A Rapid Review of the Literature on the Association Between Nutrition and School Pupil Performance

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Executive Summary

It is often assumed that New Zealand children are well nourished and that overweight children receive more than adequate nutrition. However diets high in energy can be low in important nutrients and a significant proportion of New Zealand children are affected by a number of nutritional and dietary problems: food insecurity at home, low vitamin and mineral intake, high fat and sugar intake, and obesity. One in three New Zealand school children is overweight or obese.

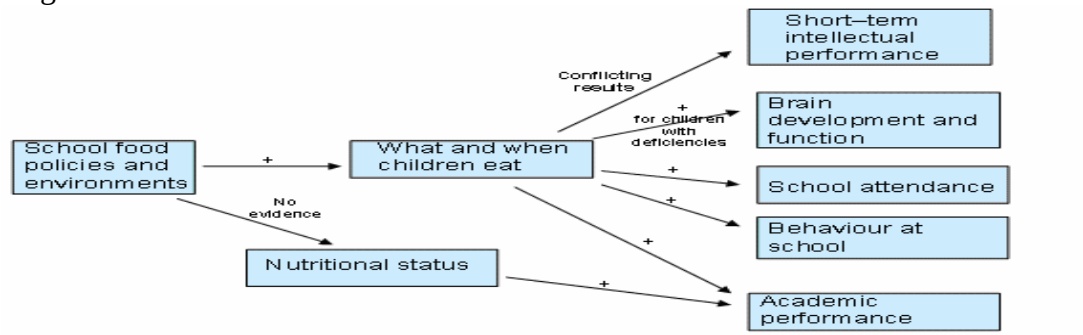
Nutritional problems disproportionately affect Maori, Pacific and children in families with a low socio-economic status, and have direct and indirect impacts on their achievement at school. Good nutrition education and food policies in schools that encourage good nutrition help children to learn important life skills, establish good eating habits and, particularly for the at-risk children, can improve nutritional status.

Anecdotal reports from teachers in schools that have improved nutrition education and introduced food policies which influence what children eat during school times are positive. The teachers believe that when children's diets improve, even just over the school day, many children become more attentive and easier to teach.

This report looks for the scientific evidence to support the theory that improved nutrition assists children to be more successful at school.

The literature review examines the relationship between nutrition and children's academic performance. The review looks at how school food policies and programmes influence what children eat. It also examines the connections between what children eat and brain development, short term intellectual performance, school attendance, behaviour at school and academic performance. Although research in some areas is limited and some of the results conflicting, overall the review clearly indicates that improving what children eat is likely to improve their school performance.

The causal links found between food and children's school outcomes are shown in the diagram below:



The review process found strong evidence that children's diets affect their attendance and behaviour in school. Research indicates that habitually disruptive children and children with other behavioural or emotional issues may well be suffering from poor

nutritional status, which is reversible with dietary changes or supplementation. Research also suggests that food insecurity at the household level has an effect on emotional and behavioural wellbeing in children, independently of nutritional intake and confounders such as socioeconomic status.

There is a clear and consistent relationship between nutrition and academic outcomes in the long term. Children who eat regular meals and have an adequate nutrient intake do better at school than those who skip meals and have inadequate nutrient intakes.

Even in the developed world, evidence suggests that a significant proportion of school age children have vitamin and mineral intakes low enough to compromise their mental functioning and conduct. While the overall number of malnourished New Zealand children is relatively small, in schools with a high proportion of children from low SES backgrounds, poor nutritional status may be the norm rather than the exception.

Research on school-based programmes has demonstrated that schools can play important and effective roles in improving what children eat and hence their nutritional status. Nutritional status in turn influences their attendance, health, behaviour and academic outcomes. Classroom-based nutrition education alone has a small effect on children's food choices and eating behaviour but comprehensive, multi-strategy programmes are consistently shown to have a positive effect on what children eat. Multi-strategy programmes include both education through the curriculum and changes to the school environment. Programmes including the following factors are most successful:

- School-wide policies that support healthy eating;
- Sequential, comprehensive health education curriculum that includes nutrition which is fun;
- Coordination between school food service and nutrition education;
- Training for school staff;
- Family and community involvement
- Evaluation.

Evidence also shows that universal feeding programmes reach nutritionally at-risk students more effectively than targeted programmes.

This literature review clearly highlights the important role schools have in improving nutrition outcomes for children. Poor nutrition in childhood is associated with poor attendance at school, poor behaviour at school and poor long term academic performance.

Improving childhood nutrition by ensuring that all schools have nutrition policies, a strong nutrition curriculum and a healthy school food environment is an important evidence-based step toward all students achieving their potential. Students who are well nourished are more likely to attend school, have better behaviour at school and better long term academic outcomes.

Introduction

The Obesity Action Coalition, funded by the Ministry of Health, has a primary purpose of advocacy for government policy, regulations and legislation that will positively influence obesity rates. The coalition provides a strong and united voice, combined with a forum for letting members know what advocacy is being planned. This allows organisations to support and strengthen each other's activities.

The Obesity Action Coalition (OAC) has a particular interest in preventing childhood obesity and in 2003 OAC focused its efforts on improving school environments. This work related to reducing the impact of inappropriate sponsorship and fundraising in schools. Schools were understandably sensitive to addressing issues relating to sponsorship and fundraising because of the need to raise revenue for essential school activities. The 2003 work further showed that sponsorship and fundraising were only two of the problems contributing to unhealthy school environments, and this literature review focuses on another potential enhancer/barrier – school nutrition policies and programmes, and their influence on what children eat, how they behave and intellectual performance.

Research Aims

The overarching aim of the research was to examine the relationship between nutrition and academic outcomes in children. To achieve this aim, six key research questions were developed:

- What is the relationship between school policies/environments and what children eat?
- What is the relationship between what children eat and brain development?
- What is the relationship between what and when children eat and school-time behaviour?
- What is the relationship between what and when children eat and short-term intellectual performance?
- What is the relationship between what and when children eat and school attendance?
- What is the relationship between what and when children eat and academic performance?

Children's Nutrition in New Zealand

Good dietary habits are presented in New Zealand's Food and Nutrition Guidelines for Children (Ministry of Health, 1997) and these have been the cornerstone of children's nutrition policy and practice in New Zealand for nearly a decade. It is well acknowledged that following these guidelines will reduce an individual's, and a population's risk of developing multiple life threatening and debilitating diseases (Mann and Truswell, 2002).

But what about relationships between food and outcomes of more direct interest to educators? Again, it is well acknowledged that significant nutrient

deficiencies, poor nutritional status and malnutrition will significantly negatively affect educational outcomes. Studies throughout the world, particularly in developing countries, have shown dramatic improvements in educational outcomes when gross nutritional issues such as severe vitamin or mineral deficiencies, or protein energy malnutrition are dealt with (Makudi, 2003; Whaley, 2003). Clearly there are strong relationships between nutrition and education, but their significance in developed countries such as New Zealand where food is plentiful is worthy of exploration.

For context, New Zealand children are far more likely to have an over-supply of nutrients and energy than an under-supply: particularly an over-supply of energy/calories, fat, sugar and salt. Almost all New Zealand children have adequate intakes of vitamin C, E, niacin, thiamine, B6, B12, phosphorus, magnesium, potassium, manganese and copper (Ministry of Health, 2003). However, what is less well acknowledged is that certain groups of the population are at far greater risk of inadequate micro-nutrient intakes and/or deficiency than others, and there is clear concern about the quality of diets for some children:

- One in two New Zealand children have mild iodine deficiency
- Two in ten boys and one in ten girls have low (sub-optimal) blood zinc levels
- One in five Pacific boys and nearly two in five Pacific girls have inadequate intakes of vitamin A
- One in ten Pacific boys and girls have inadequate intakes of riboflavin
- One in three Pacific, one in five Maori, and one in seven New Zealand European girls aged 11-14 years have inadequate intakes of folate
- four in ten Pacific, three in ten New Zealand European and two in ten Maori girls have inadequate intakes of calcium
- One in ten Pacific boys, and one in ten of girls from all ethnic groups have inadequate iron intakes. Blood measures show only one in twenty New Zealand children have anaemia and just one in 300 have iron deficiency anaemia (but one in twenty in girls aged 11-14 years) (Ministry of Health, 2003).

Low energy intakes in New Zealand are rarely an issue; instead, excess energy is a significant concern as demonstrated by New Zealand's rapid rise in childhood obesity (Ministry of Health, 2003; Duncan, 2005). So while under-nutrition does exist in New Zealand, it is not the protein-energy malnutrition variety that we see in developing countries, instead it is the micro-nutrient variety. This is due to the high-calorie low-nutrient foods marketed to, offered to, provided for and/or chosen by children – leading to micronutrient-poor diets high in fat, salt and sugar. Therefore despite outward appearances it is probable that a proportion of children who are overweight or obese also have inadequate intakes of important micronutrients. Furthermore, these deficiencies, and therefore their effects, tend to cluster in the vulnerable groups listed above: Pacific, Maori and low socio-economic.

As well as nutritional intake, changing eating patterns are also of concern in New Zealand. The Children's Nutrition Survey (Ministry of Health, 2003) found 17% of children do not regularly eat breakfast at home before school and that

those who miss breakfast are not spread evenly throughout the population. Maori, Pacific and low SES children are much more likely to miss out on breakfast, with about 30% of Maori, nearly half of Pacific and almost one third of the lowest deprivation quintile eating breakfast at home only sometimes or never. These groups are also much more likely to eat on the way to school, and to source some or most of their food consumed at school from a shop, takeaway, canteen or tuckshop. Research has also shown that less healthy foods are cheaper than lower-fat and lower-sugar options (Wilson, 2005), which further explains the link between poverty and poor nutrition.

Of even greater concern were the Ministry of Health (2003) findings in relation to household food security. Overall 20% of New Zealand households with school-age children reported that they can only sometimes afford to eat properly. When sub-sections of the population are examined the picture becomes even more alarming: 48% of Pacific families, 34% of Maori families, and 38% of the lowest SES quintile can only sometimes afford to eat properly, and 54%, 38% and 45% respectively sometimes or often run out of food because of lack of money.

What the Children's Nutrition Survey shows very clearly is that, while an overall snapshot of the nutrition of the total population does not look too bad, the nutrition issues for the most deprived families and communities are very serious indeed. And these are the same sectors of the community that face a whole range of risk factors and disadvantages in relation to educational attainment.

These findings are corroborated by anecdotal evidence from teachers who report that in some deprived areas, children are coming to school hungry and are unable to concentrate on their school work as a result (Katikati Advertiser, 2005).

In summary, it is clear that New Zealand does have nutritional issues that are likely to be of direct interest to educators. And how nutrition interacts with education is of special importance to our society as a whole because childhood and adolescence are crucial periods for acquiring knowledge, behaviours and skills to cope and live within our modern communities.

Community, educational and food company's interest in nutrition

Television and movies are undoubtedly part of the problem when it comes to influencing food intakes of children, particularly in the marketing of high fat, salt and sugar foods. However, communities are also now being exposed to programmes and movies that document the importance of nutrition in education settings, and the current inadequacies that exist. Two examples from popular culture are the movie 'Super Size Me', and the television programme 'Jamie Oliver's School Dinners'. Websites associated with these shows are useful and accessible, and demonstrate that healthy foods can not only be nutritious, but also entertaining:
Supersize Me - http://www.supersizeme.com/

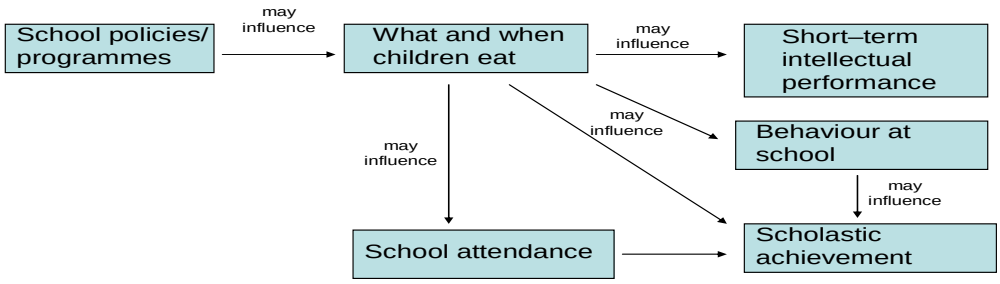
Jamie's - http://www.channel4.com/life/microsites/J/jamies_school_dinners/
Feed me better - http://www.feedmebetter.com/getinvolved/map.php

The success of these shows demonstrates the growing level of concern and interest in the issue of nutrition within communities.

Food companies commit enormous resources marketing and promoting foods to children. There are many environments in which this marketing is placed, and the education sector is one of the main targets. The involvement of food companies within the education sector moves well beyond the usual forms of marketing – such as direct product promotions, but also extends into creating educational resources for teachers to use in the classroom (workbooks, exercises, DVDs, websites, etc), providing sponsorship for school events and funding research on how nutrition affects educational outcomes, etc. Because of this influence, this review also considers the funding sources of research.

A simple model to explain the relationship between nutrition and education

The relationship between school nutrition policies/programmes and their influence on what children eat, their brain development, how they behave and their intellectual/scholastic performance is complex. To study such relationships typically requires the component parts to be considered separately. A simple representation of the hypothesised relationship would be:



Research reported in the literature often only covers one of the linkages represented, rather than multiple linkages or the whole pathway. Such a situation is common in many disciplines, including public health, and whole pathways may never be fully elucidated due to the many forms of confounding that may occur. In the meantime, policy decisions must be taken on the best available evidence, as is presented in this report.

Complexity is evident in each of these pathways, as consideration is given to what else might impact on any of the relationships shown above. The list is endless, but examples include the:

- relative wealth of the community the school draws its students from
- age of the children
- motivation of children, parents, community and educators
- gender of the children
- baseline nutritional status of the children
- social factors such as family
- knowledge and skill level of the educator
- what role the educator normally plays in the school (for example school nurse, physical education teacher, home economics teacher, etc)
- other supportive school policies and programmes
- time spent on, and quality of any interventions
- genetic influences.

This makes the area both challenging and interesting for parents, educators, researchers and policy makers.

Natuaralistic studies in the school setting can tell us about trends, impacts and correlations in the medium to long-term, but because it is difficult to control for confounding factors in a complex real-life environment, it is difficult to establish cause and effect with any certainty in such studies. On the other hand, tightly controlled lab-based studies give us certainty about the short term effects of single factors, but they cannot tell us about the long-term or cumulative effects which are so important when it comes to nutrition. By bringing together the results of a range of different studies, we can gain the fullest understanding of how nutrition impacts on learning outcomes.

Sugar, caffeine and hyperactivity

This document does not attempt to reinvestigate these issues in detail. However numerous previous studies have shown no link between adverse behavioural responses and ingestion of any kind of sugars. Despite well-intentioned beliefs from the public about negative impacts, when studied objectively using rigorous methods, no adverse effects on behaviour could be attributed to sugar (Krummel et al, 1996). An identical result was returned by other researchers (Wolraich et al, 1994; Beseler, 1999).

