. A multitude of learning outcomes have been compared with physical activity or assessed following physical activity interventions.

This varied approach in measuring learning outcomes has led to difficulty in determining the strength of the relationship between physical activity and cognitive functioning and academic success, and in undertaking meta-analysis of data *(Martin, 2010; Sibley & Etnier, 2003)*.

However, the strategy of measuring multiple responses has aided with identifying potential pathways between physical activity, cognitive functioning and academic success, and these have been collated to develop the Move to Learn Model *(Figure 1) (Martin, 2010)*.

This model, developed for this review, highlights the many pathways where sport and physical activity have the potential to affect learning, test scores and academic success.

Move to Learn

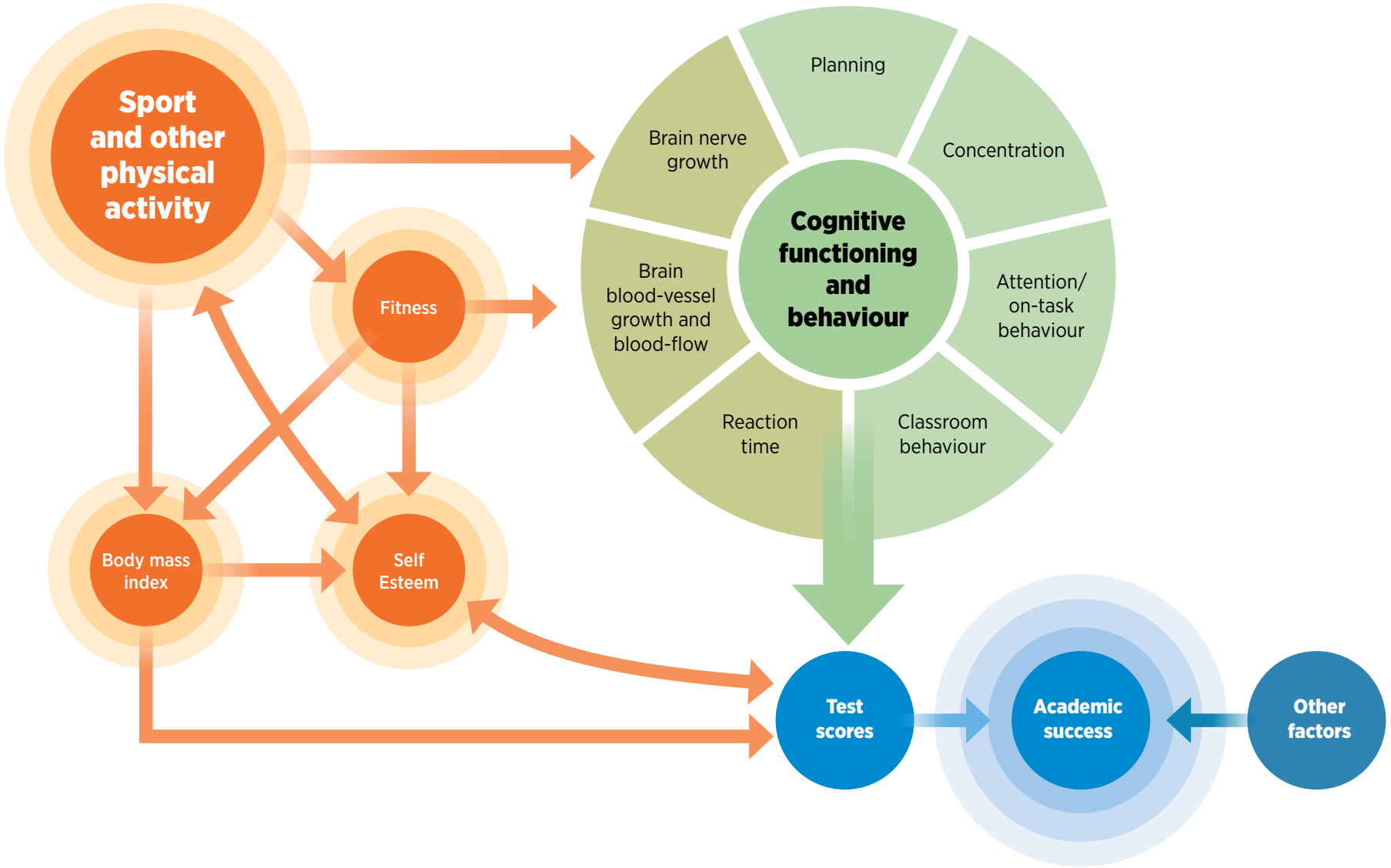


Figure 1: Move to Learn, theoretical pathways linking physical activity, cognitive functioning and academic success *(Martin, 2010)*

In summary, the evidence indicates that physical activity enhances children's cognitive functioning, concentration and on-task behaviour.

Intervention research relating to the effects of physical activity on cognitive processing indicates that:

- Physical activity improves children's cognitive control, concentration, attention and reasoning ability *(Ardoy et al., 2014; Budde, Voelcker-Rehage, Pietraßyk-Kendziorra, Ribeiro, & Tidow, 2008; Hillman et al., 2014; Hillman et al., 2009; Taras H, 2005)*.
- On-task behaviour can be improved with short bouts of exercise *(Macdonald et al., 2014; Mahar, 2006)*.

As well as that, correlation studies and reviews of research have concluded:

- There is a significant positive relationship between children's physical activity and cognitive functioning *(Davis et al., 2007; Kwak et al., 2009; Sibley & Etnier, 2003)*.
- Physical activity benefits children's achievement and cognitive outcomes *(Fedewa & Ahn, 2011; Tomporowski P.D., 2003)*.

Evidence of the physiological affects of physical activity on the brain assist in explaining this relationship. Exercise can increase levels of a brain growth factor (brain-derived neurotrophic factor), stimulate nerve growth and development in the brain and increase the brain's resistance to injury, reduce plasma noradrenaline (a vasoconstrictor), increase blood flow to the cortex of the brain *(L. Chaddock et al., 2010; Laura Chaddock et al., 2010; Cotman CW & Berchtold NC, 2000; Herholz B et al., 1987; Jennings G et al., 1986)*.

This evidence indicates that regular physical activity is likely to provide children with the optimum physiological condition for maximising learning *(Martin, 2010)*.

HIGHER PARTICIPATION IN PHYSICAL ACTIVITY IS THE KEY

Data from the Australian Bureau of Statistics (2012) indicates that of 2.8 million children aged from five to 14 years old, 1.7 million (60%) participated in at least one organised sport outside of school hours.

Evidence indicates that despite national initiatives to increase children's physical activity, children are still not doing enough to meet the recommended levels.

But is this enough? Given that the health benefits of regular physical activity are widely known, evidence indicates that despite national initiatives to increase children's physical activity, children are still not doing enough to meet the recommended levels *(Daly & Joyce, 2010; Guthold, Cowan, Autenrieth, Kann, & Riley, 2010)*.

Efforts need to be made worldwide to increase levels of physical activity among schoolchildren.

