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Diet, a factor for academic performance in school-aged children: systematic review of recent studies

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ABSTRACT

Diet is a factor that is significant in the formative ages of humans. Nutrition has been related to cognitive development and abilities. Cognitive abilities are demonstrated by academic performance in school children. This study seeks to review literature on the influence of diet on academic achievement of school-aged children. It was found that dietary intakes have significant effects on the academic performance of children in schools. High intakes of fruits, vegetables, milk, fish, and healthy snacks and dietary patterns were significantly associated with good academic performance. However, frequent consumption of soft drinks, sweetened beverages, fast food, and unhealthy dietary patterns and snacks had negative correlations with academic performance. Healthy dietary behaviour is thus required for good academic performance.

Keywords*: diet, academic performance, children, adolescents, school.*

Introduction

Academic performance is generally linked to intelligence. Intelligence is a trait that has been defined by researchers to be controlled by both genetic and environmental factors (Bartels *et al*., 2002). Though genetic factors are generally responsible for cognitive abilities, environmental factors account for the stability and development of the cognitive abilities. It cannot be overemphasized that nutrition and for that matter diet is one of such environmental factors.

Governments in some countries have made initiatives to feed school children in schools; a policy to ensure that children get adequate nutrition. It is clear these governments appreciate that Sustainable Development Goal (SDG) 4 of quality education for all cannot be achieved without significant progress in SDG 2 which seeks to achieve food security and improve nutrition. United Nations General Assembly (2015) set these goals among other fifteen goals for the year 2030. Good nutrition can affect academic performance through elevation of brain function, promotion of better behaviours and positive school outcomes (Chan *et al*., 2017, Woodhouse and Lamport, 2012). Parents will normally focus on providing food for their children other than quantifying the nutrient contents of these diets. For the school-aged child, the pleasure of satisfying their hunger, with the available food or their choice of food, is paramount. This paper presents a review of evidence investigating the effects of diet on academic performance of school-aged children. A similar review was published earlier, but focused on college students (Burrows *et al*., 2017) and a review on overall ‘school-valued’ outcomes (Chan *et al*., 2017). Burrows *et al.* also reported on breakfast consumption which has been among the most common dietary outcomes in researches relating diet to academic performance.

Methods

A search of literature was done systematically to access published studies, on the effects of diet and nutrition on the academic performance of school children. A preliminary search was conducted with Google Search to assess the text words for keywords to be used in the main literature search. The main search was done in PubMed, Scinapse, Google Scholar and MEDLINE with the identified keywords and combinations: food, diet, dietary pattern, quality diet, school, children, academic performance, adolescent. A final search was done in the reference list of selected studies for additional studies. The search strategy is summarized in **Figure 1** and the inclusion and exclusion criteria are presented in **Table 1**.

Table 1 Inclusion and Exclusion criteria

Inclusion Criteria	Exclusion Criteria
Population Children or adolescents between the age-group of 4 – 18 years.	Population Children or adolescents not in the specified age-group; animals.
Setting Schools	Setting Community and clinical
Exposure Diets, dietary patterns, foods and food groups	Exposure Nutrients (without dietary intakes or involving supplements), integrated lifestyle like diet + exercise, meal pattern (e.g. breakfast) without component foods
Outcome Academic performance/achievement as the main dependent outcome variable	Outcome Cognitive function or cognitive function not inferenced from academic performance
Study Design Experimental or observational study design (randomized controlled trial, quasi-experimental, longitudinal, cohort or cross-sectional).	Study Design Reviews (systematic and general), editorials, library thesis, opinions and letters, commentaries, abstracts without available full texts online
Study Published, from January 2000 to June 2019, in English language.	Study Published before January 2000