Caffeine from rich sources on the other hand, such as tea, coffee and soft-drinks has been associated with a number of behavioural problems, including headaches (Hering-Hanit, 2003). Similarly, short term withdrawal of caffeine (within 24 hours of stopping use and persisting for up to one week) can also affect children's sustained attention (Bernstein et al, 1998). Other studies have found that caffeine intakes of children have had 'modest or innocuous behavioural impacts on normal healthy children' (Castellanos et all, 2002). Intakes of caffeine have been recommended that are believed to have no adverse health effects - set at no more than 45mg per day for young children 4-6 years (or 2.5 mg/kg/day for other children) (Nawrot, 2003). The majority of children are unlikely to consume amounts as high as this, though heavy consumers in the USA (top tenth percentile) were at or just below this limit (Knight et al, 2004).

Explanation of terms used in this report

Nutrition: Nutrition has several components: energy (calories), macronutrients (eg, protein, carbohydrate, fat) and micronutrients (vitamins and minerals). The optimum levels of each are required for good nutrition.

Malnutrition: Malnutrition occurs when there is a major imbalance or insufficiency of nutrients. Note that obesity is a form of malnutrition.

Nutritional intake: Nutritional intake refers to the energy, macronutrients and micronutrients consumed in food and drink. The methodology for measuring nutritional intake is complex, and usually involves 24 hour diet recall.

Nutritional status: Nutritional status refers to the adequacy of energy, macronutrients and micronutrients in the body. Because people have different nutritional needs, people with the same nutritional intake may vary in nutritional status.

Food security: Food security means consistent availability of sufficient nutritious food to sustain wellbeing.

What and when children eat: The type and quantity of foods, for example, glucose solutions, piece of fruit, school meals, etc. The timing of food consumed, for example, breakfast, pre-test snack, lunch, morning tea break, etc.

School nutrition policies: Policies are written statements that describe how a school will move toward providing a complete environment that protects and promotes good nutritional outcomes for staff, students and the community.

School nutrition programmes: Programmes are a set of tangible projects and approaches that are implemented to promote and protect good nutritional outcomes. They are used to implement a school nutrition policy, or may be used when no overarching policy exists.

School environment: The school environment includes type and availability of food and drink at school; advertising and promotion of food and drink at school; whether or not there are vending machines, tuck shops or a canteen; school rules about food and drink; the existence of nutrition policies and/or programmes; fundraising and sponsorship connected to food companies etc.

Short term intellectual performance: Cognitive/mental and psychomotor performance is measured in a battery of tests. For example, rapid information processing, focussed and sustained attention, maze learning, arithmetic ability, recall tasks, reaction time etc.

Behaviour at school: Suspensions, exclusions, disciplinary actions, bullying, ability to get on with peers. Also covers 'internal' factors eg, motivation, depression, and anxiety.

School attendance: tardiness, absenteeism, truancy.

Scholastic achievement: Longer term impacts on national exam and educational attainment results.

Methodology

This rapid review has collected primary data from a number of sources. While there was a lack of randomised control trial (RCT) research, findings were elicited from other studies such as non-randomised trials and experiments, observational studies and systematic reviews (but not literature reviews). This synthesis is not a systematic review of primary data as the time frames did not allow for such a comprehensive approach. However the methodology follows the Agencies for Nutrition Action review methodology (ANA, 2005) where possible. In addition, we have not conducted a systematic search for grey literature in the chosen countries (except New Zealand). Again, this is not to discount the validity of such data – we believe they have an important place in the process of gathering evidence for making decisions about this area.

However, methods to systematically search and gather such data were beyond the scope of this rapid review.

Identification of the relevant literature

An extensive and systematic search of the published scientific literature was conducted. The search strategy was devised in collaboration with the New Zealand Health Technology Assessment Agency (NZHTA) and an example of a search strategy is shown in Appendix 1. Key words were determined by the authors in conjunction with the NZHTA.

Searches were conducted on the following:

Bibliographic databases

- Medline
- Embase
- Current Contents
- Cinahl
- Web of Science
- ERIC
- PsychInfo

Full-text databases

- EBSCO Host
- Science Direct

Review databases

- Cochrane Database of Systematic Reviews
- DARE Database of Abstracts of Reviews of Effects
- HTA database
- NHS EED

Evidence based sources

- ARIF
- Attract
- Bandolier
- Clinical Evidence
- Health Evidence Bulletins
- Organised Networked Medical Information (OMNI)
- Turning Research Into Practice (TRIP)

Websites

- Ministry of Health, New Zealand
- Department of Health, United Kingdom
- NHS Direct
- Australian Department of Health and Ageing
- Centers for Disease Control, USA
- Health Canada
- American Academy of Pediatrics
- American Dietetic Association
- Food Research and Action Center
- United States Department of Agriculture Food and Nutrition Service

Search engines and directories

- Google

All databases were searched from January 1999 to June 2005. This was an arbitrary choice to make the search manageable. The references generated were downloaded into EndNote software for removal of duplicates, leaving 104 references for consideration.

Data handling process

Titles and abstracts of the 104 identified references were assessed for relevance by one reviewer (R Quigley). The following inclusion criteria were used:

- English language only;
- January 1999 to June 2005;
- Human studies;
- Systematic reviews, syntheses, meta-analyses, interventions, observation studies, evaluations and commentaries;
- Explicitly uses or considers the relationship between nutrition, the school environment and educational outcomes;
- Research from countries where parasites, famine or severe malnutrition are an issue were excluded;
- Healthy children.

Reference lists of key papers were also searched to identify further papers. Two key papers published in 1998 were included, due to their high quality and relevance. From both processes a total of 48 papers and reports were ordered. Due to time pressures a cut-off date was set beyond which papers that had not arrived would not be considered. 44 papers were able to be retrieved within the timeframe.

Assessment of papers

The 75 papers were each appraised in terms of relevance and quality by the authors. There was no blinding of authorship of retrieved documents. The questions from the Agencies for Nutrition Action critical appraisal form were used to help assess the quality of the papers retrieved. The questions related to the type of study, power and statistical analyses performed, adjustment for confounders, bias and consistency of findings. A joint decision was made about whether a document should inform the reports recommendations and conclusions, or be used in the report to inform discussion only, or discarded.

All authors contributed to the writing of the report and all authors have final responsibility for the report.

Results and Discussion

Question One: What is the relationship between school policies and environments and what children eat?

What and when an individual child eats is affected by a number of factors including family situation (socio-economic status, education-level of parents), culture, knowledge and attitudes about food and health, individual tastes, and the availability, affordability and attractiveness of various food options.

While some of these factors are outside the control of schools, many of them are amenable to change and may be impacted by school policies, environments and programmes. School-based interventions to improve nutrition have had a long history, for example the free milk in schools scheme in New Zealand from 1937 – 1967. This paper looks at recent school-based nutrition intervention studies from developed countries and their effect on what children eat. While the literature on nutrition education and school-based feeding programmes is extensive and well-developed, research on the effect of policy and environmental interventions alone is a relatively new but growing area.

1A Multi-strategy nutrition interventions

One review and four studies looking at multi-strategy interventions (including the school environment and school curriculum) were found that fit the criteria for inclusion in this review (see table 1A). All but one study provides evidence that comprehensive multi-faceted school-based interventions are effective in favourably influencing what and when children eat, and improving their nutritional intake. Only one study (Parker, 2001) did not show significant changes to dietary intake at the end of the two year intervention period. While no significant changes were found in consumption overall, there were positive changes in the early stages of the intervention.

One of the studies (Radcliffe, 2005) used a randomised controlled trial (RCT) design to determine the efficacy of a breakfast promotion intervention based on Health Promoting Schools (HPS) processes. Intervention schools formed working groups representative of the whole school community and developed their own action plan that included strategies for the curriculum, the school environment and partnerships with the wider community. The intervention was undertaken over one school year. Breakfast skipping increased by a greater percentage in the control groups compared to the intervention group (20.2% vs. 4.5%). The proportion of children reporting that they ate a least one ‘poor food choice’ for breakfast decreased in the intervention group while the rate more than doubled in the control group. This study confirms that the

HPS is effective approach allowing individual schools to design their own strategies to address issues.

In the other RCT Birnbaum, 2002 tested three interventions in the TEENS study. The three nutrition-based interventions consisted of:

1. environment only
2. environment + classroom education
3. environment + classroom education + peer leaders.

The only group that showed significant changes was the third group, environment + classroom education + peer leaders. In this group fruit and vegetable consumption increased by one serving and there was also increased tendency to choose lower fat foods. The results of this study support the need to use multiple intervention strategies to achieve behaviour change.

Veugelers, 2005 examined two types of nutrition programmes in primary schools in Nova Scotia, Canada. The first type of programme consisted of policies or practices to offer healthy menu alternatives, the second was a multi-strategy nutrition programme based on the Centres for Disease Control (CDC) healthy eating programs. Interestingly, it was only children exposed to the comprehensive program that had healthier diets and lower rates of overweight and obesity, again supporting the importance of multi strategy interventions which include environment, educational and policy components. Such interventions inform and support behaviour change via a number of strategies for example, classroom teaching and learning, environment (food availability & promotion - tuck shop, canteen, vending machines), and school-home-community interaction.

In the review of 12 school-based intervention studies, four found gender differences in results, with girls more likely to improve their eating habits than boys (Perez-Rodrigo, 2001).

In addition to utilising a number of integrated strategies, factors associated with successful programmes are: (Auld, 1998)

- School-wide policies that support healthful eating;
- Sequential, comprehensive health education curriculum that includes nutrition which is fun;
- Coordination between school food service and nutrition education;
- Training for school staff;
- Family and community involvement
- Evaluation.

1B Multi-strategy nutrition and physical activity interventions

Seven papers, describing five studies, were found that included multi-strategy interventions aimed at influencing both nutrition and physical activity (summarised in Table 1B). All five studies reported positive outcomes for

some aspect of healthy eating (Sahota, 2001; Trevino, 2004; Himes 2003; Cabellero, 2003; Gortmaker, 1999; Manios, 1999; Manios 2002).

Two papers (Manios, 1999; Manios 2002) describe the results of a large intervention study in Crete. Two counties in Crete were assigned to the intervention and one county acted as the control. All first grade children were enrolled in the study and the intervention took place over a six year period. The intervention consisted of teacher delivered curriculum focus on nutrition and physical activity and parental involvement. After the six year intervention biochemical indices for total cholesterol were better in the intervention group and Body Mass Index (BMI) was lower. Total energy intake, fat and saturated fat intake increased less in the intervention group and leisure-time physical activity increased more compared to the control. Although it is difficult to ascertain whether the improved cholesterol and lower BMI values are due to changes in diet or physical activity, we do know that the intervention had a positive impact on dietary risk factors. Interestingly the positive results for dietary intake were not seen at the three year follow-up but were seen at the six year follow-up.

Two papers (Caballero, 2003; Himes, 2003) describe the results of the large Pathways randomised controlled trial in 41 schools in American Indian communities. The multi-component intervention was run over three years and included four areas, healthy eating and physical activity classroom curricula, changes to the school food service, increased physical activity at school and family support for nutrition and physical activity. The intervention resulted in a reduction in energy intake and the percentage of energy from fat (measured by 24 hour recall).

Three studies focused on interventions with primary school-aged children, two in the US and one in the UK. The interventions all had a mixture of classroom education, school environment and/or home environment changes. Two of the studies were RCT (Trevino, 2004; Sahota, 2001) and the third was a longitudinal cohort study (Gortmaker, 1999). Each of the interventions was between one-two years in duration. All three interventions resulted in some significant dietary change. Trevino, 2004 saw an increase in dietary fibre intake, Sahota, 2001 found an increase in vegetable consumption in intervention schools and Gortmaker, 1999 found a decrease in energy from fat and saturated fat and an increase in fruit and vegetable intake in intervention schools.

In summary, of the five studies describing a nutrition and physical activity-related intervention all showed some positive impact on what children ate. In one of the studies (Manios, 2002) positive changes were also seen in cholesterol levels and BMI.

1C Education focused interventions

There is evidence that providing information about nutrition in classroom lessons increases knowledge but does not always lead to behaviour change.

> *"A study of school-based nutrition education programs found that 10-15 hours of health education resulted in a gain in knowledge, 30 hours resulted in effecting health practices, 40 hours were needed to change attitudes and 50 hours were needed to change knowledge, attitudes and behaviour. In reality, the average amount of time spent on nutrition education per year for students between kindergarten and 5th grade is 13 hours" (Malone, 2005).*

Two studies met the criteria for classroom education interventions (summarised in Table 1C). Both studies involved primary school-aged children, the first was a longitudinal study with intervention and control groups in Alabama, USA (Powers, 2005), the second was a RCT based in the southwest of England (James, 2004).

In the first study nutrition educators delivered six weekly nutrition classes based on social cognitive theory (Powers, 2005). Children in the intervention group had improved dietary behaviours in all areas measured and improved nutrition knowledge scores. The questionnaire used to assess dietary behaviours was not validated and therefore cannot be considered a valid indicator of actual intake. However, it is interesting to note that nutrition knowledge did improve in the intervention group.

The second study (James, 2004) examined the efficacy of a focused nutrition educational programme aimed at reducing consumption of carbonated beverages and therefore preventing excessive weight gain in children. The intervention consisted of a one hour education session each term delivered by a nutrition educator with ongoing reinforcement from teachers. The results showed that children in the intervention group decreased their consumption of carbonated drinks by 0.6 glass and children in the control group increased their consumption by 0.2 glass. At 12 months the percentage of overweight and obese children increased in the control group by 7.5% and decreased in the intervention group by 0.2% (mean difference 7.7%).

1D Environment interventions altering food/drink availability, price and promotion

There have been a number of recent studies (see Table 1D) looking at the effect of food availability on what children eat, and these have been summarised in table 1. The evidence is clear that the school environment has an impact on what children eat. For example, one cross-sectional study (Kubik, 2003) found that a la carte food availability (where each item is priced individually and students buy the items they choose, either in the school canteen or via a tuck-shop or vending machines) is associated with higher fat intake and lower intake of fruits and vegetables compared to school lunch programmes where menus are set. Another study (Cullen, 2004) looked at the

changes in children's eating patterns when they moved from elementary school, where school lunch was served and there was no shop, to middle school with a 'snack bar' where children could purchase their choice of food. The study found that the children consumed fewer fruits and vegetables, and less milk and consumed more sweetened drinks and fries when they moved to a new school environment and gained access to a snack bar. A third study (Templeton, 2005) found that when competitive foods (CF) items, (salty and sweet snacks and non-carbonated drinks) were offered in addition to the school lunch one third of students purchased CF items. Those purchasing CF had significantly higher energy (20% higher) and fat intakes and lower protein, calcium, vitamin A intakes. Food waste was higher in those students purchasing CF.