One study looked at the patterns of physical activity and sedentary behaviour among 13-to-15-year-old school children from 34 mainly developing countries *(Guthold et al. 2010)*. It found that the majority of students did not meet physical activity recommendations. In addition, their levels of sedentariness — that is, the time spent sitting down — were high.

These findings suggest efforts need to be made worldwide to increase levels of physical activity among schoolchildren. Participation in physical activity is therefore not rising *(Martin K et al., 2009)*.

Although, a growing body of evidence indicates that schools can be encouraged to maximise the time children spend in physical activity and sport and be reassured that replacing academic time with physical activity and sport will not have a detrimental effect on their academic success. Indeed, it may actually support and optimise learning.

Other strategies to promote children's physical activity opportunities, such as providing environments that focus on physical activity and reducing obesity rates, are warranted.

The benefits of greater physical activity participation include assisting with maximising children's learning, as well as improving their physical, social and mental health – benefits that are likely to extend into adolescence and adult life.

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TABLE 1: INTERVENTION AND LONGITUDINAL RESEARCH:

RELATIONSHIP BETWEEN PHYSICAL ACTIVITY, SPORT OR FITNESS AND COGNITIVE TESTING OR ACADEMIC TEST RESULTS IN CHILDREN

Table 1: Intervention and longitudinal research: relationship between physical activity, sport or fitness and cognitive testing or academic test results in children

Author, year and organisation	Study design	Sample	Methods	Measures	Results	Association	Study limitations
Ardoy et al., 2014, (Ardoy et al., 2014) University of Granada, Spain	Intervention study group-randomised controlled trial	67 adolescents	Control group, experimental group 1 and experimental group 2. CG received usual PE (two sessions/week), experimental group received four PE sessions/ week and experimental group 2 received four PE sessions/ week of high intensity.	Cognitive performance (non-verbal and verbal ability, abstract reasoning, spatial ability, verbal reasoning and numerical ability) was assessed by the Spanish Overall and Factorial Intelligence Test.	All the cognitive performance variables, except verbal reasoning, increased more in experimental group 2 than in control group (all $P < 0.05$). Average school grades (e.g., mathematics) increased more in experimental group 2 than in control group. Overall, experimental group 2 improved more than experimental group 1 , without differences between experimental group 1 and the control group.	+	The main limitation of this study was its small sample size and consequent small statistical power.

Author, year and organisation	Study design	Sample	Methods	Measures	Results	Association	Study limitations
Chen et al., 2014, (Chen et al., 2014) Yangzhou University, Yangzhou, Jiangsu, People's Republic of China	Intervention study, randomised control trial	Thirty-four third-grade children and 53 fifth-grade pre-adolescents	Pre-adolescent participants were randomly assigned into either an acute exercise group or a control group.	Participants completed inhibition, working memory, and shifting-related executive function tasks prior to and following the treatment.	Acute exercise benefited three primary aspects of executive function in general, regardless of the pre-adolescent age group, whereas the distinct components of executive function had (Gao et al., 2013) different developmental trajectories.	+	The same instructor was utilised and the experimental process was not blinded, it is possible that the instructor consciously or unconsciously provided information (e.g., tone of voice, instruc-tions, encouragement) differently to participants in each group, which is particularly difficult to control in group testing.

Author, year and organisation	Study design	Sample	Methods	Measures	Results	Association	Study limitations
Gao et al., 2013, (Gao et al., 2013) The University of Minnesota, USA	A repeated-measures crossover design was used	208 Latino school children. Year 1, Grade 4 students	Students were assigned to the intervention group and offered 30 minutes of exercise (DDR, aerobic dance) three times per week. Grade-3 and Grade-5 students made up the comparison group and were offered no structured exercise at school. In Year 2, the Grade-4 students were again assigned to the intervention, whereas Grade-5 and Grade-6 students were in the comparison group.	The baseline measures included time to complete a one-mile run, BMI, and reading and math scores. Data were collected again nine months later. Overall, data were collected in 2009–2011 and analysed in 2012.	The Dance Dance Revolution based exercise intervention improved children's cardiorespiratory endurance and math scores over time.	+	It was not possible to investigate the potential confounding effect that age and maturation and selection bias had on the outcome variables.

Author, year and organisation	Study design	Sample	Methods	Measures	Results	Association	Study limitations
Ericsson & Karlsson, 2014, (Ericsson & Karlsson, 2014) Malmö University, Sweden	Longitudinal study design Intervention	All pupils born 1990–1992	An intervention group (n = 129) achieved daily PE (5 X 45 min/ week) and if needed one extra lesson of adapted motor training. The control group (n = 91) had PE two lessons/ week.	Motor skills were evaluated by the Motor Skills Development as Ground for Learning observation checklist and school achievements by marks in Swedish, English, mathematics, and PE and proportion of pupils who qualified for upper secondary school.	Daily PE and adapted motor skills training during the compulsory school years is a feasible way to improve not only motor skills but also school performance	+	Lack of separate baseline motor skills data for the intervention and the control group

Author, year and organisation	Study design	Sample	Methods	Measures	Results	Association	Study limitations
Hillman et al., 2014, (Hillman et al., 2014) University of Illinois at Urbana-Champaign, Urbana-Champaign, Illinois, USA	Intervention study Randomised control trial	221 children (7–9 years)	Randomly assigned to a 9-month afterschool PA program or a wait-list control	In addition to changes in fitness (maximal oxygen consumption), electrical activity in the brain (P3-ERP) and behavioural measures (accuracy, reaction time) of executive control were collected by using tasks that modulated attentional inhibition and cognitive flexibility.	Fitness improved more among intervention participants from pre-test to post-test compared with the wait-list control. The intervention enhanced cognitive performance and brain function during tasks requiring greater executive control. These findings demonstrate a causal effect of a PA program on executive control, and provide support for PA for improving childhood cognition and brain health.	+	The use of a wait-list control renders it difficult to attribute the observed group differences entirely to the PA participation because other aspects of the program such as the educational component, social interaction with peers and intervention staff, and refining motor skills may have contributed to the results.

Author, year and organisation	Study design	Sample	Methods	Measures	Results	Association	Study limitations
Macdonald, Abbott, lisahunter, Hay, & McCuaig, 2014, (Macdonald et al., 2014) University of Queensland, Australia	Intervention study	Twelve Year 5 students, their classroom teachers, and the school principal's perspectives are shared in this paper. They were key informants from 107 students and five teachers who participated in the intervention.	Qualitative focus	Researcher field observations, along with a diary kept by the dedicated AKAM teacher, were used to interrogate the complexity and pragmatics of both delivering the intervention and succeeding in the intervention.	Data suggested that the intervention group benefited from and welcomed the additional daily physical activity when it offered high time-on-task, fun, and reflected students' interests. The intervention design with a dedicated physical activity leader and professional development support seemingly promoted teachers' confidence and enthusiasm.	+	
Niemann et al., 2013, (Niemann et al., 2013) Jacobs University Bremen, Germany	Intervention	Primary school students (n = 42, mean age = 9.69, SD = .44; experimental group (EG), n = 27; control group (CG), n = 15).	The students were randomly assigned to an experimental (EG) and a control group (CG).	• Physical activity • Saliva sampling and analysis • Cognitive testing	The results indicate that intensive physical activity only attenuates the reactivity of the hypothalamic-pituitary-gonadal axis in habitually low active preadolescents, but had a beneficial effect on cognitive performance for all participants independent of their physical activity level and testosterone.	+	The size of the saliva sample time points was relatively small (one pre-exercise, one post-exercise).