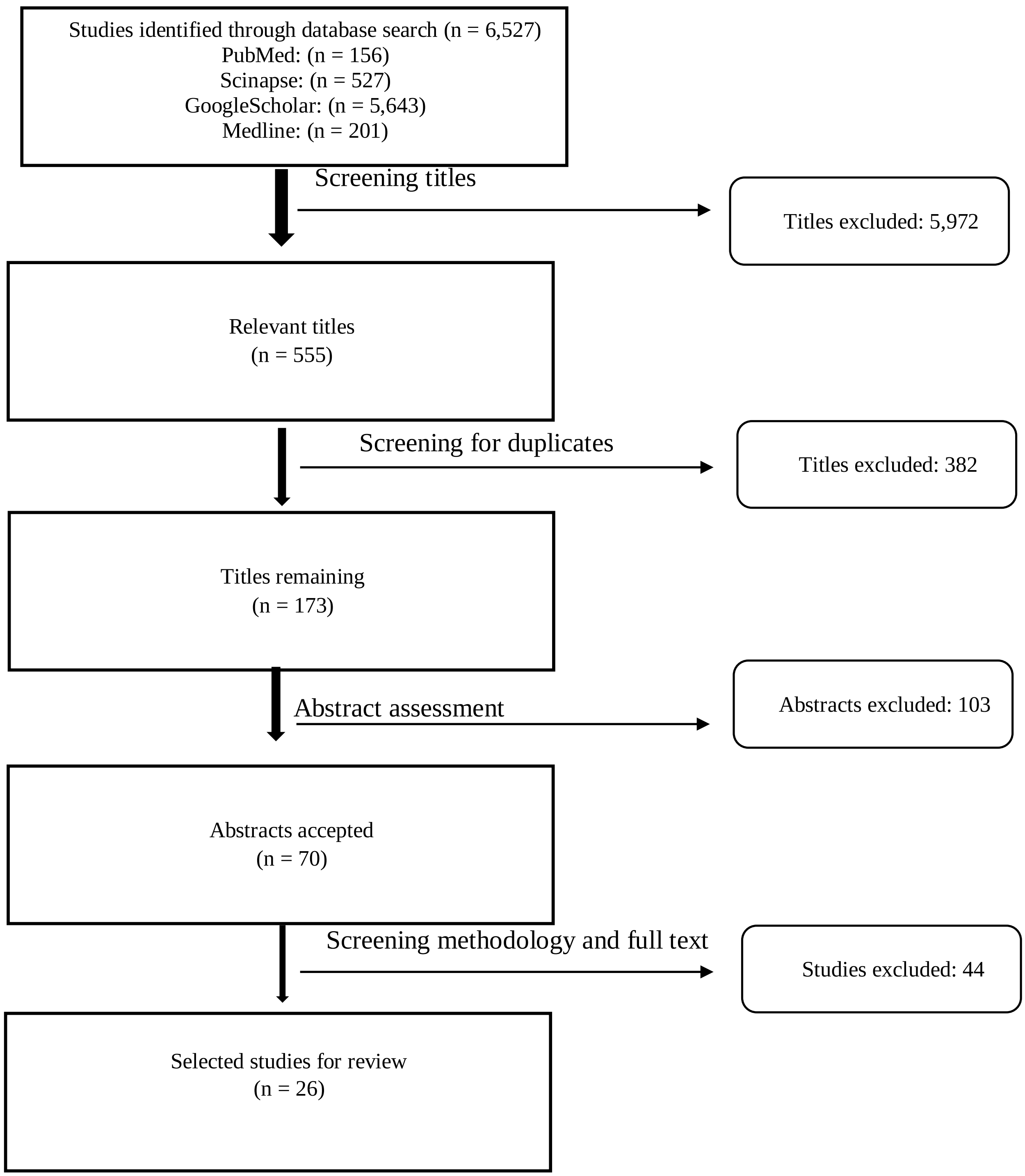

Figure 1 Identification of study and selection process

Results

The search strategy produced 6,527 studies; however, 26 studies met the inclusion criteria. The selection process is shown in **Figure 1**. Of the 26 studies, 19 were cross-sectional, 2 cohorts, 2 randomized control trials, and 3 longitudinal. One of the longitudinal studies was retrospective. The number of participants ranged from 213 to 395,264 with a total of 459,293 participants aged 4 to 18 years old. Thirteen studies reported both the age and educational level (grade), five studies reported only grade, and eight studies reported only age, of participants. The studies involved six different continents with some continents dominating. Nine studies were conducted in Europe (Spain 1, Denmark 1, Iceland 1, Norway 2, Greece 1, Italy 1, Sweden 1, England 1), seven in North America (USA 4, Canada 2, Prince Edward Island 1), three in Australia, three in South America (Chile), three in Asia (Palestine 1, Korea 2), and one in Africa (Kenya).