Intervention studies have also shown that school policies and environments can affect what children eat. Increased availability and promotion (French, 2004; Dwyer, 2002; Carter, 1999) and reduced prices (Hannan, 2002; French, 2001) of lower-fat foods in school canteens and vending machines, resulted in increased consumption of lower-fat foods. These empirical studies are supported by qualitative research (Bauer, 2004) in which students identified the quality of the food served in school lunches and the easy availability of non-nutritious snacks as key barriers to eating nutritious food at school.

Pricing reduction interventions demonstrate that lowering prices is a very effective method of promoting desired food choices. In French, 2001 the price reduction and promotion interventions had no significant effect on the profits in dollars (from the control) due to a significant increase in sales. Signage and placing low fat snacks in designated low fat row improved sales a little but was not nearly as effective as price reduction.

1E Multi-strategy fruit and vegetable interventions

Two recent reviews (Perez-Rodrigo, 2001; French, 2003) suggest that the most successful schemes to increase fruit and vegetable intake in children have used multi-strategy approaches.

The results of several large multi-component school-based programs to increase fruit and vegetables have shown positive results (O'Neill, 2002; Baranowski, 2000, Reynolds, 2000). All three studies were randomised controlled trials with an intervention period greater than two years. All of the studies took place in the USA, two in elementary (primary) schools and one in a high school. All three studies were based on sound theoretical models of behaviour change, two used Social Cognitive Theory, the other used the PRECEDE-PROCEED model.

Increases in fruit consumption were achieved ranging from 0.2-0.6 servings per day. Vegetable intake was proven more difficult to change. Most of the programs include classroom education, behaviour change modules, food service changes and a parent component.

1F Environment focused interventions for fruit and vegetables

Four studies were found that matched the criteria for environmental interventions aimed at influencing fruit and vegetable consumption (see Table 1F). Three of the studies were with primary-school aged children, two in the USA (Perry, 2004; Cullen, 2000) and one in the UK (Wells, 2005), the fourth study was a small study in two US secondary schools (French, 2003).

All four studies showed positive results. Cullen, 2000 showed that availability of other foods for sale via a snack bar had a negative impact on the consumption of fruit and vegetables. Perry, 2004 used a randomised controlled study design to increase opportunities during the school lunch period to eat a variety of fruit and vegetables. This was reinforced with healthful role models and increased social support to eat fruit and vegetables. Changes in total fruit and vegetable consumption (excluding potato and juice) of 0.31 of a serving were achieved. The changes were mainly explained by an increase in fruit intake. In another study using the same intervention with the addition of classroom curriculum activities and parental involvement an increase for fruit (without juice) and fruit and vegetables together was observed of more than double achieved in this study. (Perry, 1999). A similar dose-response effect was reported in the Teens Eating for Energy and Nutrition at School (TEENS) study for young adolescents fruit and vegetable intake – reinforcing the need for a comprehensive multicomponent program to increase the potency of interventions (Birnbaum, 2002).

Wells, 2005 describes the results of the pilot National School Fruit Scheme (NSFS) in the UK. The NSFS has one primary component – the provision of fruit. While it is clearly effective in the short term at increasing fruit intake it does not appear to have longer term effects post intervention. The fruit intake of children receiving fruit (4-6 years) in infant school and those that had received fruit (7-8 years) now in junior school was measured in grams from a validated Food Frequency Questionnaire and a tick list for fruit and vegetables. Median intake of fruit in intervention infant schools was significantly higher (117g vs. 67g), however, there was no difference in intake of fruit at junior school between those that had been part of the NSFS and those that had not. The authors conclude that it would be appropriate within the context of the NSFS to consider how other aspects of nutrition promotion and integration of nutrition into the primary school curriculum might need to be presented in a more systematic way to promote a more sustainable outcome.

1G Education focused fruit and vegetable interventions

One study (Auld, 1999) was found that matched the criteria (see Table 1G). This study replicated the previously successful Integrated Nutrition Project (Auld, 1998) but used fewer classroom sessions (16 compared to 24 lessons) and alternated classroom teacher and special resource teacher (SRT) rather than just using SRT. Though absolute difference between the treatment and comparison groups relative to lunchroom fruit and vegetable consumption were similar to the original study (0.38 vs. 0.35 servings), children in the treatment group did not increase their consumption as in the original study. The original study saw an increase in the intervention group of 0.25 of a

serving of fruit and vegetables as well as a decrease in the control group of 0.14 servings. This study saw a decrease in the control group but no change in the intervention group consumption, although there were changes in knowledge and attitudes. The differing results are possibly explained by the lower intensity of intervention in this study.

1H School Breakfast Programmes

It is estimated that 17% of New Zealand children (Ministry of Health, 2003), up to 42% of Canadian children (Papamandjaris, 2000), up to 34% of US children (Rampersaud, 2005), and almost half a million children in the UK (Shemilt, 2004) regularly go to school without having had breakfast at home.

Research strongly supports a relationship between regular breakfast consumption and nutritional adequacy (Pollitt, 1995) with breakfast eaters having a significantly healthier nutritional profile than breakfast-skippers (Rampersaud, 2005). This finding is partly due to the direct contribution that breakfast makes to overall nutrition, and partly due to the fact that breakfast consumers tend to have healthier eating patterns throughout the day (Rampersaud, 2005). This tendency can be explained by confounding variables such as socioeconomic status that affect both the likelihood of eating breakfast, and also affect other nutrition-related behaviour. For example, in New Zealand, children from the most deprived quintile are least likely to eat or drink at home before school, most likely to buy food or drink on the way to school, and have a higher consumption of high-fat foods and soft drinks and lower consumption of vegetables than less deprived children (Ministry of Health, 2003).

School feeding programs have been developed in response to concerns that hunger and poor nutrition lead to behavioural problems, health problems and, ultimately, poor learning outcomes. Many evaluations of school breakfast programmes are based on qualitative reports from teachers and parents, rather than quantitative evidence. Such reports are generally very positive, with teachers and parents attributing improvements in students' motivation and concentration, discipline, health, attendance and educational attainment to implementation of breakfast programmes (Hyndman, 2000; Wahlstrom (1999). Most of the few rigorous studies that have been conducted were in the 1980s and early 90s and therefore did not fit criteria for inclusion in this review.

Those early evaluations in the 1980s and 90s showed that only a small proportion of the under-privileged and nutritionally at-risk for whom breakfast programmes were intended were actually participating (Pollitt, 1995). On the positive side, early research concluded that school breakfast programs do increase the overall likelihood of children eating breakfast on a regular basis (Pollitt, 1995).

School-based breakfast clubs or breakfast programmes are either targeted at underprivileged children and provided at little or no cost to these eligible children (and may also be available to others at a higher cost) or offered

universally to any child who wishes to participate at no cost. Studies conducted over the past six years in the US have focused on changes as a result of the implementation of universal-free school breakfast programmes (USBP) in schools that previously had targeted programmes. These studies, along with two from the UK are summarised in Table 1.

All three USBP implementation studies included in this review show that participation rates increase greatly when universal free breakfast is made available. For example, Murphy (1998) found that participation rates almost doubled after implementation of a universal-free school breakfast programme, and a USBP pilot in Minnesota elementary schools had participation rates of 75%-95% compared to a previous average of 12% when targeted programmes were in place. Prior to USBP only a small proportion of under-privileged children were accessing school breakfasts. For example, Murphy (1998) found that 57% of hungry or at-risk children rarely or never participated in school breakfast, and Kleinman (2002) found that despite more than 70% of children in the sample being eligible for free or reduced priced meals only 24% often ate school-breakfast. This data suggests that the stigma associated with participating in targeted programmes along with other barriers prevent the programmes reaching the majority of those they are targeted at.

Although the evidence is clear that school breakfast programmes, particularly universal-free programmes, can affect when and where children eat and the likelihood that they will consume breakfast, research showing changes in *what* children eat as a result of school breakfast programmes is lacking. Only one study fit the criteria for inclusion in this review – a UK based controlled intervention study which showed that a year after the introduction of school breakfast club, consumption of fruit at breakfast had significantly increased in the intervention sample compared with control (Shemilt, 2004). This is an isolated but positive finding, since it is in line with nutritional recommendations to increase fruit and vegetable consumption.

Evidence around the actual nutritional benefit of breakfast programmes is also lacking or inconsistent. An early study in the US found that while breakfast programmes increased the chances of children eating breakfast, at the population level they had no effect on the overall nutrient intake of the students (Radzikowski, 1984 in Pollitt, 1995). There are two studies included in the present review that examine the relationship between school breakfast and nutritional intake, neither providing particularly positive results with regard to nutritional benefits of school breakfast programmes. Kleinman (2002) found a much more modest nutritional benefit than is reported in school feeding programmes in the developing world (Cueto, 2001). Belderson (2003) compared the nutritional intake of breakfast club attendees in three UK schools with matched controls who did not attend breakfast club. The results are sobering – breakfast club attendees had higher total fat, saturated fat and salt intakes and lower carbohydrate intakes than controls.

Differences between developing and industrialised countries may be due to the effect of ‘averaging’ results over an entire sample. In industrialised countries where the majority of children are well nourished, participation in the

school breakfast programme is likely to be of significant nutritional benefit only to the sub-set of children whose nutritional intake is poor, and this improvement in nutritional intake may not be visible when averaging over the entire school population. However in schools where the majority are undernourished, a school breakfast programme is likely to raise the nutritional intake of most of the children and therefore the overall average will change significantly.

A second hypothesis to explain why school breakfast programs sometimes appear to have a neutral or negative impact on nutrition relates to the nutritional quality of the food offered. If school breakfasts are low in vitamins and minerals and high in fat, sugar and salt then it stands to reason that such meals will not be of nutritional benefit. The only study that reports the content of the school breakfast supports this hypothesis (Belderson, 2003); one of the schools gave children a fried sausage sandwich and another offered a selection of snacks including biscuits, sausage-rolls, doughnuts and crisps.

It has also been hypothesised that the effectiveness of school breakfast programmes may be due to psychological, social and attendance benefits of the programmes, rather than improved nutritional intake per se (Hyndman, 2000, Schoenthaler, 2000). If true, this would also help to explain why improved behaviour and academic performance are reported by teachers, even when overall improved nutritional intake is not observed.

In summary, school breakfast programmes are designed to improve the wellbeing and performance of students by decreasing hunger and improving the nutritional status of nutritionally at-risk students. Programmes have greater success in reaching these students with universal rather than targeted programmes, although the question of whether or not the children who need it most are benefiting remains. Evidence for improvements in nutritional intake as a result of school breakfast programmes is equivocal – at best, it appears that only a small proportion of students gain nutritional benefits from participation and at worst participation may have a detrimental affect on nutrition. However teachers generally report positive behavioural and learning outcomes as a result of programme implementation. It is possible that the school breakfast programmes have benefits on educational attainment independent of their effect on what children eat. Empirical evidence of the effect of breakfast on short term cognitive performance, academic outcomes, attendance and behaviour will be further examined in the remaining sections.

In summary, interventions and programmes focused on school policies, school curriculum and the school food environment can have an independent positive impact on what children eat. The most effective interventions combine all three aspects in a multi-strategy approach. Intervention dose has an impact on the effectiveness of interventions (Auld, 1999) as does duration (Manios, 2002). It is likely in some of the studies reviewed that low dose and short duration limited the full potential of the intervention.

It is clear, even after acknowledging the obvious limitations of some studies, that school policies and the school environment have an impact on what

children eat. This impact can also influence what children eat outside of school when parents are involved in programmes (Caballero, 2003, Himes 2003) and have a lasting impact past the end of the intervention (Manios 2002, Dwyer, 2002). While some of the factors that influence dietary behaviour are outside the control of schools, it is clear that schools can have a significant impact, through policies, healthy school environments and the school curriculum, on what children eat.

Question Two: What is the relationship between what and when children eat and brain development and function?

Nutrition affects the development of the brain in a number of ways:

1. the development of whole components of the brain, such as the hippocampus
2. the development of sub-components such as the myelination of neurons
3. the amount and functionality of neurotransmitters such as dopamine levels or receptor numbers (Wachs, 2000).

Timing is also of critical importance with brain development, and therefore much research has focussed on what is considered to be the most critical point in development, from gestation to age two years.

The current literature search turned up a number of studies which shed light on the relationship between what children eat and the development and functioning of their brains (see Table 2). Correlational and longitudinal studies from Chile and the Philippines show that poor nutrition in early life is associated with low IQ and long term academic outcomes (Ivanovic, 2002, 2004) even after adjusting for confounders within and across households (Glewwe, 1999). Ivanovic concludes that children who experienced post-natal malnutrition 'have some degree of alteration of brain development associated with decreased IA (intellectual ability) and SA (scholastic achievement)' (2004, p884). Thus the effects of gross malnutrition (in particular, protein-calorie malnutrition) on brain development are well established.

What is of more direct relevance to educators, perhaps, is the effect of nutrition on brain functioning and development of school-age children in the West. The brain continues to develop during childhood and through into the mid-teens, particularly in the area of the brain that is thought to be responsible for higher order cognitive activities such as focussing attention, blocking out irrelevant stimulation, testing questions in problem solving and planning (Bryan et al, 2004). Therefore, does a 'junk food' diet (high in calories but lacking in vitamins and minerals) affect brain development or IQ of New Zealand children? We found one review article (Benton, 2001) and one randomised controlled trial (Schoenthaler, 2000b) that fit our criteria that may help to shed some light on this question (see table 2). They look at the effect of vitamin-mineral supplementation on the IQ scores of school-age children.

Studies in the US, UK, and European countries consistently show that the non-verbal IQ of a sub-set of children is substantially improved as a result of vitamin-mineral supplementation (Benton, 2001). The majority of children however do not show any improvement. These findings are consistent with the hypothesis that the majority of children in developed countries have an adequate micronutrient intake, and therefore their intellectual performance

cannot be enhanced with additional nutrients. A subset however - 19% of children in the most recent study by Schoenthaler (2000b) – have a micronutrient intake so low that optimal brain function is not possible. Therefore, when their micronutrient intake is supplemented, their non-verbal IQ scores increase markedly – an average of 15.9 IQ points net gain in Schoenthaler's 19%. Blood-tests confirm this hypothesis – the children whose blood concentrations of nutrients improved as a result of supplementation were the ones whose test scores dramatically increased (Benton, 2001).

Given the similarities between New Zealand and the countries in which these studies were conducted, and the micro-nutrient inadequacies in New Zealand children discussed in the introduction to this paper, it is reasonable to conclude that a significant number of New Zealand children's diets are so poor that their brain functioning is affected. The good news is that these studies suggest that the effects of such deficiencies can be ameliorated with improved diet or supplementation.

In their 'Statement on the link between nutrition in cognitive development in children' the US Nutrition-Cognition National Advisory Committee (1998) state:

Cognitive deficits related to undernutrition are now believed to result from complex interactions between environmental insults and undernutrition. A cumulative effect of persistent exposure to undernutrition and poverty has been shown clearly. The longer a child's nutritional, emotional and educational needs go unmet, the greater the overall cognitive deficits. Continuous low nutritional intake, for example, usually affects psychological factors such as motivation, attentiveness and emotional expression. These in turn may have a negative effect on critical developmental processes including parent-child interaction, attachment, play and eventually learning. But unless major and irreparable physiological insult has occurred, improved nutrition and conditions in the social environment can modify the developmental effects of biological and social risk factors to which the child is exposed in early life.

