

**Describing the link between school
performance, healthy eating and physical
activity in children and youth:
a research synthesis**



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A RESEARCH SYNTHESIS SUMMARY HEALTHY EATING, PHYSICAL ACTIVITY AND SCHOOL PERFORMANCE

Why is this important?

Given the increasing demands on schools, it is important to understand the relationship between healthy eating, physical activity and school performance if educational partners are to be expected to invest, support and implement healthy school initiatives.

What did the report find?

Researchers have theorized that the link between healthy school food policies and programs influences school performance through improving the nutritional status of children. In the school performance related review literature reducing nutritional deficiency or food insufficiency are emerging as the mechanisms responsible for the potential relationship, and is most pronounced in children and youth with poor nutritional status or who are at a socio-economic disadvantage. The most commonly researched type of school policy or program that is reported with the capacity to could improve both nutritional deficiency and food insufficiencies are universal healthy breakfast programs. The evaluation of these programs is complex and difficult to implement, however improvements in school performance outcomes are being reported. Specifically, studies are showing that breakfast programs can improve children and youth nutritional status, and if the school is well functioning and academically strong, improvements in school performance for children and youth. This also suggests that other school food policies and programs that improve the nutritional status of children and youth through supporting healthy eating within the school have the potential to also improve school performance.

There is substantial evidence to support a relationship between physical activity and school performance with the largest effect on children's mathematics achievements, IQ and reading. School-based opportunities for physical activity is an important opportunity to improve school performance and time allocated should be viewed as enhancing, not impeding, academic achievement of students. Physical education should be part of a more comprehensive approach in schools (e.g., extra-curricular physical activity, interscholastic sports, activity breaks, recess, etc.) and smaller group, younger age and mixed-gender interventions had larger effects on school performance. The evidence suggests that physical activity could be a mechanism to stimulate and maintain learning among students that have difficulty at school or are in situations that may place them at risk for poorer health and learning outcomes.

Take away message

Finally, it should not be forgotten that scholastic achievement also depends on numerous individual (e.g. psychological, emotional), economic, familial, social and school related factors. However, it is unquestionable that improved nutritional status, through healthy regular meals, and adequate physical activity at school can play an important role in the academic success, as well as overall health, of young people. School stakeholders should consider how they could integrate healthy, school food programs and opportunities for physical activity throughout the school day to maximize both health and learning outcomes for students.

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HEALTHY EATING, PHYSICAL ACTIVITY AND SCHOOL PERFORMANCE

Establishing early healthy eating and physical activity behaviours is critical in protecting children from a lifetime of chronic disease. Schools are recognized as being an essential point of intervention to support healthy behaviours among children and youth. Schools offer inherent opportunities to support healthy eating through school food programs, and nutrition education. Furthermore, schools traditionally offer different structured (i.e., physical education, school sports) and unstructured opportunities (free-play) for physical activity throughout the school day.

Despite the unique opportunities for supporting healthy behaviours in the school setting, there is a trend to “cut-back” on important activities that support health. For example, with increasing pressure on schools to improve academic scores, schools may reduce the time allotted for physical education to increase instructional time for mathematics, language or arts. In fact, one research study reported that only 57% of Canadian schools (that were sampled) met provincial requirements for allotted time devoted to physical education (Hardman & Marshall, 2000). Moreover, initiatives to improve the school food environment often require volunteer time from school staff that is beyond their designated responsibilities. With a growing workload, these activities become difficult for school staff to maintain; especially when there is a lack of understanding of the importance and significance to student learning.

We know that health and education are interconnected (more education indicates better health and vice versa); however, the mechanisms that contribute to this relationship is not well understood (Suhrcke & de Paz Nieves 2011). Furthermore, health behaviours like healthy eating and physical activity are common focal points for school health programs, but these are not embedded and protected in our current school system. Given the increasing demands on schools, it is important to understand the relationship between healthy eating, physical activity and school performance if educational partners are to be expected to invest, support and implement healthy school initiatives.

Purpose of review

The Heart and Stroke Foundation of Canada have contracted the research consultants Tarra L Penney (TP) and Jessie-Lee McIsaac (JL) to review the literature and describe the current evidence demonstrating the link between healthy eating, physical activity and school performance in children and youth.

Review scope and methodology

The scope of this project was to examine the scientific literature to collect and synthesize studies that examined the link between healthy eating and physical activity in relation to school performance. The review included a non-systematic¹ search of PubMed, Web of Science, ERIC and PsycInfo databases for literature in the areas of healthy eating, physical activity, and school performance in children or youth using appropriate key

¹ A non-systematic search is a method of rapid review that may not capture all available evidence on a topic.

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terms². Papers were then screened by TP and JL for relevance³ and scientific merit, with studies using stronger methodological rigour (e.g. meta analysis and systematic reviews) receiving a higher rank than weaker methodologies (e.g. cross-sectional). Data was then extracted from studies including full citation, number of studies for reviews, design and study information and main findings. A summary of results can be found in the appendix and is categorized and sorted in three ways. The first is by type of manuscript in order from most comprehensive to least (review, intervention and primary study), the second is by type of outcome (diet, physical activity and the combination of both) and the last is the level of rigour of the study design from most rigorous to least (review: meta-analysis, systematic review, non-systematic review; intervention: randomized controlled trial, controlled trial, other; primary: longitudinal, cross-sectional, other).

The synthesis and following discussion was based on the most comprehensive, rigorous literature (section I.1 and I.2 of Appendix) while other sections are summarized for review by the reader (section II and III of Appendix). Included literature was then grouped according to emerging themes and presented in narrative form. Also, due to the descriptive nature of this review it does not deliver a set of recommendations, but rather a set of themes and take away messages relevant to the link between healthy eating, physical activity and school performance in children and youth.

² Physical activity and school performance: "school performance" AND "physical activity" OR "physical education" OR "exercise"; "academic performance" AND "physical activity" OR "physical education"
Healthy eating and school performance: "breakfast OR school meals OR school feeding programs OR diet OR healthy eating OR lunch OR snack" AND "school performance OR academic performance OR cognitive performance OR schools performance OR education outcomes OR learning outcomes"

³ Evidence relevant to school performance, diet and physical activity for school aged children (aged 5-12) and youth (aged 13-18) of developed countries was included.

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THE LINK BETWEEN HEALTHY EATING AND SCHOOL PERFORMANCE FOR CHILDREN AND YOUTH IN THE SCHOOL SETTING

Eating a nutritious diet has been known to have a variety of benefits to the health of our population, especially on children and youth during development. However, there are a limited number of studies that broaden our understanding of healthy eating to the school context and specifically examine the influence of healthy eating on student academic performance⁴. Therefore, this section of the review will explore the relationship between school based food policies and programs (i.e. breakfast programs), nutritional status (i.e. nutritional deficiency and food insufficiency) and school performance in children and youth (see Figure 1). Measures of nutritional status and school performance are varied (see Appendix for details), however there are no clear trends that indicate differences according to specific outcome measures (i.e. no effect if school performance is measured using student test grades rather than national standardized testing). Evidence for this section includes a synthesis of 8 review papers⁵ that reported results for over 191 primary studies⁶.

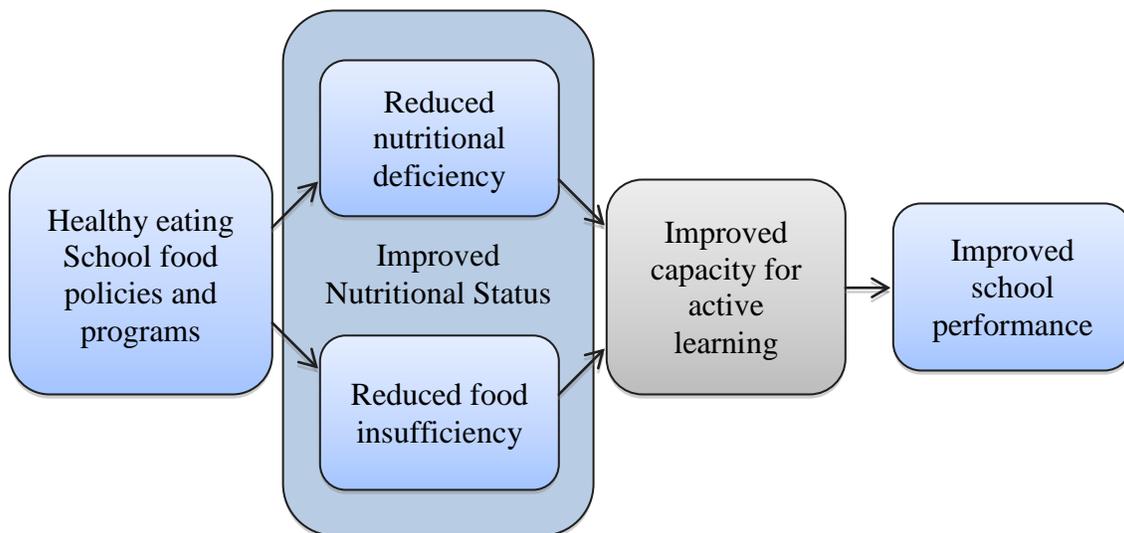


Figure 1: Theorized model for relationship between healthy eating school food policies and programs and school performance in children and youth (adapted from Cueto, 2001). Nutritional status, nutritional deficiency and food insufficiency are defined in the section below.

Nutritional status and school performance: food insufficiency and nutritional deficiency

⁴ Note that academic performance and school performance are used interchangeably throughout this report and both refer to a measure of success or failure at school.