More than 75% of the studies (n = 20) reported either body mass index (BMI) or weight. Fifteen studies reported on household income or socioeconomic status (SES). Eight studies reported on parents' education, while another eight studies considered either maternal education or reported parental education without specification. Lifestyle factors were as well reported in some studies. While three studies reported only breakfast (Edwards *et al.*, 2011; McIsaac *et al*., 2015; Burns *et al*., 2018), four studies reported all three meals (Øverby *et al*., 2013; Stea and Torstveit, 2014; Kim *et al*., 2016a; Barchitta *et al*., 2019). Screen time over television was considered by four studies (Vassiloudis *et al*., 2014; Edwards *et al*., 2011; McIsaac *et al*., 2015; Purtell and Gershoff, 2015), smoking by two studies (Stea and Torstveit, 2014; Barchitta *et al*., 2019) and physical activity by twelve studies. MacLellan and Taylor (2008) did not report any anthropometric, SES or lifestyle measures. Males dominated only in three studies (Purtell and Gershoff, 2015; Kim *et al*., 2016a; Esteban-Cornejo *et al*., 2015); the other studies (n = 23) were female-dominated.

Dietary exposures of participants

The dietary exposures were so diverse in the studies selected for this review. Dietary exposures included animal foods, milk inclusive (n = 7 studies), fruits and vegetables (n = 10 studies), soft drinks (n = 4 studies), and tea/coffee, fruit juice, soda, lemonade, salad, instant noodle, cookies and fish (n = 1 study each). Intake of snacks and fast foods were each individually reported by four studies. Intakes of sweetened beverages as well as sweets/candy/confectionery were each reported by three studies. Twelve studies assessed food groups: diet quality based on composition (n = 2 studies) and dietary pattern (n = 10 studies). Each study involved more than one food or food item, except one which reported on only fish consumption (Kim *et al*., 2009).

The dietary patterns included 'Unhealthy diets/Nutrient-poor' foods (high in fat, sugar, salt and calories) and 'Fair diets/highly processed' foods low in fat, and 'Healthy diets/nutrient-rich' foods (Correa-Burrows *et al*., 2016); Mediterranean diet (high intakes of vegetables, fruits and nuts, legumes, cereals, and fish; relatively low intakes of meat and dairy products and the use of olive oil as an important fat source) (Esteban-Cornejo *et al*., 2015; Vassiloudis *et al*., 2014; Barchitta *et al*., 2019); 'Healthy' pattern (high in fruits, vegetables, whole grains, legumes

and fish) and 'Western' pattern (high intake of take-away foods, red and processed meat, soft drinks, fried and refined food) (Nyaradi *et al*., 2015); 'Core' foods (fruits, vegetables, milk, whole grains, fish, eggs, milk, yogurt, cheese and/or their alternatives, and fruit juices and 'Non-core' foods (foods high in saturated fat such as cakes and pastries, pizza, fried foods, hot chips, crisps and other savory snacks, foods containing added salt and/or sugar, sugar-sweetened soft drinks, ice cream, fruit drinks, energy and sports drinks (Pearce *et al*., 2018). Other dietary patterns were 'New Nordic' diet characterised by relatively high content of berries, cabbage, root vegetables, legumes, fresh herbs, potatoes, whole grains, nuts, fish, seaweed and game (Sørensen *et al*., 2015); 'Healthy' foods (vegetables, fruits, fish) and 'Unhealthy' foods (Sugar-sweetened soft drinks, candy, chocolate, potato chips, pizza, hamburger/hot dogs) (Øverby *et al*., 2013); 'Prudent' diet (high intake of potatoes, cooked vegetables, legumes, fruits, nuts, yoghurt, offal (entrails), shellfish and tea), 'Western' diet (white bread, red and processed meat, shellfish, vegetable oil, dipping sauces and fries), and 'Energy-dense' diet (high intake of yoghurt, butter and margarine, sweets and refined sugar, dipping sauces, pizza and fries) (Barchitta *et al*., 2019),
'Bad' diet (potato chips, French fries, or a hamburger or a hot dog) (Kristjánsson *et al*., 2010); 'Junk' food pattern, 'Health-conscious' dietary pattern and 'Traditional' food pattern (Feinstein *et al*., 2008).

