Impact of School-Based Interventions on Children's Healthful Nutritional Outcomes (2009-2013): Implications for Future Research

Paloma Rohlfs Domínguez[*]

Department of Psychology and Anthropology, Faculty of Nursing and Ocuppational Therapy, University of Extremadura, Cáceres, Spain

Abstract: *Objective*: The objective was to review the literature on school-based interventions during compulsory education (published in 2009-2013) that may be effective in increasing healthful nutritional outcomes in children. Specific strategies and their limitations will be identified.

Methods: A qualitative systematic analysis of seventeen school-based interventions applied to six-eleven year-old children, and published in peer-reviewed journals from 2009-2013 was carried out.

Results: These studies taken as a whole used a variety of fourteen strategies, such as provision of nutritional and gardening education; repeated exposure to vegetables (V); peer and adult modelling; chefs going into schools to teach healthy nutritional issues. These studies showed four types of limitations: limitations derived from the experimental designs and experimental procedures used and limitations affecting participant samples and data collection. Fifteen recommendations for overcoming the targeted research limitations were identified, such as applying the intervention during longer time intervals; examining the effectiveness of these interventions in different ethnicities and socioeconomic groups; including larger participant samples; using randomized designs. Finally, six new working hypotheses to guide future studies are proposed here. For example, a small number of V offered might lead to insufficient opportunities to learn to like the flavour of V; schools' previous experience with these interventions might distort children's post-intervention data related to their nutritional outcomes; providing children with nutritional and gardening education might increase their fruit (F) selection, consumption and preferences and application of evaluative conditioning under more appropriate experimental conditions might increase child V consumption.

Conclusion: seventeen school-based interventions were included. These studies taken as a whole used a variety of strategies (fourteen), and showed four types of limitations. Fifteen recommendations for overcoming the targeted research limitations as well as six new hypotheses are proposed here. Future research in this field should focus on overcoming its research limitations, such as the ones highlighted here, and building new working hypotheses, such as those proposed here.

Keywords: Children, vegetables, fruits, consumption, schools.

INTRODUCTION

It is well known that early vegetable consumption -a healthy nutritional habit - counteracts childhood obesity, one of the most worrying public health problems throughout the world [1], as well as health problems in adulthood, such as obesity [2], hypertension, heart disease and cancer [3-5]. Children's intake rates remain, however, lower than national recommendations [6, 7], an average of 3 portions daily in Europe [7].

Children's patterns of food intake are also linked to their food preferences [8, 9] and their liking for specific foods [10], those early preferences lasting until adolescence and even young adulthood [11-13]. However, these early likings and preferences for foods are not immutable. Indeed, early experiences (i.e. during childhood) with edibles, including V, may induce and modify the establishment of stable food preference patterns and nutritional habits [14-18].

In Spain, primary education is compulsory for 6-12-year-old children [19], while children from birth until the age of 6 years may voluntarily attend schools specially designed for their early age (kindergarten) [20]. It has been estimated that at least 20% of the children who attend a Spanish school (either private or public) have lunch (the main meal in Spain) each day in school during the 8-9 month academic period [21]. Other countries, such as the United Kingdom, Ireland, Argentina, Sweden, and United States of America also provide children with food in the school dining rooms [22-26]. Therefore, the fact that many children receive at least one meal at school is not only exclusive to Spain, but is a worldwide social phenomenon.

Because the school is an environment that provides many children with edibles, it may thereby shape childhood food preferences and eating habits [27-30].

Based on this brief overview, the following questions were considered: Which school-based

*Address correspondence to this author at the Department of Psychology and Anthropology, Faculty of Nursing and Ocuppational Therapy, University of Extremadura Avda. de la Universidad s/n, 10003 Cáceres, Spain; Tel: 927257000/Ext. 51241; E-mail: prohlfsdomnguez@yahoo.es

interventions during the compulsory education period may be effective in increasing healthful nutritional outcomes in children? Nutritional outcomes are considered here as being healthy when the involved edibles were fruits (F), V, or F and V (FV). What limitations are found in these school-based interventions? How can these limitations be overcome in future research efforts to develop viable strategies for promoting healthy nutritional outcomes in children? In an attempt to answer these questions, pertinent research on school-based interventions published from 2009 to 2013 is reviewed. This work begins with a description of the criteria for considering studies and the corresponding search strategy, along with a synthesized comparison of the study findings. This is followed by a discussion of the implications of the results of these studies for future research in this field (recommendations for overcoming identified research limitations and new working hypotheses).