⁵ Reviews included 3 systematic reviews and 5 non-systematic reviews.

⁶ Some reviews did not state the number of reviewed studies, see appendix for details.

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It is theorized that the relationship between school based policies and programs and improved school performance of children and youth is mediated by the nutritional status of students. There are many factors that could influence the nutritional status of children both within and outside of the school setting. However, the literature includes outcomes of school performance which are often conceptualized in two ways. Firstly, nutritional status is thought to improve school performance through reducing nutritional deficiency by ensuring that children and youth are not lacking in any important micronutrients such as iron or zinc, and that they are exposed to those nutrients associated with a healthy diet and improved school performance including calcium and vitamin C (Taras, 2005). Secondly, there is evidence suggesting that nutritional status can be improved by reducing food insufficiency by ensuring children do not attend school hungry and have access to a healthy breakfast, lunch and/or snack(s) during the school day whether the food is provided by the school or purchased on school property (Taras, 2005).

Within the area of nutritional status and school performance the evidence is still in the early stages of development but is showing some promise. A couple of systematic reviews have been conducted; however highly rigorous studies and consistent methodology and measures are not yet prevalent enough for conclusive findings. A systematic review by Ells et al., 2008 concluded that the importance of diet for educational attainment is inconclusive, however that the evidence for promotion of healthier diets, through reduced fat, salt and sugar and improved and fruit, vegetable and complex carbohydrate consumption is critical for improved health outcomes for all schoolchildren (Ells et al., 2008). In another systematic review, findings showed limited evidence that improvements to nutrition services (and therefore nutritional status) had a positive impact on academic outcomes. However, the review identified the many challenges in rigorous evaluation of school health programs and conclude that school health programs still hold promise for improving academic outcomes in children (Murray, Low, Hollis, Cross, & Davis, 2007).

This trend toward supporting the influence of nutritional status on school performance is reinforced in less structured review evidence. In particular a non-systematic review concluded that overall, the literature suggests that good regular dietary habits are the best way to ensure optimal cognitive and academic performance across time, and that these effects are most pronounced in children who have poor nutritional status (i.e. are deficient in essential nutrients and/or regular meals), while school performance specifically may not be improved for those children who already have good nutritional status (Bellisle, 2004).

In addition to cognitive and academic performance outcomes, there is literature growing in the area of behavioural outcomes related to nutritional status. Specifically, evidence related to behavioural disorders such as 'attention-deficit/hyperactively disorder' and the link to increased sugar and food additives in the modern diet is evolving. Specifically, in controlled studies the role of sugar in hyperactivity has not held ground, but the link between the many possible types of food additives and hyperactivity remains unclear. More rigorous interventions are needed to keep up with changes in food additives, and the existence of a causal link with behavioural outcomes (Bellisle, 2004).

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School food policies and programs, nutritional status and school performance

Within the literature examining school food policies and programs, the most commonly researched program with measured links to school performance is universal, free breakfast initiatives. Breakfast consumption is thought to impact cognitive performance by alleviating hunger and provide needed nutrition, which improves emotional, behavioral, and academic problems in children and adolescents. Research has found both links from breakfast programs to nutritional status of children and youth and contributions to school performance. Specifically, a systematic review by Hoyland et al., (2009) found that studies of school breakfast programs can have positive effects on academic performance; however the mechanism for this connection is still under investigation and thought to possibly be due to improved attendance rather than improved nutritional status (Hoyland, Dye, & Lawton, 2009). However, another review found that school breakfast programs have a positive effect directly on the nutritional status of children, in addition to school attendance and dropout rates (Cueto, 2001). The authors also emphasized the role of the school in moderating the effect of breakfast consumption on school performance stating that unless the school setting guarantees a minimum quality standard of education, the benefits of breakfast consumption may not be evident in performance in complex areas like language or math (Cueto, 2001).

In addition, breakfast programs are thought to reduce food insufficiency and increase nutritional status through minimizing breakfast skipping and providing adequate nutrition through a healthful breakfast. In particular, a review by Rampersaud et al. (2005) found that children who reported eating breakfast on a consistent basis tended to have improved nutritional profiles compared to other children who were breakfast-skippers. Specifically, results suggested that breakfast consumption might improve cognitive function related to memory, test grades, and school attendance. The authors advocate for the regular consumption of a healthful breakfast on a daily basis, suggesting that breakfast consist of a variety of foods, especially high-fiber and nutrient-rich whole grains, fruits, and dairy products (Rampersaud, Pereira, Girard, Adams, & Metz, 2005). These positive effects have also been found in other reviews. Grantham-McGregor (2005) found that most studies of giving breakfast found benefits to school performance, especially those children who were already malnourished. However the authors reiterate that classroom conditions are also important in linking nutrition to school performance (Grantham-McGregor, 2005). In addition Taras (2005) also found that offering a healthy breakfast is an effective measure to improve academic performance and cognitive functioning among undernourished populations. They reported that eating breakfast, in contrast to fasting, may improve performance on the morning it was eaten. However, that the longer-term effects of eating breakfast on the performance of school children who do not have physical signs of severe undernourishment is less certain (Taras, 2005).

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THE LINK BETWEEN PHYSICAL ACTIVITY AND SCHOOL PERFORMANCE FOR CHILDREN AND YOUTH IN THE SCHOOL SETTING

There is a strong evidence to suggest that regular participation in physical activity has a variety of health and social benefits for children and youth. Participation in physical activity has also been linked to enhancement of brain function and cognition; however, the relationship is better established with maintenance of cognitive function of older adults (Singh, Uijtdewilligen, Twisk, van Mechelen, & Chinapaw, 2012). A relationship between physical activity and cognition is beginning to emerge in recent literature on children and youth; improved cognition has important implications on school performance (Trudeau & Shephard, 2008). Research studies have tested this relationship with school performance with a numbers of measures of physical activity. The majority of studies reported self-reported participation in physical activity (including athletics, school programs and physical education) and objective measures of physical fitness (through fitness testing). This section will explore the relationship between overall physical activity, physical fitness and opportunities for physical activity in the school setting (i.e., physical education), as well as provide comment to the research related to specific student populations. Evidence for this section will include a synthesis of 8⁷ review papers that reported results for over 209 primary studies.

Physical activity, physical fitness and relationships with school performance

Recent systematic reviews provide substantial evidence to support a relationship between physical activity and physical fitness on cognition and school performance. It is important to note that an indirect relationship between physical activity and fitness⁸ (i.e., high levels of physical activity does not necessarily mean high levels of fitness and vice versa) has complicated these relationships in reviews from the past (Etnier, Nowell, Landers, & Sibley, 2006). Physical *activity* does appears to have a significant positive effect on children's cognitive outcomes and school performance (Fedewa & Ahn, 2011; Rasberry et al., 2011; Singh et al., 2012, Taras, 2005), as well as having an impact on attitudes and academic behavior, including enhanced concentration and attention as well as improved classroom behavior (Rasberry et al., 2011). Fedawa and Ahn (2011) reported that the largest effect of physical activity on school performance was on children's mathematics achievements, followed by IQ and reading. The authors also suggested that more research is needed to understand the dose-response of physical activity and school performance (i.e., how much physical activity is needed to observe an effect); however, higher levels of physical activity appears to produce higher achievement outcomes.

Generally, acute physical exercise exerts a positive effect on cognition; however, the linkage between physical *fitness* and school performance is less clear. Broadening the definition to include aspects beyond cardiovascular fitness (i.e., strength, flexibility and body measurements) appears to have more positive correlations between measures of psychomotor performance, cognitive abilities and school performance (Trudeau &

⁷ Reviews included 2 meta-analysis, 3 systematic reviews and 3 non-systematic reviews.

⁸ Physical activity refers to an amount (any body movement that requires more energy than resting), whereas fitness refers to a level of health (that includes cardiovascular and muscular endurance, muscular strength, flexibility and body composition).

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Shephard, 2008). Furthermore, interventions that focused on aerobic exercises yielded the largest impact on children's cognitive outcomes and children and those students who were more physically fit tended to have higher cognitive functions and school performance (Fedewa & Ahn, 2011)

Contributions of school-based physical activity on school performance

School-based physical activity appears to be an important opportunity to improve school performance. Specifically, research suggests that the effects of regular physical education programs yield important influences on children's cognitive outcomes and does not compromise academic outcomes (Fedewa & Ahn, 2011; Rasberry et al., 2011). Furthermore, interventions that have enriched physical education programs have appeared to enhance the learning efficiency of students (Trudeau & Shephard, 2008). This meant that that there was no decrease in academic achievement as a consequence of increased participation in physical activity; despite the fact that enriching physical education resulted in less time for other academic subjects. Furthermore, the authors reported that a common and valuable consequence of enriching the physical education program was a significant increase in measures of physical fitness (Trudeau & Shephard, 2008). Thus, the evidence suggests that increasing time for physical education and/or enhancing the quality can help to improve both school performance and physical fitness.

Physical education should be part of a more comprehensive approach to support physical activity in schools (Erwin, Fedewa, Beighle, & Ahn, 2012). Research suggests that many different types of school-based activities, including extra-curricular physical activity, interscholastic sports and recess have some relationship with school performance. Physical activity interventions appear to have the largest effect with small-group interventions; with peer influence suggested as a potential contributor (Fedewa & Ahn, 2011). Interventions that focused on only one child and youth at a time did not appear to have an impact on children's cognitive outcomes. Thus, offering active opportunities for students in smaller groups may enhance the impact of physical activity on school performance (Erwin et al., 2012; Fedewa & Ahn, 2011).