Academic performance outcome measures

Academic outcome measures by subjects dominated (n = 18 studies), five studies reported the grade point average (GPA), and three studies reported both subjects and GPA. Studies reported academic performance in specific subjects or cumulatively as GPA. By subject, mathematics was most assessed (n = 17 studies), language (n = 11 studies), reading (n = 9 studies), writing (n = 6 studies), and science (n = 5 studies). Four studies assessed at least one of other subjects: physical education, social science, geography, civics, culture, religion, arts, crafts, music, and history. All the studies assessed more than one subject as shown in **Table 2**. Thirteen studies obtained academic results from school records, while eleven other studies used standardised test scores to measure academic performance. One study used learning difficulties to measure academic performance (Øverby *et al*., 2013). Teacher-evaluated academic performance was reported by one study (Vassiloudis *et al*., 2014).

Dietary intake and academic performance

Specific foods and food groups including dietary patterns improved academic performance by improving either scores in subjects or overall GPA. According to Correa-Burrows *et al*. (2016), best academic performance was found for 'Healthy' diet takers compared to 'Fair' diet and 'Unhealthy' diet in Math (P= 0.013), Language (P= 0.016) and overall GPA (P= 0.03). Academic achievement was positively correlated with Mediterranean diet (Esteban-Cornejo *et al*., 2015; Vassiloudis *et al*., 2014; Barchitta *et al*., 2019), 'Healthy' dietary pattern (Nyaradi *et al*., 2015; Øverby *et al*., 2013; Feinstein *et al*., 2008), 'Core' foods (Pearce *et al*., 2018), New

Nordic Diet (Sørensen *et al*., 2015) and 'Prudent' diet (Barchitta *et al*., 2019). In contrast, academic performance was negatively correlated with 'Western' dietary pattern (Nyaradi *et al*., 2015; Barchitta *et al*., 2019), 'Non-core' foods (Pearce *et al*., 2018), 'Unhealthy' foods (Øverby *et al*., 2013;), 'Energy-dense' diet (Barchitta *et al*., 2019), 'bad' diet (Kristjánsson *et al*., 2010), and 'Junk' food (Feinstein *et al*., 2008). Even decreased diet quality (in terms of diet adequacy, variety, balance, and moderation; with higher scores indicating better diet quality) was significantly related to poor academic performance in assessments (Florence *et al*., 2008; McIsaac *et al*., 2015). Similarly, compared to healthy snacks (nutrient-rich items and protective foods), consumption of unhealthy snacks (items of poor nutritional value and high in fat, sugar, salt and energy) was associated with poor academic performance in high school students (Correa-Burrows *et al*., 2017) and in younger students (Correa-Burrows *et al*., 2014).