In conclusion, there is undoubtedly a relationship between what children eat and their brain development and functioning. Poor nutrition alters brain development and intelligence by interfering with overall health as well as with the child's energy level, neural functioning, rate of motor development and growth. Even mild or moderate undernutrition, as experienced by some children in New Zealand, is enough to affect IQ, which in turn is a major determinant of academic achievement. Although mild to moderate under-nutrition affects the functioning of the brain, evidence suggests that improvements to nutrition and social environment can largely reverse the negative effects of a poor diet.

Question Three: What is the relationship between what and when children eat and behaviour in school?

Both anecdotal and scientific evidence suggest that what children eat affects outward behaviour, for example classroom discipline, hyperactivity and interactions with peers. There have also been links drawn between nutrient intake and children's internal emotional wellbeing (eg, anxiety, depression and motivation). For the purposes of the current review, both externalised and internalised social and emotional functioning are referred to as 'behaviour'.

As well as a direct link between food and behaviour, it has also been hypothesised that food insecurity at the household level (ie, lack of sustained access at all times, in socially acceptable ways, to food adequate in quantity and quality to maintain a healthy life) affects behaviour and psychosocial functioning.

Behaviour is clearly of interest to educators, since disruptive children miss out on learning opportunities themselves and interfere with the learning of others. Similarly, children who are anxious, depressed, poorly motivated or have trouble getting on with their peers may spend less time at school and be less 'teachable' than their well-adjusted peers.

This section looks at the evidence on the relationship between what children eat (including food security) and their behaviour. We found ten studies examining these issues that fit our criteria, summarised in table 3 under three sub-headings: Nutritional intake/status, food security, and breakfast program.

Nutritional intake and behaviour

High quality intervention studies provide strong evidence for a causal link between nutritional intake and behaviour. Kleinman et al. (2002) found that low nutrient and/or calorie intake was correlated with poorer psychosocial functioning (in terms of score on the Pediatric Symptom Checklist). After the introduction of a universal school breakfast programme, improvements in nutrition were associated with corresponding improvements in psychosocial functioning (Kleinman, 2002). Both this finding and Schoenthaler's (2000) randomised controlled trial, discussed below, point to a direct relationship between nutritional intake and behaviour.

In a placebo-controlled study looking at the effect of vitamin-mineral supplementation on school conduct (Schoenthaler, 2000a), it was found that the children on the active tablets committed 47% fewer rule violations that the children taking the placebo. Similar results were found in an earlier study of incarcerated children who underwent dietary modification alone. Interestingly, like the studies looking at supplementation and IQ (Benton, 2001; Schoenthaler, 2000b), the researchers found that it was a small minority of students who responded dramatically to the treatment who accounted for the

difference between the groups. Before the intervention, poor conduct was heavily skewed towards a small number of students: 2.5% of students were responsible for 55% of the rule violations. After the intervention, there were ten 'habitually disruptive' students amongst the study sample who committed three or more rule violations, nine of them in the placebo group and only one student who was receiving the vitamin-mineral supplementation. This tends to suggest that, as with IQ, there is a subset of children whose nutrition is so poor that their behaviour is affected, possibly due to impairment of cognitive functioning affecting impulse-control or ability to learn from mistakes. It follows that the majority of students with adequate nutrition are not affected by dietary improvements, however habitually disruptive children can be greatly affected by improved nutritional intake.

Neither Kleinman (2002) nor Schoenthaler (2000a) investigated the particular vitamins and minerals responsible for the effects. However, a body of research around the effects of specific nutrient deficiencies suggests that deficiencies in a number of nutrients or a combination of nutrients can lead to behavioural effects. Iron deficiency is perhaps the best researched of the specific deficiencies and has been linked to learning and behaviour problems, including hyperactivity (Grantham-McGregor, 2001).

The initial literature search only produced one study examining the relationship between macronutrients and behaviour in school children (Zhang, 2005). A further brief search of the literature for research on the effects of diets high or low in a particular macronutrient (fat, carbohydrate, protein) on children's behaviour or emotional wellbeing revealed that little research has been conducted on this topic. Recent empirical research on the effect of caffeine, food additives or sugar on children's behaviour is also scarce – findings from earlier research have been outlined in the introduction.

In summary, evidence strongly suggests that micronutrient (vitamin and mineral) deficiency can lead to behavioural problems, independently of social environment and psychological factors. Amongst children with micronutrient insufficiencies, improved nutrient intake can result in dramatic improvements in behaviour. The long-term effects of diets high or low in macronutrients such as sugar (carbohydrate) and cholesterol (fat) have not been established, though new research is raising some interesting questions.

Food security and behaviour

'Food insecurity', 'food insufficiency' and 'hunger' are all terms used to describe the lack of consistent availability of sufficient nutritious food to sustain wellbeing. While there are subtle differences in how each is defined and measured, for the purpose of this overview, 'food insecurity' will be used to cover all three. Questionnaires used to assess household food insecurity focus on whether or not there is always enough food in the house, whether or not there is always enough money to buy food, and may also ask about worry or anxiety associated with having enough food to feed the household.

Unsurprisingly, there is a strong relationship between food insecurity and socio-economic status (SES), with poor households more likely to experience food insecurity than rich households. It is not an absolute relationship however – many low SES households are food-secure while some high SES household do experience food insecurity. The question arises then, does food insecurity affect behaviour independently of SES?

The relationship between food insecurity and behaviour is a relatively new area, but there is growing evidence that an association exists. Research from the late 90s (Kleinman, 1998) established that low-income children classified as 'hungry' had more psycho-social problems than their low-income but 'not-hungry' peers. Two recent studies (Alaimo, 2001; Dunifon, 2003) have provided further evidence around the effect of food security on children's educational and psychosocial development, independent of nutritional intake and SES.

Amongst primary school children (aged 6-12) both Alaimo (2001) and Dunifon (2003) found an association between food insecurity and behaviour, even after adjusting for a range of confounding variables. Alaimo (2001) found that children from food insecure households were more likely to have difficulty getting on with other children, to have repeated a grade, and to have seen a psychologist than children from food-secure households. In the study by Dunifon (2003) food insecurity was associated with decreased positive behaviour, and increased health limitations, that is, health problems that interfered with ability to attend school or participate in daily activities. The only study looking at the effect of food insecurity on teenagers found that, after adjusting for confounders, food insecurity was associated with higher rates of suspension, difficulty getting on with peers, and likelihood of having seen a psychologist (Alaimo, 2001).

In conclusion then, periodic hunger and food insecurity at the household level is significantly and consistently associated with behavioural and health problems in school-aged children and this effect is independent of SES.

School feeding programmes and behaviour

Five studies on school breakfast and lunch programmes included in this review have looked directly at the relationship between programme implementation and behavioural outcomes.

Three out of five (Murphy, 1998; Wahlstrom, 1999; Kleinman, 2002) found that school breakfast programmes (USBP) seemed to have a positive effect on behaviour of those who participated. In one study (Wahlstrom (1999) Dept. of Children, Families and Learning, 1998), the introduction of a universal-free school breakfast programme was associated with very high participation rates (75-93%) and teacher reports of better discipline and classroom behaviour:

"*Classes at the pilot sites lose less educational time due to discipline problems. Nutritious school breakfast increases attention span and reduces*

classroom disruption. Fewer students are sent to the principle's office. Administrators feel that school breakfast plays an important role in their 40-50% decline in discipline referrals" (*Wahlstrom (1999) Dept. of Children, Families and Learning, 1998).*

While more rigorous research is in line with these findings, it is important to note that this research based on teacher-report does not have the rigor required to come to any definitive conclusions. This study does not compare participators with non-participators within the pilot sites, for example, nor were any pre- and post-intervention measures taken.

Murphy (1998) and Kleinman (2002) also examined the changes resulting from the implementation of USBP using more rigorous intervention study methodology. Murphy (1998) found that child and teacher ratings of psycho-social problems decreased to a significantly greater degree for children whose participation in the school breakfast programme increased, as opposed to children whose participation declined or did not change. Kleinman (2002) found that after implementation of USBP, those who decreased their nutritional risk showed significantly greater improvements in psychosocial functioning than those whose nutritional risk did not change or declined.

The other two studies found that students who participated in school feeding programs had significantly poorer psychosocial functioning (Dunifon, 2003, Shemilt, 2004) and conduct (Shemilt, 2004) than students who did not participate. It was hypothesised these results were due to unmeasured confounders – that is, characteristics of the children or their families that made them more likely both to attend the feeding programme *and* have behavioural problems. Indeed when Dunifon (2003) paired children from the same families, one of whom attended the lunch programme and one who did not, the effect disappeared. Therefore we can conclude that it was the family environment rather than the feeding programme that caused the poor behaviour. The researchers in these two studies concluded that school feeding programmes neither helped nor hindered the children's behaviour.

It seems, then, that in at least some schools, improved behaviour and emotional wellbeing can be seen in children who increase their participation in the school breakfast programme and/or decrease their nutritional risk. In other schools, feeding programmes do not appear to lead to improved behaviour, indicating that either the programmes are not reaching the children who are nutritionally at risk, or that participants' nutritional intake is not improved as a result of participation.

As well as the nutritional aspect of the programmes, there may also be other differences in the way the programmes are implemented that affect behaviour. For example, if participation rates are high and the school uses the shared mealtime as an opportunity for positive social interaction and learning, as seems to be the case in the Minnesota pilot schools (Wahlstrom, 1999), then additional social benefits are likely to be derived from the programme, as indeed is reported. However, if there is a stigma attached to participating in the feeding programme, it is poorly supervised and is a site for the most at-

risk children to act out their behavioural problems (as seems to be the case in some of the schools studied by Shemilt, 2004), then it is possible that any nutritional benefits on psychosocial functioning are outweighed by the negative effects of a disruptive school-breakfast environment.

In summary, there is a strong relationship between what children eat and their behaviour in school. Well-nourished children from food-secure households have better conduct & psycho-social functioning than poorly nourished or 'food-insecure' children. The relationship between food and behaviour can be partly explained by the direct effect of nutritional intake on behaviour, and partly explained by stress associated with food insecurity. The effectiveness of school feeding programmes for improving behaviour and psychosocial functioning of 'at risk' students is inconsistent and may depend upon social and organisational aspects of the programme's implementation as well as nutritional factors.

Question Four: What is the relationship between what and when children eat and intellectual performance in the short term?

There has been a great deal of research examining the short term effects of fasting (that is, skipping a meal), and of intake of particular macro-nutrients (eg, carbohydrate, protein or fat) on short term cognitive performance, eg, memory, attention, spatial skills, reaction times, mathematical ability and so on. Much of the literature dates back to the 1980s and 90s, so the studies that fit our criteria for inclusion in this review (summarised in Table 4) are only a small subset of what is now a large body of research. The results of these studies are confusing, to say the least, and it is difficult to come to any firm or general conclusions.

For example, the findings of studies examining the effect of skipping breakfast are inconsistent, with the four studies included in the current review giving a range of results. Two found that skipping breakfast was associated with poorer attention (Wesnes, 2003, Busch, 2002), one found that episodic memory was also impaired (Wesnes, 2003) whereas two studies concluded that memory was not affected by skipping breakfast (Busch, 2002; Benton, 2001). One study concluded that a glucose drink did not provide any cognitive benefits (Wesnes, 2003) while another (Morris, 2001) found that listening span was improved after a glucose but not after a saccharine drink. The general direction of results tends to indicate that the one-off omission of a meal may affect attention, but does not significantly impair the performance of normally well-fed children on other cognitive tasks, although they may require to greater effort to sustain the same performance.

These results are consistent with findings of earlier studies which also present an array of data which is difficult to interpret in a coherent way. It is evident from this research that children's impairment as a result of short-term fasting depends on the time of day, the amount of time that elapses between when the meal is missed and when the tests are performed, the type of test that is performed, the general nutritional status of the child, the type of food or drink consumed by the comparison group and also on individual metabolic differences. It is also worth noting the funders of such studies (often producers of a particular type of food) and how this might influence whether and how results are reported.

Because of the importance of optimal functioning of cognitions for survival, these functions are quite strongly protected against short term dietary and physiological disturbances (Dye, 2002: S187). Therefore, Dye argues, it is not surprising that studies looking at the short-term effects of missing a single meal or eating a particular food find small and inconsistent effects amongst generally well-nourished subjects. Interestingly, research from developing countries, although also inconsistent, tends to suggest that children who are under-nourished to start with are more impaired by fasting than their well-

nourished peers. If so, it is likely they are less able to compensate for a missed meal since they do not have reserves to draw on.

Studies that have looked at the effects of certain types of foods on performance have also produced what appear to be contradictory results. Along with the factors above (time of day, type of test etc), meal size and nutritional composition also affect the results. In the short term, it does not appear that intake of any particular macronutrient improves performance amongst generally well-nourished children.

What *is* clear is that the relationship between nutritional intake and mental performance in the short term is complex, and possibly not very relevant to the question of how nutrition relates to academic performance in the longer term. It is likely that the *accumulated* effect of ongoing dietary habits and their impact on the functioning of the brain is of greater interest and relevance to educators. The relationship between what children eat and academic performance is covered in section six.

Question Five: What is the relationship between what and when children eat and school attendance?

There is strong and consistent evidence from both developing and industrialised countries that children who are not well-nourished have higher rates of absenteeism and truancy than those who are well-nourished. The implementation of school-based feeding programmes is associated with improved school attendance in both developing and developed countries (Cueto, 2001, Nutrition-Cognition National Advisory Committee, 1998).

This paper examines one review and six studies which include measures of absenteeism or truancy (Rampersaud, 2004; Shemilt, 2004; Dunifon, 2003; Kleinman, 2002; Wahlstrom, 1999)Dept of Children, Families and Learning, 1998; Alaimo, 2001; Murphy, 1998), summarised in Table 5. Without exception, the studies found a robust association between what children eat and school attendance. Good nutritional intake, high participation in school breakfast programmes, and household food security were all consistently associated with good school attendance. Conversely, children who had poor nutritional intake, irregular participation in school breakfast programmes or food-insecurity at home had poorer school attendance. This relationship holds even when results are adjusted for confounding variables such as socioeconomic status.

Longitudinal and intervention studies (Shemilt, 2004; Kleinman, 2002; Murphy, 1998) show that changes in nutritional intake and school breakfast participation lead to corresponding changes in attendance rates. The evidence is therefore strong that there is a significant causal relationship between what children eat and school attendance. Well-nourished, food-secure children are less likely to get sick (Powney, 2000), tend to achieve better academically (see section 6), and get on better with their peers (Alaimo, 2001). These are some of the factors that explain why children who eat well are more able and motivated to attend school.