A systematic review reported an effect of physical activity on school performance regardless of who was delivering intervention (Fedewa & Ahn, 2011). This is significant because it suggests that that all school staff could help to increase physical activity by incorporating opportunities for activity throughout the school day. However, it is important to note that the capacity (i.e. time) of the individual plays an important role in how this can be achieved. Furthermore, knowledge and skills do play a critical role in the delivery of opportunities for physical activity, especially physical education (Hardman & Marshall, 2000; McKenzie, Marshall, Sallis, & Conway, 2000). Interventions that integrated physical activity into organizational routine have demonstrated modest but consistent benefits for physical activity; some of these studies also observed improvements in academic achievement but more research needs to be done to understand this relationship (Barr-Anderson, AuYoung, Whitt-Glover, Glenn, & Yancey, 2011). Classroom teachers could achieve this integration and possibly enhance the academic curriculum and classroom environment by incorporating movement activities and physical activity breaks into the classroom on a regular basis.

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School-based physical activity can also indirectly support school performance through school connectedness and self-esteem. For example, participation in school sports (as compared to other sport contexts) was found to benefit school performance. The close proximity of educational resources and environment may support this relationship as the school offers an opportunity to support both task orientation and skills acquisition, without decreasing the pleasure and satisfaction of being good at sports and physical activity (Trudeau & Shephard, 2008).

Focusing on specific student populations to optimize impact on school performance

Differences in the relationship across age and gender of students were also explored in recent reviews of the literature. Evidence from physical activity interventions, suggested that younger children had the greatest cognitive benefit although older children and youth benefited as well. The authors commented that this might be because physical activity interventions are sometimes inherently more accessible for younger children. For example, recess is typically scheduled into a school day for elementary school students but not for junior and senior high students. Furthermore, mixed-gender groups had stronger relationships with school performance (Fedewa & Ahn, 2011) but it is important to keep in mind other social and health benefits of programming for separate boys and girls groups.

Emerging literature exploring the association between physical activity and academic-related outcomes among low-income and minority children suggests that physical activity and aerobic fitness may have a positive influence on minority and low-income children's academic-related outcomes; however these findings are relatively recent and primarily cross-sectional in nature. Nevertheless, it is important to note that promoting physical activity in schools with low-income and minority students may not only improve health outcomes but may also improve academic related outcomes and narrow achievement gaps (Efrat, 2011).

Physical activity interventions have also been shown to significantly reduce disruptive behaviour. Furthermore, relationships are reported between physical activity outcomes and potential factors that might prevent students from dropping-out of school, such as school satisfaction and school connectedness (Trudeau & Shephard, 2008). Finally, children who are cognitively impaired (or classified as disabled) appear to benefit even more than typically developing children (Fedewa & Ahn, 2011). These contributions suggest that physical activity should not be overlooked as an effective intervention in stimulating and maintaining children's learning.

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A NOTE ON COMBINED HEALTH BEHAVIOURS AND SCHOOL PERFORMANCE FOR CHILDREN AND YOUTH

Much of the literature in this review is categorized based on a specific behaviour (i.e. healthy eating or physical activity), which provides valuable insights related to their independent effects on health and school performance. However, there is also emerging literature that is trying to understand the combined relationship of these behaviours to provide a more comprehensive view of supporting healthy living, especially in response to the need to address the of childhood obesity. This evidence has not yet made it to the review level with school performance as an outcome measure of interest and therefore is not synthesized in this review (see Appendix for list of primary studies). Furthermore, evidence is emerging to explore the relationship between comprehensive school health approaches on school performance (Murray, Low, Hollis, Cross, & Davis, 2007; Rosas, Case, & Tholstrup, 2009; Vinciullo & Bradley, 2009). Similar to the findings of this review, implementation of these programs did not adversely impact school-level academic indicators and some positive relationships with school performance were reported.

Limitations

There are some limitations inherent in our review methodology. Firstly, although this review cannot claim that the results (appendix) represent an exhaustive list of available evidence, the employed search strategy did result in a significant body of work across multiple levels of rigour (systematic review, intervention and primary studies) suggesting that the results, while not systematically searched, represent a breadth of work in this topic area. In addition, our research synthesis is based exclusively on review studies. While these are the most comprehensive and rigorous studies available through our search methodology, our synthesis does not include emerging evidence that has not yet been reviewed. Typical of all review studies, there may be an overestimation of a potential positive relationship because positive findings are more likely to be published in the academic literature. Finally, it will be important to understand the role of mediators in considering relationships with school performance. For example, socio-economic status is an important predictor of academic performance as well as nutrition and physical activity behaviours.

CONCLUSIONS

The purpose of this review was to explore and describe the literature on the link between healthy eating, physical activity and school performance in the school setting for children and youth. The research synthesis was reported thematically to represent how evidence is currently emerging in the literature which is categorized based firstly on the health behaviour of interest (i.e. healthy eating and physical activity) and concepts that are of interest (i.e. healthy eating food policies and programs, nutrition status, physical activity, physical fitness, school-based physical activity and specific student populations).

Researchers have theorized that the link between healthy school food policies and programs influences school performance through improving the nutritional status of

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children. In the school performance related review literature reducing nutritional deficiency or food insufficiency are emerging as the mechanisms responsible for the potential relationship, and is most pronounced in children and youth with poor nutritional status or who are at a socio-economic disadvantage. The most commonly researched type of school policy or program that is reported with the capacity to could improve both nutritional deficiency and food insufficiencies are universal healthy breakfast programs. The evaluation of these programs is complex and difficult to implement, however improvements in school performance outcomes are being reported. Specifically, studies are showing that breakfast programs can improve children and youth nutritional status, and if the school is well functioning and academically strong, improvements in school performance for children and youth. This also suggests, although this literature is currently sparse at the review level, that other school food policies and programs that improve the nutritional status of children and youth though supporting healthy eating within the school have the potential to also improve school performance.

There is substantial evidence to support a relationship between physical activity and school performance with the largest effect on children's mathematics achievements, IQ and reading. School-based opportunities for physical activity is an important opportunity to improve school performance and time allocated should be viewed as enhancing, not impeding, academic achievement of students. Physical education should be part of a more comprehensive approach in schools (e.g., extra-curricular physical activity, interscholastic sports, activity breaks, recess, etc.) and smaller group, younger age and mixed-gender interventions had larger effects on school performance. The evidence suggests that physical activity could be a mechanism to stimulate and maintain learning among students that have difficulty at school or are in situations that may place them at risk for poorer health and learning outcomes.

Finally, it should not be forgotten that scholastic achievement also depend on numerous individual (e.g. psychological, emotional), economic, familial, social and school related factors. However, it is unquestionable that improved nutritional status, through healthy regular meals, and adequate physical activity at school can play an important role in the academic success, as well as overall health, of young people and should be embedded into school settings.

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APPENDIX

SUMMARY OF LITERATURE

The relationship between diet and physical activity, within the school setting, and school performance: An annotated bibliography of review papers, intervention studies and primary studies

The evidence in this table is categorized and sorted in three ways. The first is by type of manuscript in order from most comprehensive to least (review, intervention and primary study), the second is by type of outcome (diet, physical activity and the combination of both) and the last is the level of rigour of the study design from most rigorous to least (review: meta-analysis, systematic review, non-systematic review; intervention: RCT, controlled trial, other; primary: longitudinal, cross-sectional, other).

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I.1 Summary of diet related literature: review papers

Review Reference	# Studies	Design	Purpose	Location, Target Population	Main Findings
(Hoyland, Dye, & Lawton, 2009)	45 primary studies	Systematic review	To evaluate the effects of breakfast on cognitive performance in well nourished children and nutritionally at risk or stunted children.	Developed countries, children	The evidence indicates that breakfast consumption is more beneficial than skipping breakfast, but this effect is more apparent in children whose nutritional status is compromised. There is a lack of research comparing breakfast type, precluding recommendations for the size and composition of an optimal breakfast for children's cognitive function. Few studies examined adolescents. Studies of school breakfast programmes suggest that such interventions can have positive effects on academic performance, but this may be in part explained by the increased school attendance that programmes encourage.
(Ells et al., 2008)	29 primary studies	Systematic review	The aim of the present review was to perform a systematic in depth review of the best evidence from controlled trial studies that have investigated the effects of nutrition, diet and dietary change on learning, education and performance in school aged children.	UK and other developed countries, children and youth	In summary, the studies included in the present review suggest there is insufficient evidence to identify any effect of nutrition, diet and dietary change on learning, education or performance of school aged children from the developed world. However, there is emerging evidence for the effects of certain fatty acids which appear to be a function of dose and time. Further research is required that is representative of all populations, undertaken for longer durations and use universal validated measures of educational attainment. However, challenges in terms of interpreting the results of such studies within the context of factors (i.e. poverty, disease etc.) will remain. Whilst the importance of diet in educational attainment remains under investigation, the evidence for promotion of lower fat, salt and sugar diets, high in fruits, vegetables and complex carbohydrates, as well as promotion of physical activity remains unequivocal in terms of health outcomes for all schoolchildren.

