Brain boost: Sport and physical activity enhance children's learning

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What is the issue?

Sport and physical activity participation are generally promoted for their positive impact on children's physical and mental health.[1] However, increased participation in sport and other forms of physical activity are also thought to lead to enhancement of cognitive functioning (information processing), memory, concentration, behaviour and academic achievement for children. The link between physical activity and academic achievement is of increasing interest in the field of education and sport.

Unfortunately, with increasing pressure on schools to ensure children achieve academic success, and the new practise of publicised average grade comparison between schools, physical activity classes (such as physical education and sport) are increasingly being pushed down the curriculum priority list. Of concern, it appears that time spent in physical activity during the school day is diminishing;[2-4] at some schools the average moderate to vigorous physical activity during the class has been reported as being less than 10 minutes daily. Removing or reducing physical activity classes from the school day may be detrimental to children's physical and mental health as research indicates that school day physical activity is associated with total daily physical activity.[5-7]

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.[8, 9] Evidence also suggests that achieving a threshold amount of physical activity may be necessary to acquire learning benefits,[10] and that participation in vigorous physical activity may further enhance learning.[11] Further to this, there is evidence that there has been a reduction over the years in children's participation in physical activity and organised community sport, and this is particularly evident in Australia.[12]

Previously, we reported the research evidence related to the relationship between physical activity or sport and learning or academic success.[13] This report provides an update of evidence reported from Australian and international research published in peer-reviewed journals; providing summaries of intervention research (Table 1), correlational studies (Table 2) and research reviews (Table 3).

> "The link between physical activity and academic achievement is of increasing interest in the field of education and sport."

What does the evidence tell us?

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

Studies exploring the relationship between physical activity or fitness and academic achievement amongst children and adolescents have been now undertaken in a number of countries and are summarised in Tables 1 and 2.

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.

Intervention studies, which generally measure baseline academic achievement scores, introduce a physical activity or physical education program and then remeasure scores, have concluded that:

- a two-year physical activity intervention led to significant improvements in children's maths scores;[8]
- average academic achievement of children in a case group (who received extra physical education) was significantly higher than children who were in the control group (who did not receive extra physical education) in a second year follow up;[9]
- greater vigorous physical activity out of school resulted in higher test scores;[11]
- reading comprehension improved following a 20-minute treadmill walking aerobic activity.[14]

Correlation studies, which explored the relationship between either physical activity or fitness and academic achievement retrospectively or prospectively, have found:

- physical activity was a significant, positive predictor of academic achievement. Body mass index, diet and physical activity explained up to 24% of the variance in academic achievement after controlling for gender, parental education, family structure and absenteeism;[15]
- there was a significant, positive link between physical activity participation and academic performance;[16]
- higher physical fitness, physical capacity and physical activity were associated with higher school ratings of scholastic ability;[17]
- students who reported a greater level of exercise spent more time in sport and achieved higher grade point averages;[18] and
- greater physical activity level was associated with positive achievement orientation.[19]

In addition to these findings, four intervention studies, one correlation study and one research review highlighted that children can spend less time in academic learning and more time being physically active during the school day, without affecting academic success or progress.[11, 20-24] This suggests superior learning occurs with greater physical activity participation,[25] supporting the theory that increasing physical activity has a positive impact on learning.[26] However, some studies have failed to find a relationship between physical activity and learning,[27, 28] and one study identified the relationship for girls only.[29]

Ideally, an intervention study would add physical activity or sport to the day for an intervention group and maintain a similar amount of academic learning time to those in a control group (for example by adding fitness or sport before school for one group). This would provide a clearer picture as to any improvement in academic grades from increased physical activity. It appears this approach has not yet been used.

What is the relationship between participation in organised sport and academic achievement?

Total physical activity participation can also be increased by increasing children's involvement in organised community sport and recreation,[30] and organised community sport and recreation have been indicated as exerting a positive effect on children's academic success and attitude to school.[31, 32]

Studies examining the correlation between sport participation and academic success have identified:

- a significant, positive correlation between sport performance and academic ability;[33]
- that the frequency and extent of sports participation were significantly greater for students with high self-ratings of academic performance;[34]
- that sports participation of high school children was associated with higher grade point average;[35]
- that sports team participation and physical activity combined were associated with a higher grade point average of middle school students;[35] and
- that sport performance was significantly associated with academic ability.[33]

What does the evidence tell us?