Question Six: What is the relationship between what and when children eat and academic performance?

This discussion has already examined several of the determinants of academic performance and the role nutrition plays in each: brain development and functioning, behaviour, short term cognitive performance and school attendance. There are also a number of studies that have looked at the direct link between what and when children habitually eat (including food security) and their school grades, or performance on academic tests.

The results are consistent – there is a strong relationship between children's diets and their academic performance. Cross-sectional studies (Ivanovic, 2005; Ivanovic 2002; Grantham-McGregor, 2001) show that there is a correlation between nutritional deficiencies in early life and poor academic performance in later childhood and adolescence, both in developing countries and developed countries. Longitudinal and intervention studies (Haojie, 2003; Grantham-McGregor, 2001, Glenwe, 1999) also support a relationship between nutrition and long-term academic outcomes, and suggest that the relationship is causal.

Research measuring current nutritional status and dietary habits has also established a consistent relationship between nutrition and academic performance (Kim, 2005; Ivanovic, 2004; Kleinman, 2002). The difference in academic performance between well-nourished and poorly-nourished children remains significant, even after adjusting for covariates such as socioeconomic status (Kim, 2002; Glenwe, 1999). Intervention studies show that when nutrition is improved, through iron supplementation (Grantham-McGregor, 2001) or increased participation in school breakfast programme (Kleinman, 2002; Murphy, 1998) for example, academic performance may improve.

In studies that broke down academic achievement by subject, there is a fairly consistent relationship between nutritional intake and mathematics grades (Kleinman, 2002; Murphy, 1998; Minnesota Dept of Children, Families and Learning). Maths scores tend to improve with better nutrition, whereas changes in reading and other subjects are less consistent across studies. For example, the Minnesota pilot sites found improvements in reading, whereas Kleinman (2002) and Murphy (1998) did not find improvements in other academic subjects when nutrition improved.

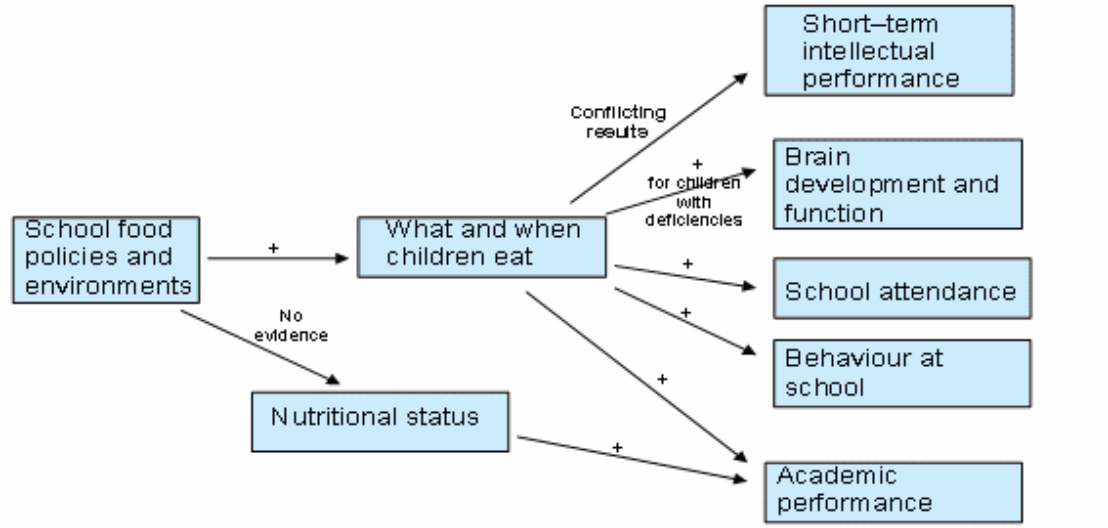
Early evaluations of school breakfast programme reported significant improvements on achievement tests for elementary school children participating in the programme over those who qualified but did not take part (Meyers, 1989). More recent research also supports this finding, with those increasing their participation in school breakfast also improving their math score in one study (Murphy, 1998) and increased participation leading to higher maths and reading scores in another (Wahlstrom, 1999) Dept of Children, Families and Learning).

Although little research has been done in relation to the effects of obesity on academic outcomes, it appears that there is an inverse correlation between body mass index (BMI) and academic performance, ie, overweight children do not do as well at school as children of normal weight. Studies from Thailand (Mo-suwan, 1999) and the USA (Datar, 2004) show that overweight children of all ages have significantly lower school test scores than their non-overweight peers. However, when confounders such as socio-economic status and maternal education are taken into account, it appears that obesity is a marker rather than an independent cause of poor academic performance, with the possible exception of maths scores for boys (Datar, 2004).

"Unfortunately, the effects that poor health and nutrition have on learning and educability are often not incorporated into efforts to improve our education system. Key educational problems such as drop-outs or school failure are rarely examined in terms of the health and nutrition status of poor children." US Nutrition-Cognition National Advisory Committee (1998)

Conclusion

A significant proportion of New Zealand children are affected by a number of dietary issues: food insecurity at the household level, low vitamin and mineral intake, high fat and sugar intake, and obesity. These nutritional problems disproportionately affect Maori, Pacific and children in families with a low socio-economic status, and have direct and indirect impacts on their achievement at school. This review has helped to clarify the causal mechanisms that explain the links between nutrition and academic outcomes, which are summarised diagrammatically below.



There is strong evidence that children's diets affect their school attendance, and their behaviour in school. Research indicates that habitually disruptive children and children with other behavioural or emotional issues may well be suffering from poor nutritional status, which is reversible with dietary changes or supplementation. Research also suggests that food insecurity at the household level has an effect on emotional and behavioural wellbeing in children, independently of nutritional intake and confounders such as socioeconomic status.

Evidence on the short-term effects of fasting or poor intake of particular nutrients/food groups is mixed, but there is a clear and consistent relationship between nutrition and academic outcomes in the longer term. Children who eat regular meals and have an adequate nutrient intake do better at school than those who skip meals and have inadequate nutrient intakes.

Even in the developed world, evidence suggests that a significant proportion of school age children have vitamin and mineral intakes that are so low that their mental functioning and conduct is affected. While the overall number of malnourished New Zealand children is relatively small, in schools with a high proportion of children from low SES backgrounds, poor nutritional status may be the norm rather than the exception.

Research on school-based programmes has demonstrated that schools can play important and effective roles in improving what children eat and hence their nutritional status. Nutritional status in turn influences their attendance, health, behaviour and academic outcomes. While classroom-based nutrition education alone may only have a small effect on children's food choices and eating behaviour, comprehensive multi-strategy programmes are consistently shown to have a positive effect on what children eat. Multi-strategy programmes include both education via the curriculum and changes to the school environment. Programmes including the following factors are most successful:

- School-wide policies that support healthful eating;
- Sequential, comprehensive health education curriculum that includes nutrition which is fun;
- Coordination between school food service and nutrition education;
- Training for school staff;
- Family and community involvement
- Evaluation.

There is good evidence that universal feeding programmes reach nutritionally at-risk students more effectively than targeted programmes.

This literature review clearly highlights the important role that schools could have in improving nutrition outcomes for children. Poor nutrition in childhood is associated with poor attendance at school, poor behaviour at school and poor long term academic outcomes. The goal of the Government's Schooling Strategy 2005-2010 (Ministry of Education, 2005) is "All students achieving their potential". This means significantly improving opportunities and outcomes for students currently underachieving, while continuing to improve outcomes for high and average achievers, across all dimensions of knowledge, skills, attitudes, values and indentity. Those children currently underachieving in the education system are from the same groups experiencing poor nutrition. In other words they are doubly disadvantaged. Improving childhood nutrition by ensuring that all schools have nutrition policies, a strong nutrition curriculum and a healthy school food environment is an important evidence-based step toward all students achieving their potential. Students who are well nourished are more likely to attend school, have better behaviour at school and better long term academic outcomes.

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Appendix 1 – Data Tables

Table 1A: Multi-strategy nutrition interventions

First Author (Year)	Study Sample	Study Type	X (data collection method)	Y (data collection method)	Confounders Adjusted for	Association Found	Who sponsored the study?
Veugelers (2005)	5517 5th Grade students Novia Scotia CLASS study	Retrospective review Cross sectional with 2 intervention groups and 1 control group	Havard Youth FFQ measuring dietary quality, F&V intake, fat and calorie intake Weight/BMI	Schools divided into 3 Groups: 1. Policy/practice to offer healthy menu alternatives 2. Multi-level intervention bases on CDC recommendations from Annapolis Valley HPS Project (AVHPSP) 3. No nutrition program	51% RR Adjusted for gender, rural/urban, parental education, income and neighbourhood income Adjusted for non-response bias	Those in the comprehensive AVHPSP had significantly lower % overweight and obesity, increased F&V and decreased fat and improved overall diet quality compared to either 1 or 3 schools No significant difference between 1 and 3	Funded by the Canadian Population Health Initiative and the Canadian Institutes of Health and Research
Radcliffe (2005)	13 schools 790 grade 7 students (11-12yrs) Queensland Australia	RCT. Randomisation at school level	Pre and post intervention questionnaire: 1. proportion of children usually skipping breakfast on one or more days of school week 2. composition of breakfast	Intervention using HPS approach focused on breakfast: 1. curriculum 2. school ethos and environment 3. partnerships with community	RR was 95% Interventions were not standard – they were designed by the school	Breakfast skipping increased by a greater proportion in the control group (20.2 vs. 4.5%) Decrease in 'poor food choice' items in intervention group and increase in control group	Commonwealth Department of Health and Ageing
Birnba	16 schools	RCT	Student self report of fruit	TEENS study intervention – 3	Possible cross	Those in the IG	NCI

um (2002)	Grade 7 N=3503 1 year intervention Minneapolis	TEENS study. 8 schools intervention, 8 schools control.	and veg and usual food scores	IG groups within each school: 1. environment only 2. environment + classroom 3. environment + classroom + peer leaders	contamination within intervention schools was not adjusted for	including environment + classroom + peer leaders increased F&V consumption by 1 serving and also increased tendency to choose lower fat foods Other interventions and control showed no difference	

Parker (2001)	3 secondary schools in Peterborough UK	Controlled intervention study 2 intervention, 1 control school	5 monitoring periods of 8 weeks each using observation of frequency of food categories consumed by individuals	2 year intervention – improve school lunches, focus on curriculum, school food team set up (including teachers and students)		Overall no significant changes in school based eating at the end of the study	Oxford and Anglia Regional Health Authority
Perez-Rodrigo (2001)		Review of 12 selected school-based nutrition education programmes	Dietary Habits	Multi-strategy nutrition interventions, using 3 or more of: Classroom teaching; family involvement; workshops; school meals/cafeteria; other		7 found increased consumption of fruit & vegetables (no decreases in F&V reported) 3 reported decrease in fat consumption (no increases in fat reported) Better results for females (4 studies) Poorer results for low SES & ethnic minority subgroups (1 study)	Not declared

Table 1B: Multi-strategy nutrition and physical activity interventions

First Author (Year)	Study Sample	Study Type	X (data collection method)	Y (data collection method)	Confounders Adjusted for	Association Found	Who sponsored the study?
Trevino (2004)	Elementary schools, inner city Texas, predominantly Mexican	RCT – school as unit	Main outcome – fasting capillary glucose levels (FCG) Secondary outcomes – SF and dietary fibre intake (3x 24 hour	Intervention based on SCT Intervention involved 50 sessions over 7 months, Taught through classroom activities, home, school cafeteria and after-school care. Focused on:	Validated dietary method for this age group	Significant change in FCG and physical fitness levels after adjusting for covariates	NIH

	American children 4th grade N=619 intervention N=602 control		recalls), physical fitness, body fat (bioelectrical impedance), height, weight, BMI	1. decrease SF intake 2. increase dietary fibre 3. increase PA		Significant increase in dietary fibre intake for IG No significant changes in SF intake, body fat	

Caballero (2003)	Pathways Study 41 schools in 7 American Indian communities in Arizona, New Mexico and South Dakota N=1704	RCT – school as unit Intervention over 3yrs	Height, weight, BMI, % body fat, PA Knowledge, attitudes and behaviour Dietary intake measured by observation of lunch and 24-hour dietary recall (5th grade only)	Intervention consisted of: 1. classroom curricula for grades 3-5 to promote healthy eating and PA 2. Low fat healthy school food programmes 3. Physical education 4. Family involvement	Validated methods 83% of those enrolled completed Implementation of each component was estimated	No significant reduction in % body fat or BMI. Significant reduction in % energy from fat in intervention schools Total energy intake was reduced when measured by 24 hour recall but not lunch observation. Several of the components of knowledge, attitudes and behaviour were positively influenced	National Heart, Lung and Blood Institute
Himes (2003)	Pathways Intervention 41 schools in 7 American Indian communities in Arizona, New Mexico and South Dakota N=1704	RCT – school as unit Intervention over 3 yrs	Dietary intake measured by observation of lunch (3rd Grade and follow up at 5th Grade) and 24-hour dietary recall (5th grade only)	Intervention consisted of: 1. Classroom curricula for grades 3-5 to promote healthy eating and PA 2. Low fat healthy school food programmes 3. Physical education 4. Family involvement		Based on observations the intervention was associated with decreased % of energy from fat and SF and increase in % energy from carbohydrate Based on 24 hour recall intervention was assoc with lower energy, fat, SF and lower % of energy from fat, SF	National Heart Lung and Blood Institute

						and higher % energy from carbohydrate	
Manios (2002)	602 (IG) and 444 (CG) randomly selected from larger study of all 1st grade students enrolled in 1992 in 2 counties in Crete	RCT - 6 year intervention	Pupils nutrition knowledge, dietary intake, PA, fitness, height, weight, BMI, fasting lipids	Teacher delivered curriculum focus on nutrition and PA Also included parental involvement	Dietary variables were controlled for baseline intake and also BMI Not clear how much was due to nutrition education component and how much to PA environmental intervention	Intervention group had significantly lower total cholesterol and BMI Total energy intake and fat and saturated fat intake were significantly lower in intervention group	Kellogg's, Greek Ministries. of Education and Sport