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<p>(Murray, Low, Hollis, Cross, & Davis, 2007)</p>	<p>17 primary studies</p>	<p>Systematic Review</p>	<p>This article presents a systematic review of the literature to examine evidence that school health programs aligned with the Coordinated School Health Program (CSHP) model improve academic success.</p>	<p>Various, children and youth</p>	<p>The strongest evidence from scientifically rigorous evaluations exists for a positive effect on some academic outcomes from school health programs for asthmatic children that incorporate health education and parental involvement. Strong evidence also exists for a lack of negative effects of physical education programs on academic outcomes. Limited evidence from scientifically rigorous evaluations support the effect of nutrition services, health services, and mental health programs, but no such evidence is found in the literature to support the effect of staff health promotion programs or school environment interventions on academic outcomes. Scientifically rigorous evaluation of school health programs is challenging to conduct due to issues related to sample size, recruitment, random assignment to condition, implementation fidelity, costs, and adequate follow-up time. However, school health programs hold promise for improving academic outcomes for children.</p>
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(Bellisle, 2004)	Not given	Non-systematic review	Explore the effects of diet on behavior and cognition in children	Various, children	<p>Diet can affect cognitive ability and behaviour in children and adolescents. Nutrient composition and meal pattern can exert immediate or long-term, beneficial or adverse effects. Beneficial effects mainly result from the correction of poor nutritional status. For example, thiamin treatment reverses aggressiveness in thiamin-deficient adolescents. Deleterious behavioural effects have been suggested; for example, sucrose and additives were once suspected to induce hyperactivity, but these effects have not been confirmed by rigorous investigations. In spite of potent biological mechanisms that protect brain activity from disruption, some cognitive functions appear sensitive to short-term variations of fuel (glucose) availability in certain brain areas. A glucose load, for example, acutely facilitates mental performance, particularly on demanding, long-duration tasks. The mechanism of this often described effect is not entirely clear. One aspect of diet that has elicited much research in young people is the intake/omission of breakfast. This has obvious relevance to school performance. While effects are inconsistent in well-nourished children, breakfast omission deteriorates mental performance in malnourished children. Even intelligence scores can be improved by micronutrient supplementation in children and adolescents with very poor dietary status. Overall, the literature suggests that good regular dietary habits are the best way to ensure optimal mental and behavioural performance at all times. Then, it remains controversial whether additional benefit can be gained from acute dietary manipulations. In contrast, children and adolescents with poor nutritional status are exposed to alterations of mental and/or behavioural functions that can be corrected, to a certain extent, by dietary measures.</p>
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(Cueto, 2001)	Not given	Non-systematic Review	Explore the impact of breakfast on performance in students	Various, children and youth	Evidence suggests that the effect of fasting on performance is not uniform, but it is dependent on the basal nutritional status of the subject. Breakfast consumption has a short-term effect in improving selected learning skills, especially work memory. School breakfast programmes have a positive effect on the nutritional status of children, on school attendance and probably on dropout rates. The effect of breakfast consumption on school performance depends on the interaction between the programme, student characteristics (malnutrition) and school organisation. Unless the school setting guarantees a minimum quality standard, the benefits of breakfast consumption will not be evident in performance in complex areas like language or maths.
(Taras, 2005)	53 primary studies	Non-systematic review	This article reviews research from published studies on the association between nutrition among school-aged children and their performance in school and on tests of cognitive functioning.	Various, children and youth	Each reviewed article is accompanied by a brief description of its research methodology and outcomes. Articles are separated into 4 categories: food insufficiency, iron deficiency and supplementation, deficiency and supplementation of micronutrients, and the importance of breakfast. Research shows that children with iron deficiencies sufficient to cause anemia are at a disadvantage academically. Their cognitive performance seems to improve with iron therapy. A similar association and improvement with therapy is not found with either zinc or iodine deficiency, according to the reviewed articles. There is no evidence that population-wide vitamin and mineral supplementation will lead to improved academic performance. Food insufficiency is a serious problem affecting children's ability to learn, but its relevance to US populations needs to be better understood. Research indicates that school breakfast programs seem to improve attendance rates and decrease tardiness. Among severely undernourished populations, school breakfast programs seem to improve academic performance and cognitive functioning.

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<p>(Rampersaud, Pereira, Girard, Adams, & Metzler, 2005)</p>	<p>47 primary studies</p>	<p>Non-systematic review</p>	<p>Breakfast has been labeled the most important meal of the day, but are there data to support this claim? We summarized the results of 47 studies examining the association of breakfast consumption with nutritional adequacy (nine studies), body weight (16 studies), and academic performance (22 studies) in children and adolescents.</p>	<p>Various, children and youth</p>	<p>Breakfast skipping is highly prevalent in the United States and Europe (10% to 30%), depending on age group, population, and definition. Although the quality of breakfast was variable within and between studies, children who reported eating breakfast on a consistent basis tended to have superior nutritional profiles than their breakfast-skipping peers. Breakfast eaters generally consumed more daily calories yet were less likely to be overweight, although not all studies associated breakfast skipping with overweight. Evidence suggests that breakfast consumption may improve cognitive function related to memory, test grades, and school attendance. Breakfast as part of a healthful diet and lifestyle can positively impact children's health and well-being. Parents should be encouraged to provide breakfast for their children or explore the availability of a school breakfast program. We advocate consumption of a healthful breakfast on a daily basis consisting of a variety of foods, especially high-fiber and nutrient-rich whole grains, fruits, and dairy products.</p>
<p>(Grantham-McGregor, 2005)</p>	<p>Could not access paper</p>	<p>Non-systematic review</p>	<p>To explore the relationship between provision of school breakfast and school performance</p>	<p>Various, children and youth</p>	<p>Rigorous short-term studies of missing breakfast have generally found detrimental effects on children's cognition whereas studies of providing breakfast have shown benefits particularly in malnourished children. Classroom conditions may modify the effects of breakfast on behavior. There are extremely few longer-term studies of the effects of giving school meals. Nearly all involved breakfast and very few had randomized controlled designs. Studies comparing participants with non-participants or comparing matched schools have found benefits (but bias due to self-selection) of receiving breakfast; inadequate matching of schools also remains possible. One longer term randomized controlled trial found benefits associated with attendance and arithmetic performance. In conclusion, most studies of giving breakfast have found benefits to school performance but many had serious design problems, were short-term, and were not</p>

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					conducted in the poorest countries. In order to advise policy makers correctly, there is an urgent need to run long-term randomized controlled trials of giving school meals in poor countries and to determine the effects of age and nutrition status of the children, the quality of the school, and the timing of the meal. The special needs of orphans should also be considered.
(Weichselbaum & Buttriss, 2011)	n/a	Briefing Paper	To review issues related to nutrition, health and school children	Various, children and youth	n/a

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I.2 Summary of physical activity related literature: review papers

Review Reference	# Studies	Design	Purpose	Location, Target Population	Main Findings
(Fedewa & Ahn, 2011)	20 cross-sectional, 39 quasi-experimental	Meta analysis	To quantitatively synthesize the research on physical activity and children's cognitive outcomes and to discuss implications for educators and other stakeholders in children's academic achievement.	USA, Canada, China, Australia; Children and Youth	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. Physical activity and education programs are both critical and appear to benefit those that need it the most.
(Erwin, Fedewa, Beighle, & Ahn, 2012)	9 studies	Systematic review and meta-analysis	To quantitatively review classroom physical activity interventions in terms of their physical activity, health and learning outcomes for students, with implications of findings discussed for school personnel.	USA, Germany, New Zealand, UK, Sweden, Belgium, Canada; Children and Youth	Classroom-based physical activity opportunities are just one part of a comprehensive approach to school-based physical activity for youth. More research on the effect of classroom-based physical activity interventions on physical activity, learning, and health outcomes is warranted (few articles were found that provided details on the effect of these interventions on children's learning and/or other health outcomes). However, the classroom-based studies that have been conducted have been positive and show a significant and moderate effect on children's physical activity and learning outcomes.
(Singh, Uijtdewilligen, Twisk, van Mechelen, & Chinapaw, 2012)	10 cross-sectional and 4 experimental studies	Systematic review	To describe the prospective relationship between physical activity and academic performance	USA, Canada, South Africa; Children and Youth	Participation in physical activity is positively related to academic performance in children. Because we found only 2 high-quality studies, future high-quality studies are needed to confirm our findings.
(Rasberry et al., 2011)	50 studies overall	Systematic review	To synthesize the scientific literature that has examined the association between school-based	USA and others (not disclosed); Children	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.