Author, year and organisation	Study design	Sample	Methods	Measures	Results	Association	Study limitations
Riley, Lubans, Morgan, & Young, 2014, (Riley et al., 2014) University of Newcastle, Australia	Intervention design, randomised control trial	Two classes from a single school (n = 54)	Classes were randomised to receive either the six-week EASY Minds intervention (n = 27) or follow their usual school programme (n = 27). The intervention involved the embedding of PA across the pre-existing mathematics program for 3 × 60 min sessions per week. Changes in PA were measured using accelerometers and 'on task' behaviour was measured using momentary time sampling observation.	EASY Minds program	The EASY Minds program demonstrated that integrating movement across the primary mathematics syllabus is feasible and efficacious in enhancing school based-PA and improving on-task behaviour in mathematics lessons.	+	The program was delivered by the researcher, a HPE trained specialist, with extensive experience in the primary classroom.

Author, year and organisation	Study design	Sample	Methods	Measures	Results	Association	Study limitations
Shachaf, Katz, & Shoval, 2013, (Shachaf et al., 2013) Givat Washington Academic College of Education	Intervention design	491 high school students in Grades 10, 11 and 12,	Participants divided into three comparison groups	Academic achievement test	Results of the study indicate the existence of a positive relationship between academic achievement and participation in competitive sport for female high school students, while a negative relationship was found between academic achievement and participation in competitive sport for male students. Female athletes who participated in competitive sport attained a higher level of academic achievement in numeracy and verbal reasoning than females who did not participate in competitive sport. On the other hand, the results indicate that male high school students who did not participate in competitive sport attained a higher level of academic achievement in numeracy and verbal reasoning than male athletes who participated in competitive sport.	+ for females – for males	Did not include the addition of an intervention in order to ascertain whether the relationship between academic achievement and sport at different levels of intensity changes as a result of the intervention.

Author, year and organisation	Study design	Sample	Methods	Measures	Results	Association	Study limitations
Tine & Butler, 2012, (Tine & Butler, 2012) Dartmouth College, Hanover, NH , USA	Intervention Randomised experimental design	Participants (n=164) were sixth and seventh grade students at a public middle school in New England (age range: 10 years, 4 months–13 years, 6 months).	Stratified sampling was used to randomly assign students to the experimental (exercise) or control (movie) condition. Participants in the experimental condition (n=86; 45 female and 41 male) included 44 lower-income participants and 42 higher-income participants. The control condition (n= 78; 40 female and 38 male) was comprised of 36 lower-income participants and 42 higher-income participants.	• Physical characteristics • Heart rate • Test of attention	Improved selective attention	+	Did not measure/ address how long the selective attention benefits from an acute bout of exercise last for higher- and lower-income children

Author, year and organisation	Study design	Sample	Methods	Measures	Results	Association	Study limitations
Koivusilta, Nupponen, & Rimpela, 2012, University of Turku, Finland (Koivusilta et al., 2012)	Longitudinal study design	The Adolescent Health and Lifestyle Surveys (AHLS), collected biennially in 1981–89 (baseline) and representing 14- and 16-year-old Finns were individually linked with national registries of the highest educational level and SEP.	Multinomial logistic regression analysis was used to study the associations between the outcomes (highest attained educational level, SEP) and PA (sports clubs, spontaneous, intensity).	• Highest educational level • Type of physical activity • Childhood socio-economic background • School performance	Participation in physical activity in adolescence and particularly its high intensity, predicts higher educational levels and SEP in early middle age. School performance to some degree mediates the impact of PA. PA behaviours in adolescence—or possibilities to participate in PA—are a potential mechanism in generating better health of higher socio-economic and educational groups in adult age.	+	The boys' lower participation rates in the surveys led to a slightly higher proportion of women in the follow-up as compared with the entire Finnish population of the same age.

Author, year and organisation	Study design	Sample	Methods	Measures	Results	Association	Study limitations
Stevens, To, Stevenson, & Lochbaum, 2008 (Stevens et al., 2008) Texas Tech University, USA	Longitudinal study	Elementary School students	Structural equation modelling	• Socio-economic status • Physical activity • Physical education • Prior mathematics achievement • Prior reading achievement	Physical activity was significantly and positively related to both mathematics and reading achievement in boys and girls. Physical education participation was not significantly related to achievement. Socio-economic status accounted for approximately 26% of the physical activity. Future longitudinal research is discussed that incorporates more comprehensive physical activity and achievement variables.	+	Assessments did not consider the intensity or frequency of each child's participation in physical education.
Wittberg, Northrup, & Cottrell, 2012, (Wittberg et al., 2012) Mid-Ohio Valley Health Department, Parkersburg, USA	Longitudinal study	Three cohorts of students (n = 50.1% male) enrolled in a West Virginia public school system. Students	n =1,725 received baseline fitness and academic assessments as fifth graders and at a 2-year follow-up assessment.	FitnessGram to assess fitness in aerobic capacity and WESTEST, a criterion-based assessment, for academic perfor-mance.	Students' aerobic capacity is associated with greater academic achievement as defined by standardised test scores. This advantage appears to be maintained over time.	+	FitnessGram tests were administered by different physical education teachers who, despite training and review, may have varied administration techniques.

Author, year and organisation	Study design	Sample	Methods	Measures	Results	Association	Study limitations
Hollar, Massiah et. al. 2010, (Hollar et al.) University of Miami	Intervention involving four study schools and one control school	This study analysed data from a sub-population incorporating children who qualified for free or subsidised lunches (n=1197).	Two-year intervention of dietary and physical activity intervention. Standardised academic test scores examined at the end of each year. Analysis adjusted for school clustering of behaviour and demographics.	• FCAT scores (standardised testing) • Demographics • BMI	Overall, children attending intervention schools had significantly higher maths scores in both study years.	+	Only one control school. As analysis only incorporated lower SES, results may have limited generalisability.

Author, year and organisation	Study design	Sample	Methods	Measures	Results	Association	Study limitations
Hillman, Pontifex, et.al., 2009, (Hillman et al., 2009) University of Illinois	Intervention incorporating moderate treadmill walking	20 pre-adolescents (mean age 9.5, SD 0.5yrs) from Illinois	Guardian completed health and demographic questionnaire. Children visited laboratory on two separate days (mean 10, SD 9 days apart) involving either resting session then 20 minute PA session (or order vice versa 50% of children). Tests administered after either rest or PA session.	• EEG at 64 sites • Modified flanker test (to assess inhibitory control) • Academic level via WRAT3 • Cardio-respiratory fitness using indirect calorimetry	Significantly better performance at reading comprehension after PA session compared with rest. No effect for arithmetic or spelling. Significant improvement in response accuracy and larger P3 amplitude (cognitive control) following PA session only.	+ (reading, cognitive control) 0 (arithmetic and spelling)	Small sample size. Testing order did not alter during the study and may have affected results (reading, spelling, then arithmetic).