Sahota (2001)	10 primary schools in Leeds (634 children aged 7-11yrs)	RCT at school level Uses HPS theory	BMI Diet assessed by both 24 hour recall and 3 day food diaries Psychological (validated tools) measures - self perception for children, dietary restraint, adapted body shape perception scale at baseline and at 12 months	Intervention: Teacher training Modification of school meals School action plans targeting curriculum, tuck shop, PA	Schools were paired by size, ethnicity and free school meals Adjusted for sex, age, baseline BMI and variable of interest	No difference in BMI (for obese or normal weight) Small increase in vegetable consumption in intervention schools Study was successful in changing ethos of schools and attitudes of children	Northern and Yorkshire Region Research and Development Unit
Gortmaker (1999)	4th grade students in Baltimore US	Longitudinal cohort intervention and control groups 2 year intervention SCT based	Data collected from a stratified random sub-sample n=2103 Two 24-hour recalls (Validated) PA recall Food and Activity self-report survey	Eat Well and Keep Moving Program taught by classroom teachers over 2 years – multi curriculum (math, science, arts, social studies) Intervention focused on reducing fat and SF intake, increasing F&V, decreasing TV viewing and increasing moderate to vigorous PA	Implementation of program evaluated RR 66% over 2 years	71% of curricula activities implemented Decrease in energy from fat and SF, increase in F&V in intervention	Havard research grant
Manios (1999)	40 schools in Crete 1st grade students 288 students (IG) and 183 (CG)	3 year intervention	Pupils nutrition knowledge, dietary intake, PA, fitness, height, weight, BMI, fasting lipids	Teacher delivered curriculum focus on nutrition and PA Also included parental involvement	Only a small number of children completed dietary records Positive changes were due to changes in PA	Intervention pupils had smaller increases in total cholesterol and a decrease in LDL cholesterol IG had smaller increase in BMI No sign changes in dietary intake IG had increases in	EU – Europe Against Cancer and Mediterranean Integrated Program of Crete

						PA out of school and fitness and health knowledge No changes in parents health knowledge	

Table 1C - Interventions focused on classroom education

First Author (Year)	Study Sample	Study Type	X (data collection method)	Y (data collection method)	Confounders Adjusted for	Association Found	Who sponsored the study?
Powers (2005)	1100 second and third grade students in Alabama	Controlled before and after assessment	Dietary behaviour changes – overall dietary behaviour, dairy consumption, F&V consumption Nutrition knowledge – food group knowledge, nutrient/food knowledge and nutrient/function knowledge	8 week nutrition education classes Social Cognitive Theory based	Control group	Significant improvements in all aspects of dietary behaviour and nutrition knowledge for intervention group	Not declared
James (2004)	6 primary schools in southwest England (644 children aged 7-11yrs)	Cluster RCT with blinding to school or class Randomisation by class	Drink consumption using 3 day diary BMI -Overweight/obese children Both measured pre and post study	Focused educational programme on nutrition over one school year Fizzy drinks, both sweet and diet discouraged One hour session per term with ongoing reinforcement from teachers	Relatively low RR – only 36% returned both diaries	Consumption of carbonated drinks decreased by 0.6 glass in IG and 0.2 glass in CG % overweight and obese children decreased by 0.2% in IG and increased by 7.5% in CG	GlaxoSmith Kline, Aventis, Pfizer – stated that companies had no input into study design or analysis Bournemouth Diabetes and Endocrine Centre

Table 1D - Environment interventions altering availability, pricing and promotion

First Author (Year)	Study Sample	Study Type	X (data collection method)	Y (data collection method)	Confounders Adjusted for	Association Found	Who sponsored the study?
Templeton (2005)	6th grade students in Kentucky, US 3 schools	Intervention offering CF in 2 schools vs. control school with no CF for sale	Trays were photographed and then waste collected and weighed to determine consumption of lunch	Offer of 'competitive food' (CF) items (salty and sweet snacks and non-carbonated drinks) in addition to school lunch.		One third of intervention students purchased CF items – they had significantly higher energy (20% higher) and fat intakes and lower protein, calcium, vitamin A intakes - food waste was higher than in control school	USDA Grant
Bauer (2004)	Sample of 26 students and 23 staff members from 2 sub-urban public middle-schools in New England (USA)	Qualitative (semi-structured interviews and focus groups)	Physical and social environment of the school	Influences of environment on students food & physical activity choices		Key barriers to healthful nutrition identified by informants: 1) poor quality and palatability of food served in the cafeterias 2) easy access to non-nutritious snacks 3) limited time for lunch period 4) weight concerns	Boston Obesity Nutrition Research Centre, Massachusetts Health Research Institute, McCarthy Family Foundation
French (2004)	20 US secondary	RCT – school as unit	Sales data and student self-report intake of a la	TACOS Trying Alternative Cafeteria Options – multi-	Dose of intervention measured	51% increase in lower fat foods	NIH

	schools Intervention over 2 years		carte items	component environmental intervention to increase availability and peer promotion of lower fat items in a la carte menus		available after 2 yrs in IG schools Higher % sales of lower fat foods in IG Student reported intakes did not vary between control and IG	
Weber Cullen (2004)	594 fourth and fifth grade students (USA)	Longitudinal study	School environment (school lunch only vs. snack bar)	Lunch intake (baseline vs. year 2)		Fourth grade students who moved from elementary school to middle school ate fewer fruits & vegetables and less milk, and consumed more sweetened drinks and fries in the 'snack bar' a la carte environment	US Dept of Agriculture, Agricultural Research Centre and Cancer Research Foundation of America
Kubik (2003)	16 schools Grade 7 students n=598 Minneapolis	Cross sectional study Random sample from TEENS study	24 hour recall: 1. total fruit servings 2. total veg servings 3. F&V servings 4. % of energy from fat 5. % of energy from SF	All schools had USDA school lunch program, some schools (13) also had a la carte menu and vending machines (7)	71% of students provided valid 24 hour recalls	A la carte menu associated with significantly lower fruit and F&V and significantly higher fat and SF intake Vending machines were associated with lower fruit servings	National Cancer Institute
Dwyer (2002)	8th grade students previously in	Random sample – cohort	24 hour recall and FFQ Healthy Eating Index (tool for assessing overall diet	Follow up of children who had been in the CATCH study aimed at reducing intakes of fat,	Results were adjusted for sex, ethnicity, site and	Significantly better fat and SF and HEI scores for those	National Heart, Lung and

	CATCH Study (USA) N=1,532		quality based of food pyramid) scores 0-100 higher scores indicate better diet	salt and SF	within school correlation	previously in CATCH	Blood Institute
French (2001)	12 secondary schools in Minneapolis	CHIPS Study RCT – school as unit	Sales data collection	Pricing reduction of low fat snacks in vending machines (10%, 25% and 50%) Changes in point of sale signage at vending machine		Each price reduction resulted in a significantly increase in % of low fat snacks sold (9%, 39% and 93% respectively) Promotion of snacks was significantly and independently associated with greater low fat snack sales	National Institute of Health (NIH)

Carter (1999)	NZ schools (primary, intermediate and secondary) achieving Heartbeat Awards between Jan 1996 and Dec 1997 n=232	Impact evaluation	Changes in food sales at the school (self report) Also included an audit of a subset of 30 schools to determine implementation of school food programme	School Food Programme (SFP) encourages schools to implement nutrition policies and introduce a wider range of healthy foods.	Possible self-selection bias not adjusted for. Data is self-report.	Increasing number of years involved in SFP associated with reduction in sales of pies, sausage rolls, doughnuts and cream buns, crisps and sweets Increases in sales seen for sandwiches and filled rolls	NZ Health Funding Authority and NHF

Table 1E: Multi-strategy fruit and vegetable interventions

First Author (Year)	Study Sample	Study Type	X (data collection method)	Y (data collection method)	Confounders Adjusted for	Association Found	Who sponsored the study?
O'Neill (2002)	12 high schools in New Orleans Students were 14-15yrs at study entry and 17-18yrs at finish	RCT – cohort 4 year study	Attitude and awareness questionnaires and self-reported F&V intake	Gimme 5 intervention based on changing attitudes, knowledge and behaviour – multi-component program: school media-marketing campaign, student workshops, increase availability of fresh F&V at school meals, parental involvement	Control group also showed improvement in intake, self-efficacy and knowledge	Intervention group had significantly higher knowledge than control group IG had significantly higher F&V intake – 14% (0.35 serve) higher than CG	Not declared
Reynolds (2000)	28 elementary schools n= 1,698	RCT – over 2 years SCT	24 hour diet recalls collected across whole week In 54 of the 108 classes a random selection of trays	High 5 Project: 1. Classroom component 2. Parent component 3. Food service component	69% RR Used 6 cluster groups to control for bias e.g. seasonality	At follow up 1yr and 2yr intervention children consumed significantly more	National Cancer Institute

	families	used	were observed at lunchtime F&V Psychosocial measures – knowledge, skills, self-efficacy and social norms		Full or partial completion achieved for 95% of classroom activities	F, V and F&V combined (24 hr recall) Differences not seen in lunchtime observation Parents had improved V and F&V intakes	
Baranowski (2000)	16 elementary schools South East USA 1,253 students completed 7 day diary in all 3 years	RCT at school level Uses SCT Cohort pre, mid, post testing over 3 years	7 day food records, questions on FJV knowledge, preferences, outcome expectations, self efficacy, social norms, asking behaviours Questions of parents about availability/accessibility Process evaluation of curriculum implementation, school lunch menus	Intervention over 2 years (12 classroom sessions/year) to encourage more fruit, juice and vegetable consumption – included increasing FJV availability and accessibility at home, enhancing preferences of FJV, increasing preparation skills and problem solving skills of students Teacher training at regular intervals Parents received video teaching Local stores were targeted to help increase sales	Schools were matched for size, free school meals and % student turnover Differential attrition assessed	Positive results for consumption of FJV combined, FJV consumed at weekday lunch, FJV self efficacy, social norms and asking behaviours and knowledge	Not declared

Table 1F: Environment focused interventions for fruit and vegetables

First Author (Year)	Study Sample	Study Type	X (data collection method)	Y (data collection method)	Confounders Adjusted for	Association Found	Who sponsored the study?
Wells (2005)	Schools in low income areas of	Intervention and control schools	Fruit intake of children receiving fruit (4-6yrs) in infant school and those that	1 piece of fruit given to every child in intervention schools	Control and intervention schools matched for	Median intake of fruit in intervention	Not declared

	London from Pilot National School Fruit Scheme (NSFS)	cross sectional study	had received fruit (7-8yrs) now in junior school measured in grams from FFQ and tick list for F&V All days of the week included		deprivation Used validated questionnaire 51% RR	infant schools was significantly higher (117g vs. 67g) No difference in intake of fruit at junior school between those that had received NSFS	
Perry (2004)	26 schools in Minnesota – 1st and 3rd grade students N=1820 students	RCT – Cafeteria Power Plus intervention based on SCT	Baseline and follow up observations of number of serves of F&V	Cafeteria Power Plus project intervention aimed to: 1. increase opportunities during school lunch to eat a variety of F&V 2. provide healthy role models 3. institute social support for children eating F&V	70% RR Results potentially influenced by cross school contamination	Significant differences observed for F&V (without potato), and F (with and without juice) Differences came from increase in fruit (not V or FJ)	National Cancer Institute
French (2003)	2 Secondary schools (USA)	Intervention (pre vs. post)	Sales data	50% reduction in price of fruit and baby carrots	Small study size	Sales of fresh fruit increased four-fold and sale of baby carrots two-fold	NIH and CDC
Cullen (2000)	312 4th grade (4 schools) and 282 5th grade (1 school) students in Texas USA	Cross sectional study	5 consecutive days of self report lunch records collected in classroom (validated method)	Comparison of 4th (access to National School Lunch Program only) and 5th grade students (snack bar available in addition to NSLP)	Results were controlled for FJV preference to minimise change occurring to age rather than environment	4th grade students consumed significantly more F, V and FJV than 5th grade students 5th grade students who ate only from the snack bar	National Cancer Institute and Cancer Research Foundation

						consumed significantly less F, V and FJV than those consuming SLP	

Table 1G: Education focused fruit and vegetable interventions

First Author (Year)	Study Sample	Study Type	X (data collection method)	Y (data collection method)	Confounders Adjusted for	Association Found	Who sponsored the study?
Auld (1999)	2 treatment and 2 comparison schools in USA n=38 classes (760 2nd-4th grade students)	Quasi-experimental pre-test post-test design, intervention vs. control.	Plate waste, classroom survey for knowledge and attitudes Validated plate waste observation methods	Integrated Nutrition Project (INP) – uses special resource teachers (SRT) for nutrition program implementation of 16 lessons taught alternately between SRT and classroom teacher and 6 parent taught lunchroom activities Aims: 1. increase F&V consumption 2. increase knowledge and attitudes to F&V 3. increase knowledge of food guide pyramid	Teachers self selected	Treatment group remained stable, control group decreased servings of F&V by 0.35 serving Treatment group had greater knowledge about F&V and food guide pyramid	Kraft Foods, USDA, NIH and the Lindsay Trust
Auld (1998)	3 Elementary schools, Denver, US n=1250 children and their families	Quasi-experimental design – Pre/post test Matched intervention (n=20) and control (n=17)classrooms	4 year programme 24 weekly hands on classroom sessions taught by teacher 6 lunch time mini sessions taught by parents. Training for teachers and parents	Consumption of whole grains, F&V Knowledge and attitudes to F&V Knowledge of food pyramid and 5A Day Food preparation skills	Schools matched by ethnicity, SES and school lunch style Separate implementers and evaluators used to reduce evaluation bias Self report checked against plate waste.	Gains in knowledge and self-efficacy regarding food preparation. Significant increase in F&V consumption of 0.4 serves at year 3 and 4 of the programme	Kraft, USDA, NIH/CDC, 5A Day, Lindsay Trust

Table 1H: School Breakfast Programmes

First Author (Year)	Study Sample	Study Type	X: (data collection method)	Y: (data collection method)	Confounders Adjusted for	Association Found	Who sponsored the study?
Shemilt (2004)	6076 primary and secondary school pupils (approx 200 sampled from each of 30 schools) in deprived areas in England	Cluster RCT (funded school based breakfast club vs. no funding) and observational analysis (note: cross-contamination in randomisation at follow-up)	Implementation of breakfast club	Health and lifestyle (self report questionnaire) Behaviours, emotions relationships (primary age – teacher report, secondary-self report) Concentration (trail making test) Attendance, punctuality, attainment.	SES, eligibility for free food programme, family situation and stress (parent completed questionnaire) Baseline vs. 3month and 12 month follow up	At primary schools, increased fruit consumption at breakfast at 1 year	UK Department of Health
Belderson (2003)	111 children aged 9-15yrs in three schools across UK	Controlled intervention study	Participation in breakfast club	Nutritional intake (3 day weighed food diary)	Participants and controls were matched for free-school-meal eligibility and other demographic variables	Children who attended breakfast clubs had significantly higher daily intake of fat, saturated fat and salt than children who didn't attend breakfast club	Not declared

Kleinman (2002)	97 students in grades 4-6 in three inner-city schools in Boston, USA	Intervention study – pre and post introduction of Universal-free school breakfast program (USBP)	Participation in school breakfast program (school records)	Health (Pediatric Symptom Checklist) School attendance & tardiness (school records) Grades for math, reading, science and social studies (school records)	Pre-intervention scores used as baseline Nutritional and energy intake (24-hour dietary recall interview of children) Hunger/Food Insufficiency (8 item parent interview + child report Child Hunger Index)	Six months after introduction of USBP 44% of students increased their participation in school breakfast program, and 19% improved their nutritional status However 18% were at increased nutritional risk	Project Bread/The Walk for Hunger (Boston, Mass.)