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			physical activity (including physical education) and academic performance (including indicators of cognitive skills and attitudes, academic behaviors, and academic achievement).	and Youth	
(Barr-Anderson, AuYoung, Whitt-Glover, Glenn, & Yancey, 2011)	40 studies (28 school-based, 12 worksite based)	Systematic review	To present a systematic review of the evidence for the effectiveness of short activity bouts incorporated into organizational routine as part of the regular "conduct of business."	USA, Canada, China, Netherlands, Australia; Children and Youth	Interventions integrating physical activity into organizational routine during everyday life have demonstrated modest but consistent benefits, particularly for physical activity, and these are promising avenues of investigation. The proportionately longer-term outcomes available in these studies compared with individual-level studies suggest that physical activity promotion strategies at the organizational level may be more sustainable.
(Trudeau & Shephard, 2008)	9 cross-sectional, 7 quasi-experimental	Non-systematic review	To review relationships of academic performance and some of its determinants to participation in school-based physical activities, including physical education (PE), free school physical activity (PA) and school sports.	France, Canada, USA, Australia, Israel, Iceland, England, China; Children and Youth	Quasi-experimental data indicate that allocating up to an additional hour per day of curricular time to PA programmes does not affect the academic performance of primary school students negatively, even though the time allocated to other subjects usually shows a corresponding reduction. An additional curricular emphasis on PE may result in small absolute gains in grade point average (GPA), and such findings strongly suggest a relative increase in performance per unit of academic teaching time. Further, the overwhelmingly majority of such programmes have demonstrated an improvement in some measures of physical fitness (PF). Cross-sectional observations show a positive association between academic performance and PA, but PF does not seem to show such an association. PA has positive influences on concentration, memory and classroom behaviour. Data from quasi-experimental studies find support in mechanistic experiments on cognitive function, pointing to a positive relationship between PA and intellectual performance.
(Taras, 2005)	9 cross-sectional	Non-systematic	To reviews the state of research on the	US, UK, Korea,	There is evidence to suggest that short-term cognitive benefits of physical activity during the school day adequately

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	and 5 controlled experimental studies	review	association between physical activity among school-aged children and academic outcomes	Estonia, Israel, Canada	compensate for time spent away from other academic areas.
(Efrat, 2011)	7 studies in total	Literature review	To evaluate studies that have examined the relationship between low-income and minority children's physical activity and/or fitness and academic-related outcomes, including academic performance, cognitive abilities, and intellectual functions.	USA, Canada; Children and Youth	The majority of the articles reviewed found that regardless of socioeconomic status or ethnicity, a positive relationship exists between physical activity and academic-related outcomes. These findings suggest that integrating more physical activity into the school day may be an effective strategy to reduce both health disparities and the achievement gap.

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II.1 Summary of diet related literature: intervention studies

Study Reference	Design	Purpose	Location, Target Population	Intervention	Measure of school performance	Main Findings
(Storey et al., 2011)	Randomized Control Trial	This study investigated the effect of tailored modifications to the food and dining experience in secondary schools on learning related behaviours.	England, Children	A tailored action plan and support to modify their food provision and dining environment over a 15week period	Learning related behaviours were systematically observed during post lunch time classes at all schools.	Observations were made by trained observers using a validated protocol to determine whether pupils were 'on task' (concentrating and alert) or 'off task' (disruptive or disengaged). At follow up, intervention group pupils were 18% more likely to be on task and 14% less likely to be off task compared with control group pupils. This study suggests that modifying food provision and the dining environment can improve learning related behaviours of secondary school pupils in the post lunch period. This finding supports ongoing investment and interventions by local authorities across the United Kingdom to improve school food and lunchtime dining facilities.

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<p>(Kleinman et al., 2002)</p>	<p>Cross-sectional and Pre-post assessment</p>	<p>To determine whether nutrient intake and academic and psychosocial functioning improve after the start of a universal-free school breakfast program (USBP).</p>	<p>United States, children</p>	<p>A universal-free school breakfast program in place for 6 months</p>	<p>School grades</p>	<p>Prior to the USBP, 33% of all study children were classified as being at nutritional risk. Children who were at nutritional risk had significantly poorer attendance, punctuality, and grades at school, more behavior problems, and were less likely to eat breakfast at school than children who were not at nutritional risk. Six months after the start of the free school breakfast programs, students who decreased their nutritional risk showed significantly greater: improvements in attendance and school breakfast participation, decreases in hunger, and improvements in math grades and behavior than children who did not decrease their nutritional risk.</p> <p>Participation in a school breakfast program enhanced daily nutrient intake and improvements in nutrient intake were associated with significant improvements in student academic performance and psychosocial functioning and decreases in hunger.</p>
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(Belot & James, 2011)	Evaluation with control group	To evaluate the effect of the “Feed me Better” campaign on educational outcomes in primary schools	UK, children	Shifting meal served in schools from low-budget processed meals towards healthier options	Grades in English, math and science	Provides evidence that educational outcomes did improve significantly in English and Science. We also find that authorised absences – which are most likely linked to illness and health - fell by 14%.
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II.2 Summary of physical activity related literature: intervention studies

Study Reference	Design	Purpose	Location, Target Population	Intervention	Measure of school performance	Main Findings
(Ahamed et al., 2007)	Cluster RCT, 16 months	To evaluate the effectiveness of a school-based physical activity intervention, Action Schools! BC (AS! BC), for maintaining academic performance in a multiethnic group of elementary children, and 2) to determine whether boys and girls' academic performance changed similarly after participation in AS! BC	School, British Columbia, children	Intervention: additional 15minutes of classroom-based activities. Overall result added 47 min/wk of varied activities for 16months. Physical activity was self reported.	Canadian Achievement Test	Physical activity delivered by teachers to children in INT schools was increased by 47 min x wk(-1). Participants attending UP schools had significantly higher baseline TotScores than those attending INT schools. Despite this, there was no significant difference in TotScore between groups at follow-up and between boys and girls at baseline and follow-up.
(Donnelly et al., 2009)	Cluster RCT, 3 school years	To test the Physical Activity Across the Curriculum (PAAC) trial designed to promote physical activity and diminish increases in overweight and obesity in elementary school children.	School, US, children	Intervention: additional 90 min of physical activity	Wechsler Individual Achievement Test to assess for academic achievement in reading, writing, mathematics, and oral language skills	Children in experimental group improved their academic achievement scores
(Donnelly &	Cluster randomized	To explore the impact of a classroom-based PA program, TAKE 10!, and	School, Kansas, children	Physical Activity Across the Curriculum	Standardized test of academic	Physically active academic lessons of moderate intensity improved overall performance on a standardized test of

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Lambourne, 2011)	experiment	health-academic integration through existing state and federal policy and programming.		(PAAC) project. Physically active academic lessons of moderate intensity	achievement	academic achievement by 6% compared to a decrease of 1% for controls. Body mass index increased less from baseline to 3 years in students with greater than 75 minutes of PAAC lessons per week compared to students with less than 75 minutes of PAAC per week.
(Reed et al., 2010)	Experimental (pre-post)	To examine the impact of integrating physical activity with elementary curricula on fluid intelligence and academic achievement.	School, South Carolina, Children	Integrated physical activity into their core curricula approximately 30 minutes a day, 3 days a week	Noninvasive fluid intelligence cognitive measures were used along with State-mandated academic achievement	Children in the Experimental Group performed significantly better on the SPM Fluid Intelligence Test. Children in the Experimental Group also performed significantly better on the Social Studies State mandated academic achievement test. Experimental Group children also received higher scores on the English/Language Arts, Math and Science achievements tests, but were not statistically significant compared with Control Group children.
(Verret, Guay, Berthiaume, Gardiner, & Beliveau, 2012)	Quasi-experimental controlled pilot study	To explore the effects of a moderate-to high-intensity physical activity program on fitness, cognitive functions, and ADHD-related behavior in children with ADHD.	School, Montreal, Children	10-week training or control period	Cognitive functions by standardized test	Findings show that participation in a physical activity program improves muscular capacities, motor skills, behavior reports by parents and teachers, and level of information processing.
(Hollar et al., 2010)	Quasi-experimental controlled pilot study	To assess the effects of a school-based obesity prevention intervention that included dietary, curricula, and physical activity components on body mass index (BMI) percentiles and academic performance among low-income elementary school	School, Florida, Children	The HOPS/OWG included the following replicable, holistic components: (1) modified dietary offerings, (2) nutrition/lifeyl	Standardized assessment	Statistically significant improvements in BMI, blood pressure, and academic scores, among low-income Hispanic and White children in particular, were seen in the intervention versus controls. Holistic school-based obesity prevention interventions can improve health outcomes and academic performance, in particular among high-risk populations.

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		children.		e educational curricula; (3) physical activity component; and (4) wellness projects. Demographic, anthropometric (body mass index [BMI]), blood pressure, and academic data were collected during the two-year study period (2004-6).		
(Shilts, Lamp, Horowitz, & Townsend, 2009)	Quasi-experimental crossover-controlled Study.	To investigate the impact of a nutrition education program on student academic performance as measured by achievement of education standards.	School, California, Children	9-lesson intervention with an emphasis on guided goal setting and driven by the Social Cognitive Theory.	Standardized tests	Using standardized tests, results of this pilot study suggest that EatFit call improve academic performance measured by achievement of specific mathematics and English education standards. Nutrition educators can show school administrators and wellness committee members that this program can positively impact academic performance, concomitant to its primary objective of promoting healthful eating and physical activity.
(Shephard RJ et al., 1984)	Quasi-experimental	Full article not available	School, Quebec, Children	5 h of specialist physical education per week for 6 years	Teacher ratings, Standard Provincial examination, WISC tests	Enhanced teacher ratings, Math but not English improved in Provincial exams, 3–4%gain on WISC
(Sallis et al., 1999)	Quasi-experime	To evaluate the effects of a 2-year health-	School California,	Two schools assigned to	Metropolitan achievement	Non-significant trend to gains in English, arithmetic and behaviour. Achievement