Author, year and organisation	Study design	Sample	Methods	Measures	Results	Association	Study limitations
Budde, Voelcker-Rehage, et. al. 2008, (Budde et al., 2008) Humboldt University	115 children attending an elite performance school in Berlin (mean age 15, SD 0.9 years)	Intervention with random assignment to coordinative exercise or sport lesson intervention with pre- and post-concentration and attention testing	Children randomly assigned to experimental (coordinative exercise) or control group (normal sport lesson). Pre-test before session and post-test after either coordinative exercise or normal sport lesson.	• D2-test (test of concentration and attention)	D2-test results were significantly higher post-exercise intervention (both coordinative and normal sports lesson). Interaction between group by performance thus subsequent ANOVA indicated that coordinative exercise led to significantly higher improvement in concentration and attention.	+	No inactive control group. D2-test learning may have occurred thus resulting in higher scores post-intervention.
Davis, Tomporowski, et al., 2007, (Davis et al., 2007) Medical College of Georgia	Intervention where children were randomly assigned to low-dose, high-dose exercise program or control condition.	94 sedentary overweight children aged 7-11 years from Augusta, Georgia	Standardised cognitive assessment test was administered before and after intervention.	• Cognitive Assessment Systems (standardised test for cognitive processes)	Planning scores for high-dose group significantly greater than control. No difference between low-dose and control.	+	Data from overweight sedentary children only thus may have limited generalisability. Children not blinded to their assignment group.

Author, year and organisation	Study design	Sample	Methods	Measures	Results	Association	Study limitations
Ahamed, Macdonald et. al. 2007, (Ahamed et al., 2007)	16-month cluster randomised controlled trial. Intervention involving Action School BC with pre- and post-academic performance testing.	Data from eight schools including 214 children from grades 4 and 5.	Half schools participated in higher PE each week and thus less academic activity. Control schools maintained usual activity.	• CAT3 (academic achievement) • Teacher logs of PE time • PAQ-C to measure child report of PA	Although children spent less time in academic activity in the higher PE schools, this had no significant impact on standardised test scores.	+ (improved learning per unit of time)	Children at the higher scoring schools may have been higher performers. School SES not assessed. PA self-report used.
Coe, Pivarnik, Womack, et. al. 2006, (Coe et al., 2006) Michigan State University	Intervention study where children were randomly assigned to PE during first or second semester	214 grade 6 children attending one Michigan Public School	Children were randomly assigned to PE during either first or second semester. When not doing PE, children participated in an exploratory task such as art or computer.	• Grades (maths, sciences, English, world studies) • Standardised test scores • PA assessed using SOFIT and 3 Day Physical Activity Recall	Although children spent less time in academic activity while enrolled in PE, this had no significant impact on standardised combined test scores. High vigorous activity out of school was significantly associated with higher combined test scores.	+ (improved learning per unit of time) + for vigorous activity	Only one school. No control group. SES not assessed.

Author, year and organisation	Study design	Sample	Methods	Measures	Results	Association	Study limitations
Mahar, Murphy et al., 2006, (Mahar, 2006) East Carolina University	Classroom-based intervention incorporating 'Energizers'- 10 minutes' classroom-based PA each day.	243 kindergarten through to Year 4 children in 15 classes at one school in North Carolina.	Pre- and post-test of observed on-task behaviour of 3rd and 4th grade students only	• Pedometers • Observation of on-task behaviour for each child every 10 seconds.	Children in Energizer groups took significantly more steps post intervention compared to control group. Children in the Energizer group also scored better in on-task behaviours post intervention.	+	Pedometers only measured steps not PA intensity. Test performance may have been influenced by other factors (than PA).
Sallis and McKenzie 1999, (Sallis JF et al., 1999) San Diego State University	Intervention study with two experimental groups and one control group	Southern California single school district, seven schools	Schools were randomly assigned to PE taught either by specialists, trained teacher or control (class teacher).	• Achievement test • Direct observation of time spent in PE classes	Children in Specialist and Trained Teacher schools spent significantly less time in non-PE academic and significantly more time doing PE than control schools without impacting on standardised academic achievement test scores.	+ (improved learning per unit of time)	Sample from affluent school district. Measure of PE class time only (no measure sport or time or PA time).
Shephard and Lavallee, 1994 (Shephard RJ et al., 1994) University of Toronto	Intervention study	546 primary school children from an urban and rural school	Study group received one additional hour per day of PE, taught by a specialist PE teacher. Controls received 13-14% more academic time than the experimental group.	• Unweighted average of classroom marks for: French (first language), maths, English, science and mean of all five assessments	No significant difference in academic achievement detected in first year of study. However, the next year grades 2, 3, 5 and 6 study group students significantly outperformed control group students in academic achievement. Girls gained a larger academic advantage than boys in the enhanced physical education class.	+ (one year later)	No information regarding the two-year post intervention period prior to follow up. Intervention held at same school, contamination of study and/or control groups may have occurred.

Author, year and organisation	Study design	Sample	Methods	Measures	Results	Association	Study limitations
Dwyer, Coonan et al., 1979 (Dwyer T et al., 1979; Dwyer T, Coonon W.E., Leitch D.R., Hetzel B.S., & Baghurst P.A., 1983), University of Tasmania	Intervention study with two experimental and one control group	519 grade 5 (10-year-olds) from seven self-selected schools in Adelaide. Three classes were selected from each school.	The three classes randomly allocated to one of three groups: fitness, skill or control. Intervention took place over 14 weeks. Trained and blinded personnel performing physical measurements and marking tests.	• Height and weight • Skin-fold thickness • Endurance fitness • Two measures of academic success (arithmetic and reading tests)	Despite reduction in academic learning time for the fitness and skills groups (210 mins per week, 14% of total teaching time) no significant differences in arithmetic performance or reading skills gains evident. At two-year follow-up, intervention schools had an advantage in teacher ratings of classroom behaviour.	+ (improved learning per unit of time)	Short period of observation

+, positive association; **Ass**, association; **CAT3**, Canadian Achievement Test 3; **EEG**, electroencephalogram; **FCAT**, Florida Comprehensive Achievement Test; **IQ**, intelligence quotient; **PA**, physical activity; **PAQ-C**, Physical Activity Questionnaire for Children; **PE**, physical education; **SES**, socio-economic status; **SOFIT**, System for Observing Fitness Instruction Time; **WRAT3**, Wide Range Achievement Test V3.