Wahlstrom (1999)	10 elementary schools in Minnesota, (6 pilot sites, 4 control)	Qualitative and quantitative evaluation of universal school breakfast pilot in Minnesota elementary schools	Universal school breakfast programme – offered to all children in study	School behaviour & performance (Teacher report) Discipline (Principle report) Test scores, Attendance, Nurse visits (School records) Benefits to family (Parent report); Other unspecified measures of educational achievement	Statistical significance of results not reported	Participation rates were 75-93% in 6 schools compared to previous 12% average when non-universal (targeted) program was in place. Pre-intervention, only around 50% of students eligible for subsidized meals ate breakfast most or all of the time	Minnesota Dept of Children, Families and Learning
Murphy (1998)	133 school age children, (grade 3 and higher) in 3 inner-city schools Philadelphia and Baltimore (USA)	Intervention study – pre and post introduction of Universal-free school breakfast program (USBP)	Change in participation in school breakfast program after implementation of USBP (school records)	Psychosocial and academic functioning	Background factors: grade, ethnicity, sex, parental marital status, food insufficiency and hunger (Community Childhood Hunger Identification Project scale – 8 item parent report questionnaire)	Participation in the school breakfast program rose from 15% of students at baseline to 27% four months after the implementation of USBP	Kellogg Corp. (Battle Creek, MI.) & Mid-Atlantic Milk Marketing Association (Towson, Md.)

Table 1J: Other papers used to inform question one.

First Author (Year)	Study Sample	Study Type	X (data collection method)	Y (data collection method)	Confounders Adjusted for	Association Found	Who sponsored the study?
French (2004)		Literature review		Review of school-based interventions that use environmental, policy or pricing to promote F&V among youth			
Hayman (2004)		Scientific Statement of the American Heart Association					
Holibar (2004)	804 schools registered with the SFP	Evaluation: Postal survey of key contact In depth interview with 15 schools		NZ Heart Foundation School Food Programme (SFP) Looks at the impact of the programme on: 1. school lunchroom menus 2. nutrition education program 3. school policy 4. promotional and marketing strategies 5. community linkages	Only 38% RR for questionnaire	Key success factors identified included individual passion, endorsement of school leaders, intra-school collaboration, school health consciousness and awards gained	
French (2003)		Literature review		Review of literature on interventions to promote F&V in school environment			
Lytle (2002)		Discussion of methods to measure upstream (policy or whole school) nutrition interventions					

Table 2: Studies investigating the effects of what and when children eat and brain development/IQ.

First Author (Year)	Study Sample	Study Type	X (data collection method)	Y (data collection method)	Confounders Adjusted for	Association Found	Who sponsored the study?
Past Nutrition & Academic Achievement							
Ivanovic (2004)	4509 school aged children randomly sampled from all grade 1,2,4,6 and 8 in Metropolitan region of Chile	Cross-sectional	Past nutrition (birth weight, weight for age Z score, height-for age Z score, and head circumference Z score)	Scholastic achievement (Spanish language and mathematics tests) Intellectual ability (Raven's Progressive Matrices Test)		Under-nutrition in first year of life is associated with poorer IQ and scholastic achievement	Not declared
Ivanovic (2002)	96 high school graduates (mean age 18yrs) sampled from a population of 1817 graduates of the richest and poorest counties in Chile	Cross-sectional, Correlational	Prenatal nutrition (birth weight) Postnatal nutrition (head circumference, % arm muscle for age) Current nutrition (BMI)	Scholastic Achievement (Spanish language and mathematics tests)	IQ (WAIS-R); SES (modified Graffar method using schooling, job held by head of household, asset ownership etc)	Past nutritional status, brain development, child IQ and scholastic achievement are strongly and significantly inter-related	Not declared
Glewwe (1999)	3,289 children from birth cohort May 1 1983-April 30 1984 Cebu City, Philippines	Longitudinal	Early Childhood nutrition	Academic Achievement		Malnourished children perform more poorly in school, even after correcting for covariates within and across households	USAID, Office of Women in Development, Asian Development Bank, the World Bank

Vitamin-mineral supplementation & IQ							
Schoenthaler (2000)	245 school children aged 6-12yrs in working class elementary schools in Arizona	Randomised, double-blind placebo controlled trial	Daily vitamin-mineral supplementation at 50% of US RDA for 3 months vs. placebo	Nonverbal IQ (Wechsler Intelligence Scale for Children – Revised)	Pretest non-verbal IQ score	Significant difference of 2.5 IQ points in non-verbal IQ found in treatment group vs. control group. The gain was limited to a minority (23%) of 'responders' who had gains of over 15 points	G.B Data (Los Angeles) – no fiscal interest in the supplement used
Benton (2001)	13 studies examining vitamin & mineral supplementation and IQ in school-children	Review	Vitamin & mineral supplementation	Intelligence (IQ)		In 10 out of 13 studies, a positive influence of supplementation was found on non-verbal IQ, at least in a sub-set of children. No studies showed improvements on verbal intelligence	

Table 3: Studies investigating the relationship between what and when children eat and behaviour in school

First Author (Year)	Study Sample	Study Type	X (data collection method)	Y (data collection method)	Confounders Adjusted for	Association Found	Who sponsored the study?
Nutritional Intake/Status							
Kleinman (2002)	97 students in grades 4-6 in three inner-city schools in Boston, USA	Intervention study – pre and post introduction of Universal-free school breakfast program (USBP)	Participation in school breakfast program (school records)	Psycho-social Health (Pediatric Symptom Checklist)	Pre-intervention scores used as baseline Nutritional and energy intake (24-hour dietary recall interview of children) Hunger/Food Insufficiency (8 item parent interview + child report Child Hunger Index)	Students with low nutrient and/or calorie intake reported more psychosocial problems than those with higher nutrient intakes Students who increased their nutrient intakes after the implementation of the USBP were more likely to improve their psychosocial functioning	Project Bread/The Walk for Hunger (Boston, Mass.)
Zhang (2005)	4, 852 children aged 6-16, US general population (excluding children with impairments)	Correlational, using existing data from cross-sectional survey (National Health and Nutrition Examination Survey)	Serum total cholesterol	Psychosocial development	Family SES Maternal marital status & education Daily energy intake Academic performance	Among White children, history of school suspension or expulsion approx 3 times higher in those with low total cholesterol	

Grantham-McGregor (2001)	10 longitudinal studies 14 treatment trials of children over 2 years old.	Review	Iron deficiency	Behaviour		Longitudinal studies provide some evidence that iron-deficiency is associated with behaviour problems	World Health Organization
Schoenthaler (2000)	468 students aged 6-11yrs in two working class elementary schools in Phoenix (USA)	Randomised, double-blind, placebo-controlled trial	Daily vitamin-mineral supplementation at 50% of the US recommended daily allowance for four months vs. placebo	Pre and post test measures of antisocial behaviour on school property (violent and non-violent delinquency measured by official school disciplinary records)		The group on active tablets produced a significant 47% lower rate of rule violations. After intervention, 9 out of the 10 'habitually disruptive' students were in the placebo group	G.B Data (no fiscal interest in the supplements used)

Food Security							
Dunifon (2003)	5000 families, sampled from US population	Cross-section, correlational	Food insecurity (18 item USDA scale) Participation in National School Lunch Program (parent report)	Behavioural adjustment using the Behaviour Problems Index (maternal report measuring externalising behaviour e.g. bullying, destroying things; and internalising behaviour e.g. moodiness, fearfulness)	Socioeconomic and demographic characteristics: some measures cross –sectional e.g. number of siblings, parental educational attainment. Other measured longitudinally from birth e.g. average family income, the percentage of the time the family owned its own home.	After controlling for covariates, food insecurity was significantly associated with behavioural indicators. Participation in the NSLP was not associated with improved behavioural outcomes.	USDA Small Grants Program administered through the Institute for Research on Poverty (University of Wisconsin)
Alaimo (2001)	National sample based on data from the Third National Health and Nutrition Examination Survey (USA)		Food insufficiency (one item on questionnaire asking if the family sometimes or often did not get enough food to eat) Overcrowding (family size divided by number of rooms) Blood lead (mg/l)	Cognitive (2 subtests of the Wechsler Intelligence Scale for Children Revised) Academic (Reading and Arithmetic on the Wide Range Achievement Test, Revised) Psychosocial measures	Sex, age, race/ethnicity, family size, multiple measures of SES, mother's age at birth, child's health status (report by responsible adult to questionnaire), past nutritional status (height of child)	Unadjusted scores showed that food-insufficient children and teenagers had poorer outcomes on a range of cognitive, academic and psycho-social measures	Not declared

Kleinman (1998)	Sample of 328 school aged children from randomly selected low income families in city of Pittsburgh and surrounding areas	Cross sectional correlational	Hunger, risk of hunger (Parent report on Community Childhood Hunger Identification Project 8 item hunger scale questionnaire)	Academic (repeating a grade – parent report) Psycho-social functioning (Parent report on Pediatric Symptom Checklist)	None, but all children were from low-income families (at or below 185% of poverty)	Those defined as 'hungry' had a higher prevalence of virtually all behavioural, emotional and academic problems measured e.g. hungry children were 7 to 12 times more likely to exhibit symptoms of conduct disorder than their low-income but not-hungry peers Aggression & anxiety were the symptoms most strongly associated with hunger	Kellogg Corporation

Breakfast Program							
Wahlstrom (1999)	10 elementary schools in Minnesota, (6 pilot sites, 4 control)	Qualitative and quantitative (pre/post) evaluation of universal school breakfast pilot	Universal school breakfast programme – offered to all children in pilot sites	School behaviour & performance (Teacher report); Discipline (Principle report)	Statistical significance of results not reported	Classes in pilot site lose less educational time due to discipline problems Reduced class disruption, fewer children sent to principal's office 40-50% decline in discipline referrals	Minnesota Dept of Children, Families and Learning
Shemilt (2004)	6076 primary and secondary school pupils (approx 200 sampled from each of 30 schools) in deprived areas in England	Cluster randomised controlled trial (funded school based breakfast club vs. no funding) and observational analysis (Note: cross-contamination in randomisation at follow-up)	Implementation of breakfast club	Behaviours, emotions relationships (primary age – by teacher report, secondary students- by self report)	SES, eligibility for free food programme, family situation and stress (parent completed questionnaire) Baseline vs. 3month and 12 month follow up	Breakfast club attendees apparently had poorer conduct despite adjustment for confounders Teacher reports were inconsistent: some felt behaviour had improved, others felt children had become overly energetic	UK Department of Health and NHS Executive

Murphy (1998)	133 school age children, (grade 3 and higher) in 3 inner-city schools Philadelphia and Baltimore (USA)	Intervention study – pre and post introduction of Universal-free school breakfast program (USBP)	Change in participation in school breakfast program after implementation of USBP (school records)	Depression (child report on Children's Depression Inventory by interview) Anxiety (child report on Revised Children's Manifest Anxiety Scale by interview) Health and functioning (parent report on Pediatric Symptom Checklist) Behavioural problems (teacher report on Conners Teacher Rating Scale 39)	Background factors: grade, ethnicity, sex, parental marital status, food insufficiency and hunger (Community Childhood Hunger Identification Project scale – 8 item parent report questionnaire)	Decreased psycho-social problems (depression, anxiety, hyperactivity) were found in students who increased their participation in the school breakfast program, compared to students who did not increase or who declined in regularity of eating school breakfast.	Kellogg Corp. (Battle Creek, MI.) & Mid-Atlantic Milk Marketing Association (Towson, Md.)

Table 4: Studies investigating the relationship between what and when children eat and short-term intellectual performance

First Author (Year)	Study Sample	Study Type	X (data collection method)	Y (data collection method)	Confounders Adjusted for	Association Found	Who sponsored the study?
Skipping breakfast							
Wesnes (2003)	29 children aged 9-16yrs in USA	Laboratory-based randomised controlled trial	Breakfast condition 1. Cheerios 2. Shreddies 3. glucose drink 4. no breakfast	Attention and memory (computer based performance tests) Mood and alertness (self-report questionnaire)	Pre-breakfast performance used as a baseline	Skipping breakfast impairs attention and episodic memory and this impairment increases in magnitude over the morning Cereal has a positive effect on cognitive function. Glucose drink failed to have such a benefit	Cereal Partners UK
Busch (2002)	21 boys aged 9-12yrs of normal weight, free of medication, learning disabilities and dietary restrictions (USA)	Controlled trial (cross-over design)	Snack (25gm simple-carbohydrate confectionery) vs. placebo (half cup of artificially sweetened soda)	Cognitive tasks – Attention Span (computer-based continuous performance task) Spatial Memory (map memory task) Verbal Memory (recall of written stories) Short Term Memory (digit	Subjects were exposed to both snack and placebo conditions, so served as their own controls	Snack and placebo conditions were only significantly different in their performance of the attention task There were no differences in verbal memory, spatial memory, visual perception or short term memory	Mars Inc.

				span recall task)			
Benton (2001)	150 female undergraduates in Wales (average age 21 years)	Randomised controlled trial	Six breakfast/snack conditions: 1. fasted throughout 2. no breakfast + snack at 11:30 3. 10g cornflakes at 10:00 + no snack 4. 10g cornflakes at 10:00 + snack at 11:30 5. 50g cornflakes at 10:00 + no snack 6. 50g cornflakes at 10:00 + snack at 11:30	Memory (recall of word lists, immediate and after 10 mins); Mood (6 item visual analogue scale, e.g. elated/depressed, energetic/tired); Blood Glucose (using ExacTech sensor)	Baseline scores used as a covariate.	Eating breakfast did not improve mood. Eating a larger breakfast was associated with poor mood later in the morning, an effect that was reversed with a snack. Eating did not affect memory, but those who had eaten breakfast spent longer trying to recall words.	Kellogg (Battle Creek, MI)
Morris (2001)	80 non-diabetic A-level students (mean age 21yrs) in the West Midlands (UK)	Randomised controlled trial	Glucose drink (orange squash with 50g glucose added and 10ml lemon juice) vs. placebo (identical but with artificial sweetener instead of glucose)	Listening span (Daneman-Capenter Listening Span test – true/false test, and recall of last word in sentence) Blood glucose level of 10 students was tested (average of 3 tests before drinking, and 3 test 20mins after	Pre-post testing meant that students' pre-test results served as a baseline Students were tested in the morning after fasting for at least 9 hours	Blood glucose levels did not change, but listening span performance significantly improved after a glucose drink yet not after a saccharine drink	Not declared

				drinking using BM Test 1-44 blood glucose test strips, measured with HC1 digital Blood Glucometer)			
Macronutrient Intake							
Dye (2002)		Review of 44 studies	Short term effect of macronutrients (carbohydrate, protein, fat)	Cognitive Function (reaction time, attention and vigilance, memory)		Acute effects vary with time of day High carbohydrate, low protein meals are sedating and relaxing High protein, low-carbohydrate meals produce arousal and improve reaction time and vigilance Nutritional interventions that facilitate a rise in blood glucose enhance performance on memory and reaction-time tasks	Orkla Foods provided support with scientific material for this review