With evidence that children who are involved in more organised community sports or recreation are likely to perform better academically, benefits from implementing strategies to increase children's involvement in community sports may 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[9, 23] provide some evidence that gains in academic achievement are achieved following greater physical activity participation, suggesting that physical activity is impacting upon learning. While children who put more effort into increasing physical activity possibly try harder academically, a more likely explanation for improved learning from greater physical activity is due to mechanisms underlying the relationship (such increased fitness being associated with faster reaction time[36]) identified by international peer-reviewed research.[37-39]

How may physical activity and sport improve learning?

Learning can be examined from multiple contexts 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 learning measuring 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.[37] 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). This model, developed for this review, highlights the multitude of pathways through which sport and physical activity have the potential to impact upon learning, test scores and academic success.

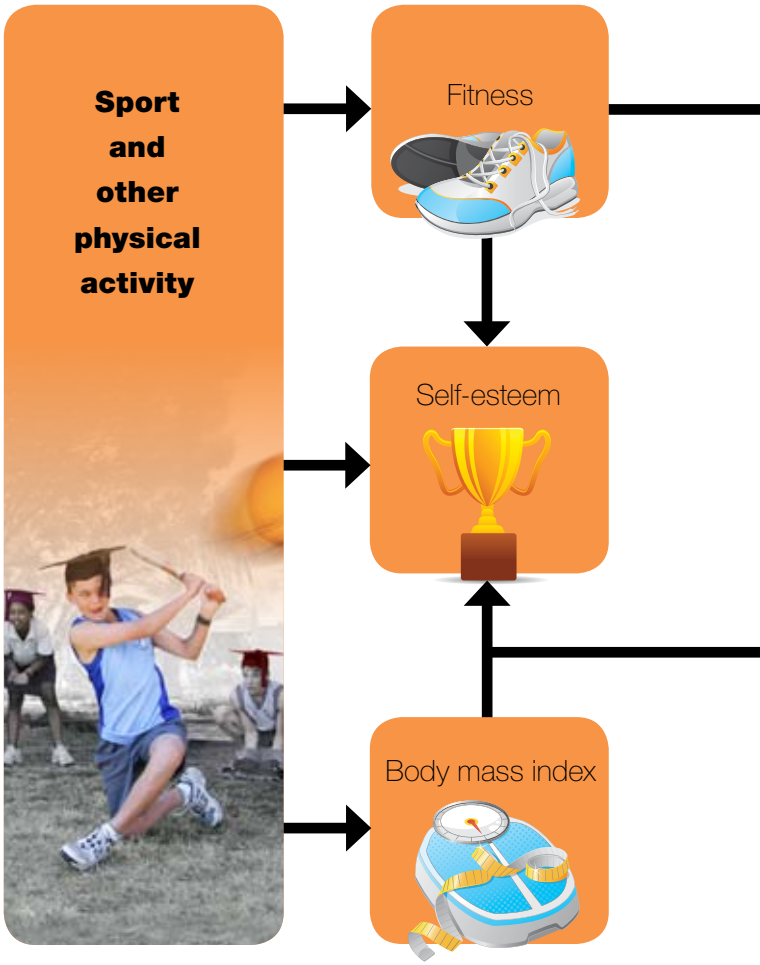
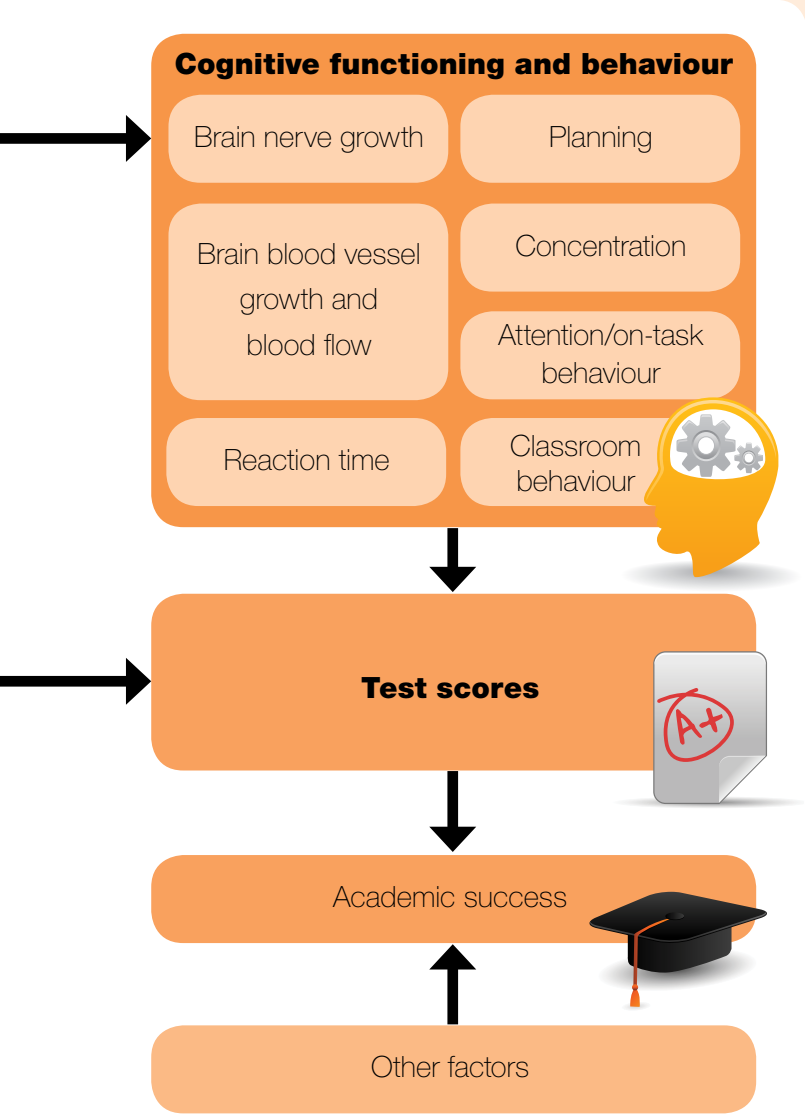