High intakes of animal source foods (Edwards *et al*., 2011; Hulett *et al*., 2013; Kim *et al*., 2016a; Kim *et al*., 2016b; MacLellan and Taylor, 2008) and at least once a week of fish consumption (Kim *et al*., 2009) were significantly associated with good academic performance ($P < 0.05$). However, Abudayya *et al*. (2011) did not find independent association between high intakes of animal foods and good academic performance. Salad (Burns *et al*., 2018) and fruits and vegetables (Abudayya *et al*., 2011; Edwards *et al*., 2011; Florence *et al*., 2008; Stea and Torstveit, 2014; Burns *et al*., 2018; Kim *et al*., 2016a; MacLellan and Taylor, 2008; Burrows *et al*., 2017; Kristjánsson *et al*., 2010) intakes were positively associated with academic performance, but meeting vegetables and fruits intake recommendations was not significantly associated with improved academic performance (No: OR = 1.46; 95% CI: 0.49–4.36 vs. Yes 1.00 (Ref) for English Language and OR = 1.22; 95% CI: 0.39–3.81 vs. 1.00 (Ref) for Mathematics) (McIsaac *et al*., 2015). Soft drinks as well as sweetened drinks consumption was related to poor academic performance (Stea and Torstveit, 2014; Kim *et al*., 2016a; Burrows *et al*., 2017; Edwards *et al*., 2011; McIsaac *et al*., 2015) except for Abudayya *et al*. (2011) in which higher frequency soft drinks intake was significantly associated with good performance (OR = 1.69; 95% CI: 1.14–2.52). High frequency of fast foods and instant noodles consumption were related with poor academic outputs (Li and O'Connell, 2012; Purtell and Gershoff, 2015; Kim *et al*., 2016a). Similarly, intakes of lemonade and salty snacks (Stea and Torstveit, 2014), 100% fruit juice (Edwards *et al*., 2011), confectionary (Kim *et al*., 2016a) were negatively associated with academic performance. Conversely, academic performance was not affected by intakes of confectionary (Li and O'Connell, 2012; Stea and Torstveit, 2014), traditional foods (lentils, chickpea paste, deep-fried chickpea balls, fava beans), and tea and coffee (Abudayya *et al*., 2011), and soda and salty snacks (Li and O'Connell, 2012).

Table 2 Descriptive summary of the included studies

S/No	Study	Year	Country	Study Design	Sample size (n)	Participant inclusion criteria	Academic performance domain measured
1	Abudayya *et al*.	2011	Palestine	Cross-sectional	n = 932 from 6 schools	12-15 years' old Grades 7-9	Overall average grade (≤ 70%/> 70%)
2	Correa-Burrows *et al*.	2016	Chile	Cohort	n = 395	16 years	Language; Mathematics; Grade point average (GPA)
3	Edwards *et al*.	2011	USA	Cross-sectional	n = 800 from 8 schools	11-13 years old Grade 6	Mathematics Reading
4	Esteban-Cornejo *et al*.	2015	Spain	Cross-sectional	n = 1371	12.04 ± 2.50 years	Mathematics; Language; Average for Math & English; GPA
5	Florence *et al*.	2008	Canada	Cross-sectional	n = 5200	Grade 5	Reading and writing
6	Li and O'Connell	2012	USA	Longitudinal, retrospective	n = 6,178 from 773 schools	Grades Kindergarten to 5	Mathematics Reading
7	McIsaac *et al*.	2015	Canada	Cross-sectional	n = 535 from 18 rural schools	9-12 years' old Grades 4-6	Mathematics English Language
8	Nyaradi *et al*.	2015	Australia	Cohort	n = 779 (math) n= 741 (reading)	14 years' old Grade 9	Mathematics, Reading, Writing

					n = 470 (writing)		
9	Pearce *et al*.	2018	Australia	Cross-sectional	n = 315 from 26 schools	9-11 years old	Reading, Writing, Numeracy, Language
10	Purtell and Gershoff	2015	USA	Longitudinal	n = 8544	Grade 5	Reading, Mathematics, Science
11	Sørensen *et al*.	2015	Denmark	RCT	n = 739	8-11 years old	Reading, Mathematics
12	Stea and Torstveit	2014	Norway	Cross-sectional	n = 2,432 from 17 high schools	15-17 years old grade 1	Norwegian English Mathematics
13	Vassiloudis *et al*.	2014	Greece	Cross-sectional	n = 528 from 21 schools	10-12 years old Primary school	Language; Mathematics; Physics; History; Geography; Spelling; Reading comprehension; Writing composition; Oral expression; Numerical ability; Ability to solve mathematical problems
14	Øverby *et al*.	2013	Norway	Cross sectional	n = 475 from 4 schools	Grades 9-10; Secondary school	Reading and writing Mathematics
15	Hulett *et al*.	2013	Kenya	RCT	n = 271 (Intervention);	7 years' old Grade 1	Arithmetic; English; Kiswahili; Kiembu; Science/Agriculture;