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	ntal	related physical education on academic achievement	Children	certified physical education specialist and an activity program. Another 2 schools, regular classroom teachers were taught how to deliver the activity program. One school was a control where classroom teachers taught physical activity in their usual way.	tests	scores were higher than national averages at baseline; nevertheless, significant differences occurred among those receiving the intervention. Spending more time in physical education did not have harmful effects on standardized achievement. Favorable effects were found on 4 of 8 academic achievement measures. Those receiving physical education experienced smaller declines in test scores over the 3 years compared to controls. In only 1 of 8 subtests, controls had an advantage over those receiving physical education.
(Tremarche, Robinson, & Graham, 2007)	Quasi-experimental (control group)	To determine the impact of increased quality Physical Education time on Massachusetts Comprehensive Assessment System (MCAS) standardized scores.	School, Massachusetts, Children	Increased PE time	Standardized tests	Results of the study revealed that the mean ELA MCAS score for School 1 and the mean ELA MCAS score for School 2 were significantly different. The mean Math MCAS score for School 1 and the mean Math MCAS score for School 2 revealed no significant difference. In conclusion, students who received more hours of quality physical education per school year scored higher in the ELA subject area of the MCAS standardized test.
(Kibbe et al., 2011)	Pre-post assessment	To explore the impact of a classroom-based PA program, TAKE 10!, and health-academic	Schools, United States children	Classroom-based PA program	Various	Children participating in the TAKE 10! program experience higher PA levels (13%>), reduced time-off-task (20.5%), and improved reading, math, spelling and

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		integration through existing state and federal policy and programming.				composite scores.
(Nansel, Huang, Rovner, & Sanders-Butler, 2010)	Pre-post assessment	To examine secular trends in school performance indicators in relationship to the implementation of a programme targeting the school food and physical activity environment.	School, Georgia, Children	Healthy Kids, Smart Kids programme, a grass-roots effort to enhance the school food and physical activity environment in the Browns Mill Elementary School in Georgia.	Publically available information on school performance indicators	The number of nurse, counselling and disciplinary referrals per 100 students demonstrated a downward trend, while standardized test scores demonstrated an upward trend beginning in the year of programme implementation. School year was a significant predictor of all indicators.
(Sibley, Ward, Zullig, Yazvac, & Potteiger, 2006)	Pre-post assessment	To examine the effects of a 4-year intervention to improve diet and physical activity at a pilot elementary school on academic performance and other related school variables.	School, Ohio, Children	school-based environmental intervention was implemented that consisted of three core components: 1) re-structuring of the school day to provide 15 minutes of teacher-led physical activity each morning, 2) access for all students to a free breakfast program to	Standardized tests of writing, math, reading, citizenship, and science	Daily school attendance improved from 94.3% in 1999–2000 to 95.9% in 2003–2004. The school has seen a 67% decline in nurse visits and a 58% decrease in the total number of discipline referrals in the 4 years of implementation of the program. Academic performance has increased such that the school has improved from passing two of the state achievement tests (citizenship and writing) prior to the intervention to passing all five tests during the 2001–2004 school years. Comparisons of the 2003–2004 school year to pre-intervention data from 1999–2000 show that the percentage of students passing each of the 5 tests has increased.

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				facilitate sound nutritional practices, and 3) a reversal of the order of lunch and recess.		
(Adsiz, Dorak, Ozsaker, & Vurgun, 2012)	Pre-post assessment	To determine the influence of regular physical activity on attention	School, Turkey, Children	Engagement in sport activities	Bourdon Attention Test	The results show that physically active children had significantly higher attention levels compared to sedentary children ($p < 0.05$).

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III.1 Summary of diet related literature: primary studies

Study Reference	Design	Purpose	Location, Target Population	Measure of diet	Measure of school performance	Main Findings
(Feinstein et al., 2008)	Longitudinal	To test the impact of dietary intake at several time points in childhood on children's school attainment and to investigate whether any differences in school attainment between children who ate packed lunches or school.		Dietary intake	Entry assessments, National tests.	The key finding at age 3 was that "junk food" dietary pattern had a negative association with the level of school attainment. A weak association remained after controlling for the impact of other dietary patterns at age 3, dietary patterns at ages 4 and 7 and other confounding factors. The authors did not find evidence that eating packed lunches or eating school meals affected children's attainment, once the impact of junk food dietary pattern at age 3 was accounted for in the model. Early eating patterns have implications for attainment that appear to persist over time, regardless of subsequent changes in diet.

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<p>(Jyoti, Frongillo, & Jones, 2005)</p>	<p>Longitudinal</p>	<p>We used longitudinal data to investigate how food insecurity over time related to changes in reading and mathematics test performance, weight and BMI, and social skills in children.</p>	<p>United States, children</p>	<p>Food insecurity was reported affirmative response in the past year.</p>	<p>Children's academic performance, height, and weight were assessed directly. Children's social skills were reported by teachers</p>	<p>Analyses examined the effects of modified food insecurity on changes in child outcomes using lagged, dynamic, and difference (i.e., fixed-effects) models and controlling for child and household contextual variables. In lagged models, food insecurity was predictive of poor developmental trajectories in children before controlling for other variables. Food insecurity thus serves as an important marker for identifying children who fare worse in terms of subsequent development. In all models with controls, food insecurity was associated with outcomes, and associations differed by gender. This study provides the strongest empirical evidence to date that food insecurity is linked to specific developmental consequences for children, and that these consequences may be both nutritional and non nutritional.</p>
<p>(Abudayya, Shi, Abed, & Holmboe-Ottesen, 2011)</p>	<p>Cross-sectional</p>	<p>To examine the associations between dietary intake, nutritional status and school performance.</p>	<p>Gaza Strip, youth</p>	<p>Food frequency</p>	<p>School records</p>	<p>Adolescents consuming fruit and vegetables more than 3 times per week were more likely to have good school performance (72.6% versus 59.9%). When adjusting for sociodemographic variables and BMI, fruit and vegetables intake was positively associated with school performance and stunting was negatively associated.</p>

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(Theodore et al., 2009)	Cross-sectional	To examine the association between intelligence and diet	European, children	Food frequency	Intelligence quotient	Eating margarine at least daily was associated with significantly lower IQ scores at 3.5 years in the total sample and at 7 years in SGA children. For all children, eating the recommended daily number of breads and cereals was associated with significantly higher IQ scores at 3.5 years, and those who ate fish at least weekly had significantly higher IQ scores at 7 years than those who did not. The consumption of fish, breads and cereals commensurate with nutritional guidelines may be beneficial to children's cognitive development. In contrast, consuming margarine daily was associated with poorer cognitive functioning. Further research is needed to identify the nutrients that may underlie this association.
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<p>(Florence, Asbridge, & Veugelers, 2008)</p>	<p>Cross-sectional</p>	<p>This study examines the association between overall diet quality and academic performance.</p>	<p>Canada, children</p>	<p>Diet quality index</p>	<p>Standardized literacy assessment</p>	<p>Across various indicators of diet quality, an association with academic performance was observed. Students with decreased overall diet quality were significantly more likely to perform poorly on the assessment. Girls performed better than boys as did children from socioeconomically advantaged families. Children attending better schools and living in wealthy neighborhoods also performed better. These findings demonstrate an association between diet quality and academic performance and identify specific dietary factors that contribute to this association. Additionally, this research supports the broader implementation and investment in effective school nutrition programs that have the potential to improve student access to healthy food choices, diet quality, academic performance, and, over the long term, health.</p>
<p>(Fu, Cheng, Tu, & Pan, 2007)</p>	<p>Cross-sectional</p>	<p>The objective of this article is to evaluate the relationship between children's unhealthful eating patterns and overall school performance.</p>	<p>Taiwan, children</p>	<p>Food frequency and dietary patterns</p>	<p>Overall school performance</p>	<p>Unfavorable overall school performance was positively associated with unhealthful eating patterns, which included high intake of low quality foods (eg, sweets and fried foods) and low intake of dairy products and highly nutrient dense foods (eg, vegetables, fruit, meat, fish, and eggs). Children with a greater number of unhealthful eating patterns were more at risk for unfavorable overall performance in school. The study shows that children with unfavorable overall school performance were more likely to eat sweets and fried foods, and were less likely to eat foods rich in protein, vitamins, and minerals. A potential relationship between eating patterns and unfavorable overall school performance is supported in our study.</p>

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<p>(Boschloo et al., 2012)</p>	<p>Cross-sectional</p>	<p>Investigated whether adolescents who habitually skip breakfast have lower end-of-term grades than adolescents who eat breakfast daily.</p>	<p>Netherlands, youth</p>	<p>Skipping breakfast</p>	<p>End of term grades</p>	<p>Results showed that breakfast skippers performed lower at school than breakfast eaters. The findings were similar for younger and older adolescents and for boys and girls. Adolescents with an evening chronotype were more likely to skip breakfast, but chronotype was unrelated to school performance. Furthermore, attention problems partially mediated the relation between breakfast skipping and school performance. This large-scale study emphasizes the importance of breakfast as a determinant for school performance. The results give reason to investigate the mechanisms underlying the relation between skipping breakfast, attention, and school performance in more detail.</p>
<p>(Alaimo, Olson, & Frongillo, 2001)</p>	<p>Cross-sectional</p>	<p>This study investigates associations between food insufficiency and cognitive, academic, and psychosocial outcomes</p>	<p>United States, children and youth</p>	<p>Score of enough food to eat</p>	<p>Academic measures</p>	<p>After adjusting for confounding variables, 6- to 11-year-old food-insufficient children had significantly lower arithmetic scores and were more likely to have repeated a grade, have seen a psychologist, and have had difficulty getting along with other children. Food-insufficient teenagers were more likely to have seen a psychologist, have been suspended from school, and have had difficulty getting along with other children. Further analyses divided children into lower-risk and higher-risk groups. The associations between food insufficiency and children's outcomes varied by level of risk. The results demonstrate that negative academic and psychosocial outcomes are associated with family-level food insufficiency and provide support for public health efforts to increase the food security of American families.</p>