Table 5: Studies investigating the relationship between what and when children eat and school attendance

First Author (Year)	Study Sample	Study Type	X (data collection method)	Y (data collection method)	Confounders Adjusted for	Association Found	Who sponsored the study?
Rampersaud (2004)	6 studies	Review	breakfast	Attendance		All six studies found that participation in breakfast programme was positively associated with attendance	Florida Department of Citrus
Shemilt (2004)	6076 primary and secondary school pupils (approx 200 sampled from each of 30 schools) in deprived areas in England	Cluster randomised controlled trial and observational analysis	Funded school based breakfast club vs. no funding	Attendance, punctuality (intervention vs. control) Baseline vs. 3month and 12 month follow up	SES, eligibility for free food programme, family situation and stress (parent completed questionnaire)	Reduced truancy amongst intervention group at 3 months and 1 year	UK Department of Health and NHS Executive
Dunifon (2003)	5000 families, sampled from US population	Cross-section, correlational	Food insecurity (18 item USDA scale) Participation in National School Lunch Program (parent report)	Health limitations (parent report of health limitations that affect participation in childhood activities, school attendance or the performance of school work)	Socioeconomic and demographic characteristics	Food insecurity is associated with health limitations, including affects on school attendance	Not declared

Kleinman (2002)	97 students in grades 4-6 in three inner-city schools in Boston, USA	Intervention study – pre and post introduction of Universal-free school breakfast program (USBP)	Participation in school breakfast program (school records)	School attendance & tardiness; (school records)	Pre-intervention scores used as baseline Nutritional and energy intake (24-hour dietary recall interview of children) Hunger/Food Insufficiency (8 item parent interview + child report Child Hunger Index)	Students who reported low nutrient intakes had higher absenteeism than those with higher nutrient intakes (11.5 day absent vs. 6.5 days absent respectively) Decline in nutritional status was associated with increased absenteeism, nutritional improvement was associated with improved attendance	Project Bread/The Walk for Hunger (Boston, Mass.)
Wahlstrom (1999)	10 elementary schools in Minnesota, (6 pilot sites, 4 control)	Qualitative and quantitative evaluation of universal school breakfast pilot in Minnesota elementary schools	Universal school breakfast programme – offered to all children in pilot sites	School behaviour & performance (Teacher report) Discipline (Principle report) Attendance, Nurse visits (School records)	Statistical significance of results not reported	Half of the pilot schools report significant decline on number of visits to nurse during morning Teachers report that students are more consistently in class	Minnesota Dept of Children, Families and Learning

Alaimo (2001)	National sample based on data from the Third National Health and Nutrition Examination Survey	Correlational	Food insufficiency (one item on questionnaire asking if the family sometimes or often did not get enough food to eat) Overcrowding (family size divided by number of rooms) Blood lead (micrograms per decilitre)	School attendance (school records)	Sex, age, race/ethnicity, family size, multiple measures of SES, mother's age at birth, child's health status (report by responsible adult to questionnaire); past nutritional status (height of child)	After adjusting for confounders, food-insufficient teenagers had significantly higher absence rates than food-sufficient teenagers	NIH training grant
Murphy (1998)	133 school age children, (grade 3 and higher) in 3 inner-city schools Philadelphia and Baltimore (USA)	Intervention study – pre and post introduction of Universal-free school breakfast program. (USBP)	Change in participation in school breakfast program after implementation of USBP (school records)	Attendance and tardiness (school records)	Background factors: grade, ethnicity, sex, parental marital status, food insufficiency and hunger (Community Childhood Hunger Identification Project scale – 8 item parent report questionnaire)	At baseline, participation in school breakfast programme associated with better attendance. Students who decreased their participation in the school breakfast program increased their absenteeism	Kellogg Corp. (Battle Creek, MI.) & Mid-Atlantic Milk Marketing Association (Towson, Md.)

Table 6: Studies investigating the long term relationship between what and when children eat and academic performance

First Author (Year)	Study Sample	Study Type	X (data collection method)	Y (data collection method)	Confounders Adjusted for	Association Found	Who sponsored the study?
Past Nutrition							
Ivanovic (2004)	4509 school age children	Cross-sectional correlational	Approx 2000 nutritional, intellectual, socioeconomic, socio-cultural, familial, demographic, and educational factors	Scholastic Achievement		Intellectual ability (IQ), maternal education level, past nutrition, book reading, in-door plumbing, level of paternal schooling, type of school, quality of housing, and current calcium intake were the variables most strongly correlated with scholastic achievement	Part funded by National Fund for Scientific and Technologic Development and the Research and Development Dept
Haojie (2003)	130 Guatemalan women in 4 rural villages	Longitudinal intervention study (30 years)	Nutrition during prenatal period and first two years (calorie and protein supplementation vs. no supplementation)	Educational achievement assessed at age 22-29 years (general knowledge, literacy, numeracy, reading)	SES (home and possessions, mother's education, father's occupational status) Schooling (<6years vs. 6yrs+)	Women who received protein and calorie supplements in early life had significantly higher educational achievement in adulthood after adjusting for SES and schooling.	National Institutes of Health

Ivanovic (2002)	96 high school graduates (mean age 18) sampled from a population of 1817 graduates of the richest and poorest counties in Chile.	Cross-sectional, Correlational	Prenatal nutrition (birth weight) Postnatal nutrition (head circumference, % arm muscle for age) Current nutrition (BMI)	Scholastic Achievement (Spanish language and mathematics tests)	IQ (WAIS-R); SES (modified Graffar method using schooling, job held by head of household, asset ownership etc);	Past nutritional status, brain development, child IQ and scholastic achievement are strongly and significantly inter-related	Not declared
Grantham-McGregor (2001)	10 longitudinal studies & 14 treatment trials of children over 2 years old.	Review	Iron deficiency	School achievement		Longitudinal studies show that anaemia in early life is associated with poorer school achievement into middle childhood.	World Health Organization
Glewwe (1999)	3, 289 children from birth cohort May 1 1983-April 30 1984 Cebu City, Philippines	Longitudinal	Early Childhood nutrition	Academic Achievement		Malnourished children perform more poorly in school, even after correcting for covariates within and across households.	USAID, Office of Women in Development, Asian Development Bank, the World Bank
Current Nutrition							
Kim (2005)	667 children aged 7-12 years (318 remote rural, 349 urban) in Korea	Cross-section, Correlational	Dietary patterns: frequency and regularity of meals, food habits, frequency of snacking (self administered questionnaires).	School performance (test scores)	Demographic information (e.g. SES, family size) was collected, but statistical methods were not used to adjust for these factors	Skipping meals, unsound food habits, low intake of calories, protein and niacin were significantly associated with poor school performance,	Not declared

			Dietary Survey (record over 3 days)			as was low SES.	
Ivanovic (2004)	See above		Current nutrition	Scholastic achievement		Current calcium intake was one of the variables most strongly correlated with scholastic achievement.	
Kleinman (2002)	97 students in grades 4-6 in three inner-city schools in Boston, USA	Intervention study – pre and post introduction of Universal-free school breakfast program. (USBP)	Nutritional and energy intake (24-hour dietary recall interview of children)	Academic performance (official school records of grade point average and grades for Math, Reading, Science and Social Studies)	Pre-intervention scores used as baseline	At baseline, children with low nutritional intakes had significantly lower GPA and subject scores than children with adequate intakes. Post-intervention, only changes in math grades were found to be significantly related to changes in nutrient intake	Not declared
Grantham-McGregor (2001)	10 longitudinal studies; 14 treatment trials of children over 2 years old.	Review	Iron deficiency	School achievement		In the majority of intervention studies, iron treatment of anaemic children led to improvements on cognitive tests	World Health Organisation

Breakfast Consumption							
Rampersaud (2005)	7 Studies, 1970-2004 (investigators' files, reference scan, MedLine search)	Review	Breakfast consumption	Academic or achievement test scores; Academic grades		All 7 studies found a positive relationship between breakfast and academic performance	Part funded by the Florida Department of Citrus (Florida State Government)
Lopez-Sobaler (2003)	180 well-nourished children aged 9-13 in Spain	Cross-sectional, Correlational	Breakfast energy intake: Adequate >20% of total daily calorie intake vs. Inadequate <20% of total daily calorie intake. (7 day weighed food record)	Scholastic performance (Scholastic Aptitude Test – SAT-1: Verbal, logical reasoning, mathematical calculation)	Age, sex. Note – no adjusting for SES	Habitually consuming an adequate breakfast was associated with significantly better performance on logical reasoning tests, but not verbal or calculation tests	Not declared

School Feeding Programmes							
Shemilt (2004)	6076 primary and secondary school pupils (approx 200 sampled from each of 30 schools) in deprived areas in England	Cluster randomised controlled trial (funded school based breakfast club vs. no funding) and observational analysis	Implementation of breakfast club	School attainment (school records)	SES, eligibility for free food programme, Family situation and stress (parent completed questionnaire). Baseline vs. 3month and 12 month follow up. (note: cross-contamination in randomisation at follow-up prevented comparison of control and intervention groups)	No effects of school breakfast implementation on school attainment were reported	
Dunifon (2003)	5000 families, sampled from US population	Cross-section, correlational	Food insecurity (18 item USDA scale) Participation in National School Lunch Program (parent report)	Maths Achievement and Reading Achievement (scores on tests from Woodcock-Johnson Psycho-educational Battery)	Background characteristics of the child's family. e.g. number of siblings, parental educational attainment, family income, the percentage of the time the family owned its own home	Participation in NSLP is not associated with improved academic outcomes	USDA Small Grants Program administered through the Institute for Research on Poverty (University of Wisconsin)

Murphy (1998)	133 school age children, (grade 3 and higher) in 3 inner-city schools Philadelphia and Baltimore (USA)	Intervention study – pre vs. post introduction of Universal-free school breakfast program. (USBP)	Change in participation in school breakfast program after implementation of USBP (school records).	Grades in a variety of school subjects (by school records)	Background factors: grade, ethnicity, sex, parental marital status, food insufficiency and hunger (Community Childhood Hunger Identification Project scale – 8 item parent report questionnaire)	At baseline, students who participated in school breakfast more often had higher maths grades on average than those who seldom had breakfast at school. Post intervention, those who increased participation in the breakfast program made a slight improvement in maths scores, while those whose breakfast program participation stayed the same or declined had a drop in Math grades.	Kellogg Corp. (Battle Creek, MI.) & Mid-Atlantic Milk Marketing Association (Towson, Md.)
Wahlstrom (1999)	10 elementary schools in Minnesota, (6 pilot sites, 4 control)	Qualitative and quantitative evaluation of universal school breakfast pilot in Minnesota elementary schools	Universal school breakfast programme – offered to all children in study	School behaviour & performance (Teacher report) Test scores, (School records)	Trend of results only reported. Statistical significance between intervention and control not reported. Other school-wide innovations were not controlled for	Increase in math and reading scores in some schools	Minnesota Dept of Children, Families and Learning

Food Insecurity							
Dunifon (2003)	5000 families, sampled from US population	Cross-section, correlational	Food insecurity (18 item USDA scale) Participation in National School Lunch Program (parent report)	Maths Achievement and Reading Achievement (scores on tests from Woodcock-Johnson Psycho-educational Battery)	Background characteristics of the child's family	After controlling for covariates, food insecurity was significantly related to health and behaviour but not maths or reading achievement.	USDA Small Grants Program administered through the Institute for Research on Poverty (University of Wisconsin)
Alaimo (2001)	National sample based on data from the Third National Health and Nutrition Examination Survey	Correlational	Food insufficiency (one item on questionnaire asking if the family sometimes or often did not get enough food to eat) Overcrowding (family size divided by number of rooms) Blood lead (micrograms per decilitre)	Reading and arithmetic scores (Wide Range Achievement Test – Revised)	Sex, age, race/ethnicity, family size, multiple measures of SES, mother's age at birth, child's health status (report by responsible adult to questionnaire); past nutritional status (height of child)	After adjusting for confounding variables: In primary school children, those from food insufficient households had poorer mathematics scores and were more likely to have repeated a grade than their food-sufficient peers. Food insecurity was not independently associated with other reading scores at primary level, or with any academic measures at high-school level.	NIH training grant

Regularity of Meals							
Kim (2005)	667 children aged 7-12 years (318 remote rural, 349 urban) in Korea	Cross-section, Correlational	Dietary patterns: frequency and regularity of meals, food habits, frequency of snacking (self administered questionnaires). Dietary Survey (record over 3 days)	School performance (test scores)	Demographic information (e.g. SES, family size) was collected, but statistical methods were not used to adjust for these factors	Skipping meals, unsound food habits, low intake of calories, protein and niacin was significantly associated with poor school performance, as was low SES	Not declared
Kim (2003)	6,463 children and adolescents in grades 5, 8 and 11 in 28 randomly selected school (14 middle and 14 high schools) in 8 cities in Korea	Cross-sectional, correlational	Diet quantity and quality - regularity of breakfast, lunch and dinner, number of daily meals eaten, number of daily snacks eaten, snack money spent, changes in meal size during examination period, nutrient supplement use (self-report Questionnaire and FFQ)	Academic performance - Grade Point Average (data from school records)	SES - parents' educational level (student completed questionnaire)	Academic performance was strongly associated with dietary behaviours, even after controlling for parents education level. The relative importance of regularity of meals was greater than that of socio-economic status and physical status in older teenagers	Part funded by a Ministry of Education, Korea

Obesity							
Datar (2004)	US national sample of 11, 192 kindergarteners (Early Childhood Longitudinal Study – Kindergarten Class)	Cross-sectional and longitudinal study (2 years)	Weight (BMI)	Academic performance (maths & reading test scores)	SES; race/ethnicity; Mother's education; parent-child interaction; child's television watching (parent report); birth weight; activity level; child's baseline test scores	Overweight children had significantly lower test scores in maths and reading at the end of kindergarten and grade one, however only boys' baseline maths scores remained significant after adjusting for confounders	National Institute for Health Care Management Research and Education Foundation, Washington D.C.
Mo-suwan (1999)	1794 children, 1207 grade 3-6 and 587 grade 7-9	Cross-sectional and longitudinal (2 years)	Current and previous weight status (BMI)	School Grades (Point Average from school records)		Being overweight and becoming overweight during adolescence was associated with poor school performance, whereas this association did not exist with younger children (grade 3-6).	Songklanagarind Hospital Foundation.

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[i] BMI – body mass index
HPS – health promoting schools
RR – response rate
F&V – fruit and vegetables
RCT – randomised controlled trial

N – number
NCI – National Cancer Institute
SF – saturated fat
SCT – social cognitive theory
PA – physical activity
HIH – National Institutes of Health
IG – intervention group
CG – control group
LDL – low density lipoprotein
USDA – US Department of Agriculture
EU – European Union
FJV – fruit, juice, vegetable
FFQ – food frequency questionnaire
CDC – Centres for Disease Control
NSLP – National School Lunch Programme
SES – socio-economic status
USBP – universal school breakfast programme
RDA – recommended dietary allowance