Figure 1 – Move to Learn: theoretical pathways linking physical activity, cognitive functioning and academic success

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 concentration [40, 41] and attention;[40]
- physical activity leads to improvement in children's cognitive control;[14]
- on-task behaviour was improved when children received 10-minute energiser sessions each day of the school week compared to a control group;[42] and
- study groups receiving extra physical education from a trained specialist or specially trained generalist teacher had advantage over control groups in teacher ratings of classroom behaviour.[21]



Correlation studies and reviews of research have concluded that:

- there is a significant positive relationship between children's physical activity and cognitive functioning;[10, 37] and
- acute bouts of physical activity exert short term benefits on children's cognitive functioning.[38]

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).[43] In addition, exercise has been shown to stimulate nerve growth and development in the brain and increase the brain's resistance to injury.[43] Regular physical activity may reduce plasma noradrenaline (a vasoconstrictor)[44] and bouts of exercise have been shown to increase blood flow to the cortex of the brain.[45] These physiological mechanisms indicate that regular physical activity is likely to provide children with the optimum physiological condition for maximising learning.

Implications

In Australia, 38% of children aged between five and 14 years of age do not participate in any sport organised by a school, club or association.[46] When defined by gender, nearly half (46%) of girls and just over a third (31%) of boys are not involved in organised sport. Furthermore, nearly three quarters of children (68%) do not meet national physical activity recommendations of 60 minutes of physical activity each day.[47]

The health benefits of regular physical activity are widely known, and the evidence indicates that, despite national initiatives to increase children's physical activity,[48, 49] participation in physical activity is not increasing.[50] An increasing body of evidence indicates that schools can be encouraged to maximise time children spend in physical activity and sport; and reassured that replacing academic time with physical activity and sport will not have a detrimental effect on children's academic success, and may actually support and optimise learning. Other strategies to increase children's physical activity opportunities, such as the provision of environments that increase physical activity participation are warranted. The benefits of greater physical activity participation include assisting with maximising children's learning as well as increasing physical, social and mental health which is likely to extend into adolescence and adult life.

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

Author, year & organisation	Study design	Sample	Methods
Hollar, Massiah et. al. 2010,[8] 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.
Hillman, Pontifex, et.al. 2009,[14] University of Illinois	Intervention incorporating moderate treadmill walking.	20 preadolescents (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 nine 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.
Budde, Voelcker-Rehage, et. al. 2008,[40] 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.
Davis, Tomporowski, et. al. 2007,[10] 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.
Ahamed, Macdonald et. al. 2007[20]	A 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.
Coe, Pivarnik, Womack, et. al. 2006,[11] 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.
Mahar, Murphy et. al. 2006,[42] East Carolina University	Classroom-based intervention incorporating 'Energisers' – 10 minutes classroom based PA each day.	243 kindergarten through to 4th year 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.
Sallis and McKenzie 1999,[23] 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).
Shephard and Lavallee, 1994[9] 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.
Dwyer, Coonan et al 1979,[21, 51],University of Tasmania	Intervention study with two experimental groups and one control group.	519 Grade 5 children (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.

- +, 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,

Measures	Results	Association	Study limitations
• 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.
• EEG at 64 sites. • Modified flanker test (to assess inhibitory control). • Academic level via WRAT3. • Cardiorespiratory 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).
• 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.
• 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.
• 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.
• Grades (maths, sciences, English, world studies). • Standardised test scores. • PA assessed using SOFIT and Three 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.
• Pedometers. • Observation of on-task behaviour for each child every 10 seconds.	Children in Energiser groups took significantly more steps post intervention compared to control group. Children in the Energiser 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).
• 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).
• 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.
• 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.