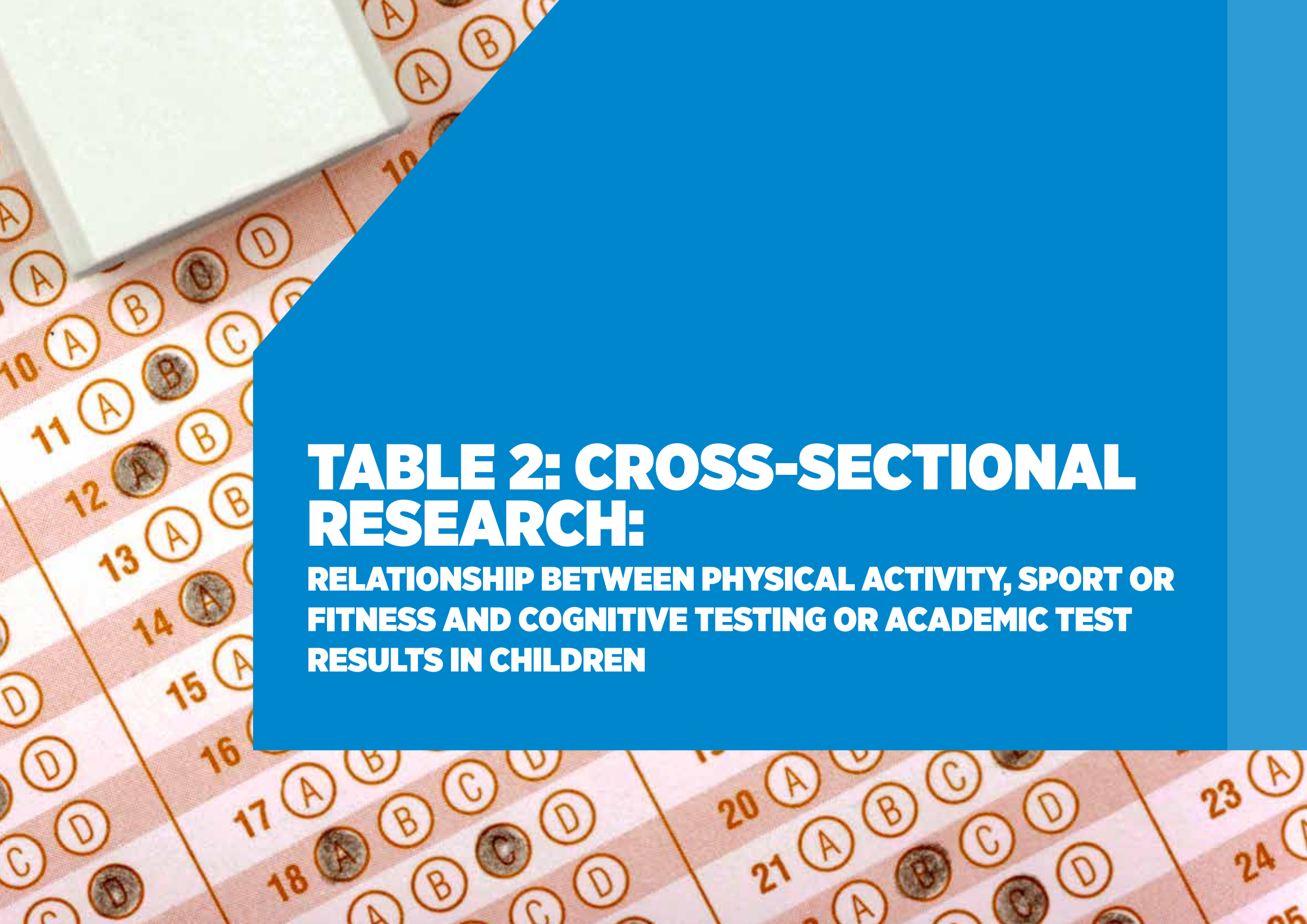

TABLE 2: CROSS-SECTIONAL RESEARCH:

RELATIONSHIP BETWEEN PHYSICAL ACTIVITY, SPORT OR FITNESS AND COGNITIVE TESTING OR ACADEMIC TEST RESULTS IN CHILDREN

Table 2: Cross-sectional research: relationship between physical activity, sport or fitness and cognitive testing or academic test results in children

Author, year and organisation	Sample	Methods	Measures	Results	Association	Study limitations
Bass et al., 2013, (Bass et al., 2013) Illinois State University, USA	Participants were students from a public middle school (grades 6–8) in central Illinois	Correlational design	The FITNESSGRAM test battery assessed students (n = 838) in the five components of health-related fitness. The Illinois Standardised Achievement Test (ISAT) was used to assess academic achievement in reading and math.	The largest correlations were seen for aerobic fitness and muscular endurance (ranging from 0.12 to 0.27, all $p < 0.05$). Boys in the Healthy Fitness Zone (HFZ) for aerobic fitness or muscular endurance were 2.5–3 times more likely to pass their math or reading exams. Girls in the HFZ for aerobic fitness were approximately 2–4 times as likely to meet or exceed reading and math test standards	+	First, this was a cross-sectional study, and causation cannot be established.
Pirrie & Lodewyk, 2012, (Pirrie & Lodewyk, 2012) Brock University, Ontario, Canada	Participants were two classes of fourth-grade students in Ontario (n = 40).	The study recruited 40 fourth-grade students from two classes in two independent schools (one semi-urban [n = 19] and one rural [n = 21]) in a school district situated in south-western Ontario, Canada.	Students in the two classes completed standardised tests for each cognitive process both after no physical activity and following it (20-minute MVPA within a 45-minute lesson).	The results indicate that performance on the planning test significantly improved after physical activity ($p<0.001$), controlling for sequence and habituation/retesting effects. No improvement was observed for attention, simultaneous processing, or successive processing.	+ planning 0 attention 0 simultaneous processing, 0 successive processing	For all of the cognitive tests, test administration timing post-activity may have impacted the strength of results.

Author, year and organisation	Sample	Methods	Measures	Results	Association	Study limitations
Jonker, Elferink-Gemser, Toering, Lyons, & Visscher, 2010, (Jonker et al., 2010) University Medical Center Groningen	128 elite soccer players aged 12-16 years, and 164 aged-matched controls (typical students)	Elite youth aged matched with typical students	Self-completed questionnaire	Findings suggests that the relatively stronger self-regulatory skills (self-conscious, goal-oriented, and problem-focused behaviours) reported by the elite youth soccer players may be essential for performance at the highest levels of sport competition and in academia.	+	Caution is needed regarding this proposition, as it may also be the case that the elite youth soccer players are high achievers in sport and education because of an inherent ability to self-regulate. In other words, do the elite youth soccer players compete at a high level because their self-regulatory skills were developed through sport, or because these skills were inherent?

Author, year and organisation	Sample	Methods	Measures	Results	Association	Study limitations
Jonker, Elferink-Gemser, & Visscher, 2009, (Jonker et al., 2009) University Medical Center Groningen	400 talented athletes participated in this study	Athletes were classified as 'talented athletes' on the basis of their qualifications by the Netherlands Olympic Committee and Sports Federation (NOC*NSF) and were therefore all part of a talent program.	Self-completed questionnaire	When compared with the national average, the athletes in 2006-07 attended pre-university classes more often ($\chi 2 = 57.001$, $p<.05$). Of the 2006-07 athletes, a higher percentage participated in pre-university programs compared with that of athletes in 1992-93 ($\chi 2$ (1, n = 400) = 32.003, $p<.05$), whereas the national averages showed stability ($\chi 2 = .325$, $p>.05$).	+	Within the Dutch educational system, all students are used to the possibility to ask for extra supervision or help by a mentor if required. Therefore, talented athletes who are also high achievers academically may be based on differences in instruction caused by the special provisions offered to them.