					n= 89 (Control) from 12 schools		Geography/Civics/Culture/Religion; Arts/Crafts; Music
16	Burns *et al.*	2018	USA	Cross-sectional	n = 4625 adolescents from 97 schools	14-18 years old; Grades 9-12	English courses
17	Kim *et al.*[a]	2016	Korea	Cross-sectional	n = 395,264	12-18 years old; Grades 7-12	General performance
18	Kim *et al.*[b]	2016	Korea	Cross-sectional	n = 630 from middle and high schools	15-16 years old; Grades 9-10	Korean; Social science; Mathematics
19	Correa-Burrows *et al.*	2017	Chile	Cross-sectional	n = 678	16-17 years old	Grade point average
20	Barchitta *et al.*	2019	Italy	Cross-sectional	n = 213 from 3 high schools	15-18 years old	Science; Mathematics; Physical education; Grade point average
21	MacLellan and Taylor	2008	Canada	Cross-sectional	n = 325 from 4 junior high schools	13-15 years old; Grades 7-9	Grade average
22	Burrows *et al.*	2017	Australia	Cross-sectional	n = 4245	8-15 years old; Grades 3, 5, 7, 9	Reading; Writing; Grammar/ Punctuation; Spelling; Numeracy
23	Correa-Burrows *et al.*	2014	Chile	Cross-sectional	n = 1073	Grades 5, 9	Mathematics; Language

24	Kristjánsson *et al*.	2010	Iceland	Cross-sectional	n = 6,346 from secondary schools	14, 15 years old; Grades 9-10	Icelandic, Mathematics, English, Danish/Swedish/Norwegian
25	Kim *et al*.	2009	Sweden	Cross-sectional	n = 9448	15 years old	Total grades of 16 subjects
26	Feinstein *et al*.	2008	England	Longitudinal, Cohort	n = 5741	4-5 years old (Entry); 6-7 years old (Stage 1); 10-11 years old (Stage 2)	English, Mathematics, Science

Discussion

Academic performance has been associated with the dietary intakes in school children, adolescents inclusive. Food consumption provides euphoria for children; food is one of the basic needs of an individual. Beyond the provision and consumption of food, is the nutritional quality of the food. Fruits and vegetables are normally part of diets promoted as healthy. It is not surprising then that all the studies that reported fruits intake, also reported vegetable intake (Abudayya *et al*., 2011; Edwards *et al*., 2011; Florence *et al*., 2008; Stea and Torstveit, 2014; Burns *et al*., 2018; Kim *et al*., 2016a; MacLellan and Taylor, 2008; Burrows *et al*., 2017; Kristjánsson *et al*., 2010; McIsaac *et al*., 2015). Improving the quality of the diet of school children nutritionally have yielded academic benefits and achievements. Students who had reduced diet quality, compared to their counterparts with higher diet quality, are more likely to perform poorly in school (Florence *et al*., 2008; McIsaac *et al*., 2015). Mediterranean diet (Esteban-Cornejo *et al*., 2015; Vassiloudis *et al*., 2014; Barchitta *et al*., 2019), 'Healthy' dietary pattern (Nyaradi *et al*., 2015; Øverby *et al*., 2013; Feinstein *et al*., 2008), 'Core' foods (Pearce *et al*., 2018), New Nordic diet (Sørensen *et al*., 2015) and 'Prudent' diet (Barchitta *et al*., 2019) by their characteristics were all of good quality, and as such their high intakes were associated with good academic performance. It is however unclear whether these effects and associations are solely due to the dietary intakes or due partly to some other factors. Though school children who had higher intakes of fruits were more likely to perform better, Edwards *et al*. (2011) found that less (< 2times/day) intake of 100% fruit juice was associated with higher mathematics scores. The influences of other variables and confounders alike cannot be overlooked. Specific foods that have been touted as unhealthy were associated with poor academic performance. The studies considered at least one variable and or confounder such as household SES, BMI, physical activity, time with television, and parental education. Academic performance is influenced by a myriad of variables; this includes individual intelligence (Bartels *et al*., 2002). Intelligence affects the understanding of students in class lessons; the teacher's methodology tends to assist students with low intelligence. Chikwere and Ayama (2016) reported an improved academic performance among students, who hitherto performed poorly, after a methodological intervention. Improvements in the diet quality of students have not been repeatedly associated with increased academic achievement. This is evidenced by the paucity of data regarding studies involving diet and academic performance. Due to the complex nature of such studies, longitudinal designs are needed if the persistent effects must be decoupled. Only three studies (Feinstein *et al*., 2008; Li and O'Connell, 2012; Purtell and Gershoff, 2015) were of longitudinal design in this review. Li and O'Connell (2012) was retrospective in design, making it skip factors that culminated to the final academic performance as does cross-sectional studies. More longitudinal studies are required to consistently understand the relation between diet and academic performance and progression.