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

Author, year & institution	Sample	Methods	Measures
Fox, Barr-Anderson, et. al. 2010,[35] 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.
Roberts, Freed, McCarthy, 2010,[52] 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).
Carlson, Fulton et.al. 2008,[29] Centers for Disease Control and Prevention	5316 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.
Castelli, Hillman, et. al. 2007,[53] 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.
Tremarche, Robinson, 2007,[54] 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 56 hours of PE per year.	• MCAS (maths and English language and arts). • School demographics.
Dollman,Boshhoff et al 2006,[22] University of South Australia	117 South Australian primary schools.	117 South Australian primary schools.	• Minutes each class spent in PE during previous week.
Sigfusdottir, Kristjanson et. al. 2006,[15] Reykjavik University	All secondary schools in Iceland sent questionnaires for children aged 14 and 15 (9th and 10th Grades). 6346 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.
Hillman, Castelli et. al. 2005,[36] 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.
Lidner, 2002,[16] The University of Hong Kong	Two randomly selected classes from randomly selected high schools in Hong Kong. 1447 students aged 13-17 years.	Self-completed survey instrument.	• Academic records collected from schools. • Self report questionnaire.

+, 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,

Results	Association	Study limitations
High school girls: PA and sport team participation independently associated with higher GPA; high school boys sports team participation independently associated with higher GPA; middles school students PA and sports team participation combined association with higher GPA.	+	All data was self report.
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.
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.
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 has limitations. Sampling not random.
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 influenced results.
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.
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.
High-fit children were significantly faster reaction time 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.
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.

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

Author, year & institution	Sample	Methods	Measures
Dwyer, Sallis et al 2001,[17] University of Tasmania	Randomly selected, nationally representative sample of 7961 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 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.
Field, Diego et al 2001,[18] University of Miami School of Medicine	Field, Diego et al 2001,18 University of Miami School of Medicine.	Self-completed questionnaire which included behavioural and exercise measures.	• Exercise regularity per week. • Sports involvement. • Grade point average.
Tremblay, Inman and Willms, 2000,[55] 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 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.
Dexter 1999,[33] 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.
Lidner 1999,[34] The University of Hong Kong	One or two randomly selected classes from randomly selected primary and high schools in Hong Kong. 4690 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.
Sillijer and Quirk 1997,[56] 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-season and out-of-season.
Dwyer, Blizzard et al 1996,[26] The University of Tasmania	2,400 Australian randomly selected children from 9,000 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.
Fisher, Juszczak et al 1996,[27] 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.
Pate, Heath et. Al 1996,[57] University of South Carolina	11,631 high school students.	Self-completed questionnaire.	• Self-perceived academic performance. • Level of exercise in last two weeks. • Involvement in sports teams (community and school based).

+, 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,

Results	Association	Study limitations
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 cardiorespiratory endurance.	+	Disparity between two cardiorespiratory endurance results may be due to possible measurement bias or confounding. Field tests may have been influenced by motivation of students to perform.
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.
No significant relationship between PA and maths and reading scores.	0	BMI and PA data self report.
Significant positive correlation between academic ability and sport performance.	+	Sport performance measurement taken under test conditions may not reflect normal performance.
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.
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.
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.
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.
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.

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

Author, year & institution	Studies included	Methods/presentation of literature
Temporowski, Davis et. al. 2008,[58] University of Georgia	Summary of studies relating physical activity with intelligence (three studies), cognition (four studies) and academic performance (five studies). Four fitness and academic achievement correlation studies also reviewed.	Descriptions of previous studies presented in tables and summarised in text.
Trudeau and Shephard 2008,[39] 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.
Taras 2005, [41] 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.
Sibley and Etnier 2003,[37] 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.
Tomporowski 2003,[38] 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.
Shephard, 1997,[24] University of Toronto	Review of four intervention projects.	Description of previous intervention studies: methods, results, conclusions and limitations.

GPA, grade point average; PA, physical activity;

Results/conclusions	Association	Review limitations
Gains in children's mental functioning due to exercise most clearly seen on executive function tasks (i.e. goal directed actions in complex stimulus environments). Systematic exercise programs may enhance the development of specific types of mental processing known to be important for meeting challenges encountered in academic situations and through the lifespan.	+	Descriptive summary.
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.
Physical activity may have some short term benefits on concentration.	+	Review did not identify all studies in the relevant area.
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.
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.
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.

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