Author, year and organisation	Sample	Methods	Measures	Results	Association	Study limitations
Kristjánsson, Sigfúsdóttir, Allegrante, & Helgason, 2009, (Kristjánsson et al., 2009) Reykjavik University, Iceland	5,810 adolescents	Self-completed questionnaire	• Academic achievement • School contentment • Body mass Index • Sedentary lifestyle • Physical activity	Model explained 36% of the variance in academic achievement and 24% in school contentment. BMI and sedentary lifestyle were negatively related to school contentment and academic achievement, but physical activity was positively related to school contentment and academic achievement (P< .01). School contentment was strongly related to academic achievement but only a weak mediator of the health behaviour indicators. Findings may inform the efforts to improve academic achievement and the general health status of youth.	+	Some of the measured relationships are quite weak, particularly those stemming from BMI and sedentary lifestyle.

Author, year and organisation	Sample	Methods	Measures	Results	Association	Study limitations
Kwak et al., 2009, Unit for Preventive Nutrition, Sweden (Kwak et al., 2009)	Swedish 9th-grade students (n = 232; mean age = 16 years; 52% girls)	Groups of pupils, within each school (n = 42), were randomly selected proportional to the sizes of the respective schools.	• School grades, pubertal phase, skinfold thickness, cardiovascular fitness, and physical activity were measured objectively. Mother's education, family structure, and parental monitoring were self-reported. Data were analysed with linear regression analyses.	In girls, academic achievement was associated with vigorous physical activity and not mediated by fitness, whereas in boys only fitness was associated with academic achievement.	+	Further studies are necessary to investigate the potential longitudinal effect of vigorous physical activity on academic achievement, the role of fitness herein and the implications of these findings for schools. The use of accelerometers, even though seen as a "golden standard"; they are limited in capturing any activities with little displacement of the body, such as cycling and snow-boarding.

Author, year and organisation	Sample	Methods	Measures	Results	Association	Study limitations
LeBlanc et al., 2012, (LeBlanc et al., 2012) Southeastern Louisiana University, USA	Participants were 1,963 children in fourth to sixth grades.	Correlational design. Adiposity was assessed by calculating body mass index (BMI) percentile and percent body fat and academic achievement with statewide standardised tests in four content areas. Socioeconomic status and age were control variables.	Children wore an accelerometer for three days to provide objective measurement of physical activity. In addition, the association between weight status and academic achievement was examined by comparing children who could be classified as "extremely obese" and the rest of the sample, as well as comparing children who could be classified as normal weight, overweight, or obese. Extreme obesity was defined as >1.2 times the 95th percentile	These results do not support the hypotheses that increased adiposity is associated with decreased academic achievement or that greater physical activity is related to improved achievement.	0	These results are limited by methodological weaknesses, especially the use of cross-sectional data.
Morales, Pellicer-Chenoll, Garcia-Masso, Gomis, & Gonzalez, 2011, Universitat Ramon Llull, Barcelona, Spain (Morales et al., 2011)	284 students (158 girls, 126 boys) with an average age of 14.7 years participated.	Self-completed survey instrument	• Physical activity measures • Student academic records	Results showed that there was a linear relationship between academic performance and physical activity; nevertheless, there was a trend to stronger correlation when modelling the relationship between these variables with a quadratic equation.	+	Did not directly account for whether academic performance and physical activity might be better explained with a second-order equation.

Author, year and organisation	Sample	Methods	Measures	Results	Association	Study limitations
Fox, Barr-Anderson, et. al. 2010,(Fox et al.) University of Minnesota	31 middle and high schools in metropolitan Minnesota, n = 7746 children	Students completed the EAT survey, demographic information, sport team participation and GPA questions.	• Sports team participation (on how many sports teams did you play in the last 12 months) and academic grades (GPA) (two grades achieved most often) • Self report of PA measured using LTEQ	High school girls: PA and sport team participation independently associated with higher GPA; high school boys sports team participation independently associated with higher GPA; middle school students PA and sports team participation combined association with higher GPA.	+	All data were self report.
Roberts, Freed, McCarthy, 2010, (Roberts, Freed, & McCarthy, 2010) University of California	1989 children in Years 5, 7 and 9 attending middle- to high-income South Carolina school district public schools.	Aerobic fitness, body weight, student demographic data, standardised test score data and school district demographic data were taken from school and district information. Parents reported additional demographic data.	• Fitnessgram • demographic • overweight risk status (from CDC weight status cut-points) • California Achievement Tests version 6 (CAT6) and California Standards Tests (CST)	Aerobic fitness significantly related to standardised test scores. BMI significantly inversely related to standardised test scores.	+	Limitations to Fitnessgram as measure of aerobic fitness. Children's efforts may have impacted upon Fitnessgram results.

Author, year and organisation	Sample	Methods	Measures	Results	Association	Study limitations
Carlson, Fulton et.al. 2008, (Carlson et al., 2008) Centers for Disease Control and Prevention	5,316 kindergarten children nationally representative sample from longitudinal study	Teachers reported PE. Children were given maths and reading tests. Demographics collected from parents via telephone.	• PE minutes per week collected from teachers • Maths and reading scores on item response theory scale	Girls who were enrolled in higher amounts of PE achieved higher maths and reading scores.	+ (girls) 0 (boys)	Time spent in PE self report and no reliability or validity assessment of this measure.
Castelli, Hillman, et. al. 2007, (Castelli, Hillman, Buck, & Erwin, 2007) University of Illinois	259 3rd and 5th grade children at four public schools	Children completed fitness testing and ISAT at school.	• Fitnessgram (muscle fitness, aerobic capacity, body composition) during PE. • ISAT	Physical fitness positively associated with academic achievement. BMI inversely related to academic achievement. Associations noted for total academic and maths and reading achievement.	+	Methods used for measuring fitness have limitations. Sampling not random.
Tremarche, Robinson, 2007, (Tremarche, Robinson, & Graham, 2007) Bridgewater State College	Convenience sample of 311 4th grade students attending two Massachusetts schools.	Comparison of test results at two schools: School 1 providing 28 hours and School 2 providing 56 hours of PE per year.	• MCAS (maths and English language and arts) • School demographics	Average English and language arts score higher at school with PE time greater than school with lower PE time. No difference in maths score averages between scores.	+ (English and language arts) 0 (maths)	Convenience sample of children tested. While many school demographics measured, other school characteristics may have influences results.

Author, year and organisation	Sample	Methods	Measures	Results	Association	Study limitations
Dollman,Boshhoff et al 2006, (Dollman J et al., 2006) University of South Australia	117 South Australian Primary Schools.	Principal (or representative) completed questionnaire. Academic attainment data received from the education department. School averages for numeracy and literacy calculated.	• Minutes each class spent in PE during previous week	Schools with high levels of time spent in PE do not have lower academic achievement despite spending less time in academic subjects. No difference in academic scores in relation to time spent in PE.	+ (improved learning per unit of time)	Low response rate of schools invited to participate in study (30%). Schools committed to PE may be more likely to participate in study. Did not account for quality of PE. School level data used.
Sigfusdottir, Kristjanson et. al. 2006, (Sigfusdottir et al., 2006) Reykjavik University	All secondary schools in Iceland sent questionnaires for children aged 14 and 15 (9th and 10th grade). 6,346 students in total.	Data obtained from 2000 Icelandic study, 'Youth in Iceland'. Self-completed survey instrument.	• Self report of academic achievement • Self report of height, weight and PA levels	PA was a significant predictor of academic achievement when controlling for other variables. Body mass index, diet and PA explained up to 24% of the variance in academic achievement when controlling for gender, parental education, family structure and absenteeism.	+	Height and weight self report. Self report of PA levels. Data of individuals who did not enter a height or weight were not included possibly biasing results. Self report of average grades may not have reflected actual grades.