Food provides pleasure and happiness, especially to children. Food security can provide an ambiance for a child to ameliorate learning difficulty thereby improving academic performance to some extent. Addressing food insecurity alone might not be enough to provide the micronutrients needed to curb cognitive impairments. It is imperative to improve both macronutrients and micronutrients in the diets of school-aged children. Addressing malnutrition, precisely undernutrition, improves growth, learning abilities and academic performance of school children (Uchendu, 2011). Since the amounts of nutrients in unlabeled foods are unlikely to be measured at home, regular consumption of nutrient-dense foods would provide surety for improved diet quality among school-aged children and subsequently good academic performance. Health promotion policies addressing nutrition problems should encourage parents and schools to provide diverse foods for school children. School feeding programs have improved diet quality and dietary diversity by contributing to the nutrient adequacy (Abizari *et al*., 2014; Zenebe *et al*., 2018) and encourages class attendance (Zenebe *et al*., 2018) in school children. Such programs should be intensified in areas faced with food insecurity especially in developing countries, and sustainable agriculture promoted to address malnutrition. Only one study from Africa, conducted in Kenya (Hulett *et al*., 2013), was included in the review. This reveals a woefully inadequate data on the effects of diet on academic performance in a continent faced with the problems of undernutrition. More studies should be conducted in Africa to increase awareness on the need to improve food security in homes, end undernutrition and eventually improve academic performance. On the roadmap to achieving SDG 4 of providing quality education for all, governments must pay special attention to food security and the dietary needs of school children.

Generally, girls were more likely to perform better than their male counterparts in school except the study by Correa-Burrows *et al*. (2014), and in physical education (Barchitta *et al*., 2019) and Mathematics (Edwards *et al*., 2011). Likewise, intake of milk and milk products was associated with good performance in boys but this association was not recorded among the girls (Kim *et al*., 2016b). The girls were more likely to take healthy foods compared to the boys. More girls were likely to take fish more than once a week (Kim *et al*., 2009), and fruits (Øverby *et al*., 2013) and vegetables (Burns *et al*., 2018). The gender-based relation of diet to academic performance has not been established. A study in Spain (Esteban-Cornejo *et al*., 2015) reported girls to have better performance in language, higher scores for average of mathematics and language and higher GPA, meanwhile the level of Mediterranean diet intake was greater in boys. Adherence to Mediterranean diet has however been associated with good academic performance among students (Barchitta *et al*., 2019; Vassiloudis *et al*., 2014), though the adherences were marginally higher in boys. The boys had higher BMI and weight but were more likely to engage in vigorous physical activity compared to the girls. Alswat *et al*. (2017) did not find significant association between BMI and performance in the subjects assessed except for physics in which the normal-weight students did better than their obese counterparts.

Though intake of certain foods or groups of foods had positive correlations with performance in some subjects in school, these relations are yet to be established. It will rather be more beneficial to adhere to healthy dietary patterns that promote adequate nutritional status than having a faddist approach in ensuring good academic performance among school boys and girls. A holistic lifestyle management including dietary diversity is necessary for promotion of good health among school children. A healthy child will be more likely to have less learning difficulty compared to an unhealthy one. As suggested earlier, more longitudinal studies involving many variables and confounders are required to gain more insight into the relation of diet to academic performance of students.

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