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(Brands et al., 2012)	Qualitative	Qualitatively examine parents' perceptions of the relationship between diet and mental performance of children	European countries, children	n/a	n/a	<p>The study was conducted with a total of 124 parents in four European countries using a semi structured interview schedule. Parents speak of the effects of diet at two levels; the nature of the effects of diet and the characteristics of the foods responsible for these effects. Mental outcomes are related to diet, with the effects perceived to be associated with attention and concentration, often mediated by effects on children's mood and behaviour. Parents categorise foods as 'good' or 'bad' with positive effects related generally to a healthy balanced diet while negative effects are perceived to be associated with sugary and fatty foods.</p>
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III.2 Summary of physical activity related literature: primary studies

Study Reference	Design	Purpose	Location, Target Population	Measure of physical activity	Measure of school performance	Main Findings
(London & Castrechini, 2011)	Longitudinal	Tracks students longitudinally to examine the ways student physical fitness and changes in fitness align with school performance.	School , California, children and youth	Physical fitness	Standardized test in math and ELA	Comparing those who are persistently fit to those who are persistently unfit, we find disparities in both math and English language arts test scores. These academic disparities begin even before students begin fitness testing in fifth grade and are larger for girls and Latinos. Overall physical fitness is a better predictor of academic achievement than obesity as measured by body mass index. Socioeconomic status acts as a buffer for those who have poor physical fitness but strong academic performance.
(Koivusilta, Nupponen, & Rimpela, 2012)	Longitudinal	To investigate if PA in adolescence is related to high education and socio-economic position (SEP) in adulthood and if improved school performance may mediate the hypothesized relationship.	School, Finland, Youth	Self reported PA and lifestyle behaviours	Highest educational level	Participating in sports club or spontaneous PA and practicing with high intensity in adolescence were associated with higher educational levels and SEP in adulthood. Childhood socio-economic background only slightly influenced the associations and largely, PA predicted the outcomes independently of background. Particularly among girls, school performance partly accounted for the associations between PA and the highest educational level and the highest SEP.
(Nelson & Gordon-Larsen, 2006)	Cross-sectional	To examine relationships between PA and sedentary behavior patterns and an array of risk behaviors, including	School, US, Youth	Standard 7-day recall questionnaire; self-reported participatio	Self-reported score in math or English	Students with high participation in school-based physical activities and students with 5 bouts per week MVPA were more likely to earn higher grades.

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		leading causes of adolescent morbidity/mortality.		n in PE, school-based sports, academic clubs, sports with parents, and use of recreation		
(Carlson et al., 2008)	Longitudinal	To examine the association between time spent in physical education and academic achievement in a longitudinal study of students in kindergarten through fifth grade.	School, US, Children	PE participation reported by classroom teachers	Math and reading tests; item-response theory scale scores	Female students with the highest exposure to PE demonstrated small academic benefits for reading and math
(Castelli, Hillman, Buck, & Erwin, 2007)	Cross-sectional	This study examined 259 public school students in third and fifth grades and found that field tests of physical fitness were positively related to academic achievement.	School, Illinois, Children	Muscle fitness, aerobic capacity, and body composition	Standardized test in mathematics and reading	Aerobic capacity was positively associated with achievement, whereas BMI was inversely related. Associations were demonstrated in total academic achievement, mathematics achievement, and reading achievement, thus suggesting that aspects of physical fitness may be globally related to academic performance in preadolescents.
(Fox, Barr-Anderson, Neumark-Sztainer, & Wall, 2010)	Cross-sectional	The purpose of this study is to examine the associations between sports team participation, physical activity, and academic outcomes in middle and high	School, Minnesota, Youth	Self-reported weekly hours of physical activity, sports team	Self-reported academic letter grades.	For high school girls, both physical activity and sports team participation were each independently associated with a higher GPA. For high school boys, only sports team participation was independently associated with a higher GPA. For middle school students, the positive association between physical activity and GPA could not be

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		school students.		participation		separated from the relationship between sports team participation and a higher GPA. Findings indicated positive associations between physical activity involvement and academic achievement among students.
(So, 2012)	Cross-sectional	To investigate the effects of various types of PA undertaken at various frequencies, on the academic performance of Korean adolescent students.	School , Korea, Children	Self-report frequency of vigorous and moderate PA and strengthening exercises	Self reported academic performance (based on examination scores)	Vigorous PA was positively correlated with academic performance in the case of boys, and moderate PA was positively correlated with academic performance in both boys and girls. However, strengthening exercises were not positively correlated with academic performance in boys or girls. Furthermore, when undertaken 5 or more times a week, vigorous PA in boys and strengthening exercises in both boys and girls were negatively correlated with academic performance.
(José Morales, Pellicer-Chenoll, García-Masso, Gomis, & González, 2011)	Cross-sectional	Aim of this study was to analyze the relationship between the amount of physical activity and academic performance in 3rd-year secondary education students.	School, Barcelona, Children	Self-reported physical activity	Students' 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 modeling the relationship between these variables with a quadratic equation.
(Van Dusen, Kelder, Kohl, Ranjit, & Perry, 2011)	Cross-sectional	The purpose of this study was to quantify the cross-sectional association between standardized mathematics and reading academic achievement scores and measures of physical fitness	School, Texas, Children	Fitness scores	Standardized academic test scores	Fitness was strongly and significantly related to academic performance. Cardiovascular fitness showed a dose-response association with academic performance independent of other socio-demographic and fitness variables. The association appears to peak in late middle to early high school. We recommend that policymakers consider physical education (PE) mandates in middle high school, school administrators consider increasing PE time, and PE practitioners

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		using more rigorous statistical methods and a larger sample of 254,743 elementary, middle and high school children and adolescents.				emphasize cardiovascular fitness.
(Edwards, Mauch, & Winkelman, 2011)	Cross-sectional	To assess the association of selected categories of nutrition and physical activity (NUTR/PA) behaviors, fitness measures, and body mass index (BMI) with academic performance (AP) for 800 sixth graders.	School, North Dakota, Children	Self-reported PA behaviors, fitness assessments (mile run, curl-ups, push-ups, height, and weight)	Standardized test scores	Higher MAP math scores were associated with NUTR (more milk and breakfast; less 100% fruit juice and sweetened beverages [SB]) and PA (increased vigorous PA and sports teams; reduced television), and fitness (higher mile run performance). Higher MAP reading scores were associated with NUTR (fewer SB) and PA (increased vigorous PA, reduced television). Regression analysis indicated about 11.1% of the variation in the mean MAP math scores and 6.7% of the mean MAP reading scores could be accounted for by selected NUTR/PA behaviors, fitness, meal price status, and gender.
(Welk et al., 2010)	Cross-sectional	examined the associations between indicators of health-related physical fitness (cardiovascular fitness and body mass index) and academic performance (Texas Assessment of Knowledge and Skills)	School, Texas, Children	Health-related physical fitness (cardiovascular fitness and body mass index)	Assessment of Knowledge and Skills)	Mixed-model regression analyses revealed modest associations between fitness and academic achievement after controlling for potentially confounding variables. The effects of fitness on academic achievement were positive but small. A separate logistic regression analysis indicated that higher fitness rates increased the odds of schools achieving exemplary/recognized school status within the state. School fitness attainment is an indicator of higher performing schools.
(S.-Y. Kim	Cross-	to examine whether	School	Number of	Self reported	It was concluded that attending ≥ 3 PE

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& So, 2012)	sectional	the number of PE classes attended per week is related with school performance in Korean adolescent students.	Korea, Youth	PE classes per week	academic performance (based on examination scores)	classes per week was positively correlated with improved school performance and that attending <3 PE classes per week was negatively correlated with school performance in Korean adolescent students.
(Ruiz et al., 2010)	Cross-sectional	To examine the association of participation in physical sports activity during leisure time, sedentary behaviors, cardiorespiratory and muscular fitness, and weight status with cognitive performance in Spanish adolescents.	School, Spain, Youth	Self reported PA and measured cardiorespiratory and muscular fitness	Cognitive performance	Participation in physical sports activities during leisure time was associated with better cognitive performance study variables, independent of potential confounders including cardiorespiratory fitness and body mass index. We did not observe an association of time devoted to study, television viewing, or playing videogames with cognitive performance. Likewise, cognitive performance was similar across cardiorespiratory and muscular fitness levels and body weight categories. Participation in physical sports activity during leisure time may positively influence cognitive performance in adolescents.
(Castelli et al., 2007)	Cross-sectional	The purpose of the present research was to investigate the relationship between physical fitness and academic achievement	School, Illinois, Children	Physical fitness	Standards Achievement Test	Physical fitness was positively related to academic achievement. Specifically, aerobic capacity was positively associated with achievement, whereas BMI was inversely related. Associations were demonstrated in total academic achievement, mathematics achievement, and reading achievement, thus suggesting that aspects of physical fitness may be globally related to academic performance in preadolescents.
(Telford, Cunningham, Telford, & Abharatna, 2012)	Cross-sectional	To examine the relationships of academic achievement with physical fitness, physical activity and	School, Australia, Children	Physical fitness, measured physical activity (pedometer	Standardized test scores	Between-school relationships of the academic scores with fitness and physical activity were strong and positive, with some evidence of (negative) relationships with percent body fat. The between-child relationships were weaker, and nonexistent with percent body fat.