Author, year and organisation	Sample	Methods	Measures	Results	Association	Study limitations
Hillman, Castelli et. al. 2005, (Hillman, Castelli, & Buck, 2005) University of Illinois	51 children and adults. 24 children recruited from Champaign elementary school system	Fitness tested using Fitnessgram. K-Bit Cognitive task and EEG administered. Matching of high and low fit participants to assist controlling for demographics.	• Demographics • Fitnessgram • EEG using 10-120 system • Cognitive task (visual oddball paradigm) • K-BIT to measure IQ	High-fit children had significantly faster reaction times than low-fit children to target stimuli.	+	Other factors not measured could account for differences. Small sample size. Field test of fitness rather than more accurate objective measure.
Lidner, 2002, (Lidner KJ, 2002) The University of Hong Kong	Two randomly selected classes from randomly selected high schools in Hong Kong. 1,447 students aged 13-17 years.	Self-completed survey instrument	• Academic records collected from schools • Self report questionnaire	Significant positive link between academic performance and PA participation. Significant positive relationship between PA participation and by band level of students (school grouping based on primary academic achievement).	+	No objective measure of PA used.

Author, year and organisation	Sample	Methods	Measures	Results	Association	Study limitations
Dwyer, Sallis et al 2001, (Dwyer T et al., 2001) University of Tasmania	Randomly selected, nationally representative sample of 7,961 Australian Schoolchildren aged 7-15 years	Data collected by 10 data collectors in each Australian state as part of the Australian Schools Health and Fitness Survey in 1985. Ratings of scholastic ability were given for each participant by school representative.	• Field tests of PA and fitness measures collected by trained data collectors • School ratings of scholastic ability • Questionnaire: self perceived academic ability, involvement in exercise and sport	School ratings of scholastic ability were significantly associated with physical fitness, capacity and activity. There were also weak but consistent associations between scholastic ability and field tests of muscular force, endurance and power. Non-consistent results of cardio-respiratory endurance.	+	Disparity between two cardio-respiratory endurance results may be due to possible measurement bias or confounding. Field tests may have been influenced by motivation of students to perform.
Field, Diego et al 2001, (Field T et al., 2001) University of Miami School of Medicine	89 high school students	Self-completed questionnaire which included behavioural and exercise measures	• Exercise regularity per week • Sports involvement • Grade point average	Students reporting a high level of exercise spent significantly more time in sport and higher grade point averages.	+	All measures were self report. Small number of study participants.

Author, year and organisation	Sample	Methods	Measures	Results	Association	Study limitations
Tremblay, Inman and Willms, 2000, (Tremblay, Inman, & Willms, 2000) University of New Brunswick	74.3% of total population of grade 6 students in New Brunswick Canada (n=6856)	Data from the Elementary School Climate Study used. Children completed of and study questionnaire and this was linked to standardised achievement test data collected by the education department.	• Maths and reading scores • BMI self report • SES • Study questionnaire, four questions on PA participation	No significant relationship between PA and maths and reading scores.	0	BMI and PA data self-report.
Dexter 1999, (Dexter T, 1999) University of Cambridge	517 candidates from sample of 17 schools taking the General Certificate of Secondary Education (GCSE)	Review of records	• Academic ability calculated from Maths and English GCSE scores • GCSE PE score	Significant positive correlation between academic ability and sport performance	+	Sport performance measurement taken under test conditions may not reflect normal performance.

Author, year and organisation	Sample	Methods	Measures	Results	Association	Study limitations
Lidner 1999, (Lidner KJ, 1999) The University of Hong Kong	One or two randomly selected classes from randomly selected primary and high schools in Hong Kong. 4,690 children grades 5-12.	Age adapted self-completed survey instrument	• Sport participation survey instrument • Desired sport activities • Self perceived rating of academic performance • Self-perceived rating of sport and PA ability	Frequency and extent of sports participation significantly higher for student with high self-ratings of academic performance	+	Self-reported rating of academic performance used. Use of grouping students of primary school students based on academic scores to their secondary school may have affected their self-perceived academic success.
Sillijer and Quirk 1997, (Silliker SA & Quirk JT, 1997) St Bonaventure University	123 high school students from five similar schools	Counsellor identified students involved in soccer. Data collected on a data sheet by school counsellor in- season and out- of-season.	• Grade point averages (GPA) for in and out of season	Participants had significantly higher GPA in-season than out-of-season.	+	Data collected only for soccer players. Small sample size. Schools not randomly selected. GPA may have been influenced by another seasonal factor.
Dwyer, Blizzard et al 1996, (Dwyer T et al., 1996) The University of Tasmania	2,400 Australian randomly selected children from 9000 school children recruited into the ASHRS study from 109 schools	Self administered questionnaire and field testing by trained personnel	• Skinfold thickness • Endurance fitness • Leisure activity • Academic performance	PA and physical capacity were significantly positively related to scholastic rating. These associations remained after adjusting for relevant confounders.	+	Motivation may have effected field testing results.

Author, year and organisation	Sample	Methods	Measures	Results	Association	Study limitations
Fisher, Juszczak et al 1996, (Fisher et al., 1996) North Shore University Hospital and Cornwell University Medical College	838 students in one school.	Self-completed questionnaires during gym class	• Sports questionnaire including number and type of sports and time spent in sport • Self report average grade	Time spent playing sport was not significantly associated with academic performance.	0	All students were involved in at least one sport. Small sample. All measures self-report. Questionnaires distributed during gym class. Reliability and validity testing of sports questionnaire not reported.
Pate, Heath et. Al 1996, (Pate, Heath, Dowda, & Trost, 1996) University of South Carolina	11,631 high school students	Self-completed questionnaire	• Self perceived academic performance • Level of exercise in last 2 weeks • Involvement in sports teams (community and school-based)	High PA levels were significantly associated with participation in high levels of sport. Low activity was associated with low perception of academic performance.	+	Measures were all self report. Perception of academic performance may not reflect actual academic performance.

+, positive association, **0**, no association; **Ass**, association; **BMI**, Body mass index; **EAT**, Eating Among Teens; **CAT6**, California Achievement Tests version 6; **CST**, California Standards Tests; **GPA**, grade point average; **ISAT**, Illinois Standards Achievement Test; **K-BIT**, Kaufman Brief Intelligence Test; **LTAQ**, Leisure Time Activity Questionnaire; **MCAS**, Massachusetts Comprehensive Assessment Systems; **PA**, physical activity; **PE**, physical education.