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		percent body fat		s) and percent body fat		Stronger between-school than between-child relationships favor the argument that variation in school cultures, characterized by concurrent attention to fitness and academic achievement, might play a more dominant role in explaining these relationships than any direct effect of fitness on academic achievement.
(Jose Morales, Gonzalez, Guerra, Virgili, & Unnithan, 2011)	Cross-sectional	The aim of this study was to look at the relationship between perceptual-motor and cognitive skills.	School, Spain, Children and Youth	Perceptual-motor skills (Tower of Cubes [TC] and Target Throwing [TT]).	Tests of cognitive Linguistic Skills and Math Skills	Stepwise multiple linear regression analyses demonstrated that TC and age were significant predictors of Linguistic Skills (LS) and Math Skills (MS) in both age groups. (R ² =0.64, 9-12 years old) and (R ² =0.45, 13-16 years old). The results from this study suggest that enhanced motor skills are associated with better academic performance.
(Du Toit, Pienaar, & Truter, 2011)	Cross-sectional	The aim of this study was to determine the relationship between physical fitness and academic achievement in an urban South African group of primary school children.	School, South Africa, Children	Fitness testing and body mass index	Average end of year academic marks	The results show a significant correlation between total strength scores and academic performance in the total group and between several fitness variables and academic performance in the female group. Significant correlations were found between specific strength tests and academic performance among older boys (12 years) and older girls (11 & 12 years). Several fitness parameters discriminated between high and low academic achievers. A positive relationship between physical fitness components and academic achievement was found with more significant correlations among girls than boys, as well as among older boys and girls.
(Roberts, Freed, & McCarthy, 2010)	Cross-sectional	To investigate whether aerobic fitness and obesity in school children are associated with	School, California, Children	Measured aerobic fitness and body mass index	Standardized test scores	Students whose mile run/walk times exceeded California Fitnessgram standards or whose BMI exceeded Centers for Disease Control sex- and age-specific body weight standards scored

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		standardized test performance.				lower on California standardized math, reading, and language tests than students with desirable BMI status or fitness level, even after controlling for parent education among other covariates. Ethnic differences in standardized test scores were consistent with ethnic differences in obesity status and aerobic fitness. BMI-for-age was no longer a significant multivariate predictor when covariates included fitness level. Low aerobic fitness is common among youth and varies among ethnic groups, and aerobic fitness level predicts performance on standardized tests across ethnic groups. More research is needed to uncover the physiological mechanisms by which aerobic fitness may contribute to performance on standardized academic tests
(R. Wittberg, Cottrell, Davis, & Northrup, 2010)	Cross-sectional	To assess the nature of the association between aerobic fitness and standardized academic performance is dose-response or threshold related.	School, West Virginia, Children	Aerobic capacity scores	Standardized test scores	Sectioning of Mile times and Pacer circuits revealed a sharp peak in academic performance for boys who completed the Mile in 9 minutes or less. Girls' Pacer revealed peaks in academic performance at 12 and 30 circuits. Discussion: Results demonstrate that select achievements in the Mile or Pacer account for significant increases in academic performance on standardized tests.
(Blom, Alvarez, Zhang, & Kolbo, 2011)	Cross-sectional	To explore the relationships among fitness and academic performance	School, Mississippi, Children and Youth	Measure of fitness	Standardized Language Arts and Math test scores, attendance record and discipline actions	The results indicated a statistically significant positive correlation between fitness and standardized test scores in Language Arts and Math and a statistically significant negative relationship with school absences. The relationships remained significant while controlling for gender, race, and socioeconomic status.
(Yu, Chan, Cheng,	Cross-sectional	To investigate the relations among	School, China,	Self-reported	Examination results and	Results showed that high academic achievers consistently attained better school conduct

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Sung, & Hau, 2006)		academic achievement, self-esteem, school conduct and physical activity level.	Children	physical activity	conduct grades obtained from the school records.	marks. However, physical activity level was quite an independent entity that was related neither to academic achievement nor school conduct. Furthermore, regression analyses showed that only academically high-achieving boys and physically active boys had higher self-esteem.
(R. A. Wittberg, Northrup, & Cottrel, 2009)	Cross-sectional	To examine which aspects of children's fitness assessment are associated with their performance on four different academic areas.	School, West Virginia, Children	Fitness assessment	Standardized test in mathematics, reading/language arts, science, and social studies	Achievement test scores were significantly better for children who were in the Healthy Fitness Zone (HFZ) for aerobic capacity and abdominal strength tests when compared to children who were unable to achieve the healthy zone. Children in the HFZ for upper body strength performed significantly better in math. Children in the HFZ for flexibility performed significantly better in math and science. No differences were found in academic performance when children in the HFZ for trunk lift were compared to children not in the healthy zone. When all FITNESSGRAM measures were used in a full factorial ANOVA with Body Mass Index (BMI), gender and meal program (a proxy variable for socioeconomic status) as covariates, aerobic capacity was found to be the only fitness variable consistently appearing as important. It was always significant as a main effect variable while no other main effect fitness variable achieved significance for any WESTEST subject. Two-way, three-way, and four-way interactions always included aerobic fitness and no other fitness measure was universal in these interactions.
(Coe, Pivarnik, Womack, Reeves, &	Cross-sectional	To determine the effect of physical education class enrollment and	School, US, Youth	Self-reported 3-day physical	Grades; national standardized test scores	Students who met or exceeded guidelines for vigorous physical activity earned higher grades

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Malina, 2006)		physical activity on academic achievement in middle school children.		activity recall		
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III.3 Summary of diet and physical activity related literature: primary studies

Study Reference	Design	Purpose	Location, Target Population	Measure of diet	Measure of school performance	Main Findings
(Ciarrochi, Heaven, & Skinner, 2012)	Longitudinal	Assessed the relationships between intelligence as assessed in Grade 7 and consequential health outcomes in Grade 11.	School, Australia, Youth	Self-reported health behaviours (grade 11)	Standardized verbal and numerical ability tests and a measure of conscientiousness (grade 7)	Results indicated that higher intelligence was associated with a number of healthy behaviors including delay in onset of cigarette smoking. Intelligence significantly predicted less time spent watching TV, lower physical exercise, and lower consumption of stimulant drinks. Covariate analyses showed that general intelligence predicted health outcomes after controlling for conscientiousness, socio-economic status, and gender.
Sigfusdottir, et al., 2007	Cross-sectional	To explore the relationship between selected health behaviours and academic achievement.	School, Iceland, Children and youth	Body mass index, physical activity and diet	Academic achievement	Body mass index, diet and physical activity explained up to 24% of the variance in academic achievement when controlling for gender, parental education, family structure and absenteeism. These findings affirm the complexity of the relationship of health to academic achievement.
Wang F, Veugelers PJ. 2008	Cross-sectional	This study aims to document the interrelationships between body weight, self-esteem and school performance in childhood. Height and weight measurements and self-report of self-esteem, diet quality and physical activity	School, Nova Scotia, Children	Self reported diet quality (survey)	Provincial Elementary Literacy Assessment	Diet quality and active living had positive effects on both school performance and self-esteem.
(Martinez-	Cross-	To examine the	School,	Adolescent	Self reported	No associations between health behaviors and

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Gomez et al., 2012)	sectional	independent and combined influence of four health behaviors on school performance in Spanish adolescents.	Spain, Youth	s were dichotomized as healthy or unhealthy based on meeting or not meeting lifestyle recommendations on physical activity, TV viewing, sleep and fruit intake.	grades in Language and Literature (LL) and Math	academic performance. Good academic performance in girls was associated with physical activity or fruit consumption. Moreover, girls who scored 3-4 health behaviors showed higher odds of passing LL, Math or LL+Math compared with those with 0-1 health behaviors. All the analyses were adjusted by weight status, family context and different school-related factors. A combination of health behaviors may have a positive influence on academic performance in adolescent girls.
(Edwards et al., 2011)	Cross-sectional	The purpose of the study was to describe differences and associations for standardized scores (math and reading) for sixth-grade (SG) students in a midwest city school district by selected categories of nutrition/physical activity (NUTR/PA) behaviors, fitness measures, and BMI, matched to gender and meal price status.	School, North Dakota, Children	Self reported nutrition and PA behaviours and fitness assessments	Standardized scores	Higher MAP math scores were associated with NUTR (more milk and breakfast; less 100% fruit juice and sweetened beverages [SB]) and PA (increased vigorous PA and sports teams; reduced television), and fitness (higher mile run performance). Higher MAP reading scores were associated with NUTR (fewer SB) and PA (increased vigorous PA, reduced television). Regression analysis indicated about 11.1% of the variation in the mean MAP math scores and 6.7% of the mean MAP reading scores could be accounted for by selected NUTR/PA behaviors, fitness, meal price status, and gender. Many positive NUTR/PA behaviors and fitness measures were associated with higher MAP scores supporting the school district focus on healthy lifestyles. Additional factors, including meal price status and gender, contribute to AP.
(H.-Y. P. Kim et al.,	Cross-sectional)	To obtain a fuller understanding of the	School, Korea,	Self-reported	GPA from school record	The academic performance of students was strongly associated with dietary behaviours,

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2003)		association of dietary behaviours, physical status and socio-economic status with academic performance in Korean teenagers	Children and Youth	survey and food-frequency, height, weight, and physical fitness score for the year were recorded from the school record.		especially with regularity of three meals even after control for parent's education level. Regular breakfast and lunch were more important in grades 5 and 8, while regular dinner was more related with academic performance in grade 11. Small, positive associations of height and physical fitness to academic performance were also found. The relative importance of regularity of meals was greater than that of socio-economic status and physical status in older teenagers.
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