TABLE 3: RESEARCH REVIEWS:

RELATIONSHIP BETWEEN PHYSICAL ACTIVITY, SPORT OR FITNESS AND COGNITIVE TESTING OR ACADEMIC TEST RESULTS IN CHILDREN

Table 3: Research reviews: relationship between physical activity, sport or fitness and cognitive testing or academic test results in children

Author, year and organisation	Studies included	Methods/ presentation of literature	Results/conclusions	Associations	Review limitations
Ahn & Fedewa, 2011 (Ahn & Fedewa, 2011) University of Miami, USA	73 published and unpublished studies, totalling 246 effect sizes	Based on a literature review, a systematic coding scheme was developed to identify salient features of each study.	Results demonstrated varying effects depending on the methodology of the examined study [i.e., correlational vs. randomised controlled trial (RCT)/non-RCT] and characteristics of the participants, although overall effects of physical activity on children's mental health were small but significant, indicating that on average physical activity led to improved mental health outcomes for all children.	+	Slight publication bias existed for the current analysis, which might threaten the validity of research findings in the current meta-analysis.
Esteban-Cornejo, Tejero-Gonzalez, Sallis, & Veiga, 2014 (Esteban-Cornejo, Tejero-Gonzalez, Sallis, & Veiga, 2014) University of Madrid, Madrid, Spain	20 articles	Percentages were used to number the links	The findings of these studies show that cognitive performance is associated with vigorous physical activity and that academic performance is related to general physical activity, but mainly in girls. Results of the review also indicate that type of activity and some psychological factors (i.e., self-esteem, depression) could mediate the association between physical activity and academic performance.	+	Studies were not ranked or weighted, and as a result, findings from studies with weaker designs and smaller sample sizes were given no less importance than findings from studies with more rigorous research designs and larger sample sizes.

Author, year and organisation	Studies included	Methods/ presentation of literature	Results/conclusions	Associations	Review limitations
Howie & Pate, 2012, (Howie & Pate, 2012) University of South Carolina, Columbia,	A brief review of studies	A total of 125 published articles were included and reviewed. Fifty-three of these articles were published in the past five years.	In recent years, the overall quality of the studies has increased, but the results continue to be inconsistent. Many use cross-sectional designs and the methods vary substantially. The majority of conclusions show a positive effect of PA on constructs related to academic achievement. Future studies should use strong study designs to examine the types and doses of PA needed to produce improvements in academic achievement.	+	To increase the breadth, the review included a wide range of published studies on PA and academics with less rigorous exclusion criteria than previous reviews. Inclusion criteria did not limit multiple publications from a single study, thus studies with multiple publications may have biased the results. Only studies published in peer-reviewed journals were included, excluding dissertations.
Kibbe et al., 2011, (Kibbe et al., 2011) The George Washington University, USA	Review of the literature	Relevant studies identified using three different databases	Children participating in the TAKE 10! program experience higher PA levels, reduced time-off-task, and improved reading, math, spelling and composite scores.	+	Focused solely on TAKE 10!
Rasberry et al., 2011 Centers for Disease Control and Prevention, Atlanta, USA	Findings of the 50 studies were summarised.	Relevant research was identified through a search of nine electronic databases using both physical activity and academic-related search terms.	Results suggest physical activity is either positively related to academic performance or that there is not a demonstrated relationship between physical activity and academic performance.	+	Studies were not ranked, weighted, or grouped according to their strengths and limitations

Author, year and organisation	Studies included	Methods/ presentation of literature	Results/conclusions	Associations	Review limitations
Trudeau and Shephard 2008, (Trudeau & Shephard, 2008) Université du Québec à Trois-Rivières	• Quasi-experimental: seven studies • Correlation: 10 studies	Tabulation and summary of studies identified from MEDLINE, PSYCHINFO, SCHOLAR. GOOGLE.COM and ERIC databases.	Quasi experimental data show: allocation of up to one hour a day of academic time to PA programs does not affect academic performance, additional emphasis on PE may results in small gains in GPA, relative increase in performance per unit of academic teaching time. Correlation data show: positive association between PA and academic performance, fitness not related to academic performance, PA positive impact on concentration, memory and classroom behaviour.	+	Difficult to draw conclusions with small number of intervention studies.
Fedewa, A. L., & Ahn(Fedewa & Ahn, 2011) Department of Educational, School, and Counseling Psychology at University of Kentucky	59 studies from 1947 to 2009 for analysis	Comprehensive, quantitative synthesis of the literature	Results indicated a significant and positive effect of physical activity on children's achievement and cognitive outcomes, with aerobic exercise having the greatest effect. A number of moderator variables were also found to play a significant role in this relationship. Findings are discussed in light of improving children's academic performance and changing school-based policy.	+	Future research would advance the body of literature in this area tremendously by explicitly defining the studied population and presenting data that would allow for ES calculations.

Author, year and organisation	Studies included	Methods/ presentation of literature	Results/conclusions	Associations	Review limitations
Lees, C., & Hopkins, J. (2013) (Lees & Hopkins, 2013)	Eight relevant randomised control trials that met inclusion criteria	A systematic review	Aerobic physical activity is positively associated with cognition, academic achievement, behaviour, and psychosocial functioning outcomes.	+	This study did not include either unpublished research findings or non-English studies, which may have resulted in the loss of relevant research. Publication bias may also have resulted in relevant studies (especially those demonstrating an equivocal outcome) not being published.
Taras 2005, (Taras H, 2005) University of California	14 articles examining the association between PA in school aged children and academic performance identified	Description of previous studies presented in table form and discussed	Physical activity may have some short term benefits on concentration.	+	Review did not identify all studies in the relevant area.
Sibley and Etnier 2003, (Sibley & Etnier, 2003) Arizona State University	16 studies using true experimental design were included in the analysis, seven of these were unpublished.	Studies were coded by design, subject characteristics, activity characteristics and cognitive assessment.	Significant positive relationship between PA and cognitive functioning in children. Effect size 0.32 which indicates that the group exposed to PA showed an improvement in cognition equivalent to 0.5 of a standard deviation. Results support that participation in PA leads to improvements in cognitive function.	+	Results of meta-analysis are limited by the designs of the studies in the area. Seven studies were unpublished so may have not met publication review rigour.

Author, year and organisation	Studies included	Methods/ presentation of literature	Results/conclusions	Associations	Review limitations
Tomporowski 2003, (Tomporowski P.D., 2003) University of Georgia	Review of four research studies on youth without clinical disorder and 18 with clinical disorders	Description of findings of studies performed to assess acute effects of exercise on children's and adolescents' behaviour and cognition.	Acute bouts of PA exert short-term positive benefits on the behavioural and cognitive functioning of youths.	+	Review based on mainly studies on youths with clinical disorders and focuses on acute bouts of activity.
Shephard, 1997, (Shephard, 1997) University of Toronto	Review of four intervention projects	Description of previous intervention studies: methods, results, conclusions and limitations.	Academic learning per unit of class time is enhanced in physically active children.	+ (improved learning per unit of time)	Review limited to only interpretation of findings from four studies.

GPA, grade point average;
PA, physical activity.

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