METHODOLOGY

Criteria for Considering Studies

A literature search of published studies on food consumption by children in school settings was carried out. More specifically, studies were included if they dealt with several particular healthy nutritional outcomes (Table **1**). Moreover, studies were included if they were school-based, that is, if they were clearly carried out, at least partially, in any physical space of the target school buildings, such as classrooms, dining halls or cafeterias. The focus of the present work concerns 6-11 year-old children exclusively, an age-range when children are typically required to attend compulsory education at schools worldwide [19]. Younger children, in contrast, may attend school in many European countries, such as Spain [20] and Germany [31] as well as the USA [32], but in a voluntary way, depending on parents' wishes. Children older than 11 years are approaching adolescence [33, 34], and the focus is childhood. A wide range of study designs were included in order to ensure the inclusion of a vast spectrum of intervention strategies that improved children's healthy nutritional outcomes. Indeed, randomized and non-randomized, controlled and non-controlled trials and school-based interventions with and without follow-up evaluations were included. Furthermore, this work includes only those studies that were published in peer-reviewed journals between 2009 and August 2013. Previous related work [35] focused on similar school-based interventions published between 2000 and 2008.

Indeed, this work aims to complement that earlier research. Studies were excluded if they were not school-based, if they targeted pupils showing medical specific problems and/or children older or younger than the above-mentioned targeted age range (Table **2**).

Table 1:　Healthy Nutritional Outcomes Included

1. FV-related nutritional knowledge.
2. Preferences for FV.
6. FV consumption.
3. Liking for FV.
4. Attitudes toward FV.
5. FV-related abilities, such as FV identification.
6. Willingness to try FV.

Table 2:　Inclusion and Exclusion Criteria

Inclusion criteria
1.　Intervention: school-based.
2.　Targeted edibles: F, V or FV.
3.　Setting: compulsory education (6-11 year old).
4.　Outcomes: Table **1**.
5.　Years of publication: from 2009 to August 2013.
6.　Study design: randomized and non-randomized, controlled and non-controlled trials and school-based interventions with and without follow-up examinations.
Exclusion criteria
1.　Not school-based intervention.
2.　Not focused on FV.
3.　Targeted children having a specific medical problem.
4.　Children aged outside the age range 6-11 years.

Search Strategy

The search strategy involved Academic Search Complete, PubMed and ScienceDirect as the databases to identify published studies. Only studies that met all of the following criteria were included: *population* (6-11 year-old and thus school-aged children); *interventions* (school-based interventions, school-based nutrition programs, or school-based nutritional interventions); *school food environment* (school lunches, school meals, canteen, cafeteria, or food services); *targeted edibles* (FV); *nutritional outcomes*.

RESULTS

Synthesized Comparison of Study Findings

A total of seventeen studies that met the inclusion criteria were included. A systematic analysis and descriptive review of these studies, rather than a

Table 3:   Characteristics of the Studies Included in this Review

Reference	Objectives	Explicit Hypothesis	Study Design, Follow-up	Participants (Groups, Age and sample size)
1. [36]	To increase children's knowledge of healthy nutritional habits; psychosocial variables. Associated with eating FV. And preferences for FV.	Children of the intervention group would achieve these objectives in a more extent than the control group.	Randomized trial. Controlled trial. No follow- up.	One intervention group. One control group. 9-11 years. n = 255.
2. [37]	To examine how slicing apples and oranges affect children's selection and consumption of fruit.		Non-randomized trial. Non-controlled trial. No follow- up.	One intervention group. No control group. Kindergarten-9-10 years. n = 491.
3. [38]	To examine the impact of a school garden on children's FV knowledge, preference and consumption.	Children of the intervention group would be more likely to choose and eat vegetables during the lunch time after the intervention, in comparison with both control groups.	Non-randomized trial. Controlled trial. No follow- up.	One intervention group: Nutrition education and gardening. Two control groups: 1) Only nutrition education. 2) No intervention. 7-8 years. n = 115.
4. [39]	To examine if repeated tastings of vegetables would increase children's liking for vegetables. To determine the number of tastings required for changing children's disliking for vegetables to liking them or liking them a lot.	Repeated exposure to vegetables would increase children's liking for vegetables.	Non-randomized trial. Non-controlled trial. No follow- up.	Three intervention groups: 1) Children who did not like vegetables prior to the intervention. 2) Children who liked them prior to the intervention. 3) Children who liked them a lot prior to the intervention. No control group. 9-11 years. n = 360.
5. [40]	To examine the effect of a comprehensive school intervention on nutritional knowledge, attitudes and behaviours.	In comparison to the other children, the children most exposed to the intervention would show: 1) Greater increases in nutritional knowledge. 2) Positive changes in attitudes toward healthy eating behaviours, including preferences for FV. 3) More consumption of FV at the school and outside of the school.	Non-randomized trial. Non-controlled trial. No follow- up.	Three intervention groups: 1) High-degree intervention development. 2) Medium-degree intervention development. 3) Low-degree intervention development. No control group. 9-11 years. n = 327.
6. [41]	To improve the school environment and child nutrition by youth partnerships.	Child peer leaders' implication in the whole intervention process (planning, implementation and evaluation of results) would improve their dietary intake, in comparison to the control group.	Non-randomized trial. Controlled trial. No follow- up.	Two intervention groups, which received a nutritional education program by the researchers and peers: 1) These peers implemented a FV snack stand in classrooms. 2) These peers implemented the access to the teachers' salad bar. One control group, which received only the standard classroom nutrition education without peers' implication. 9-10 years. n = 104.

Reference	Objectives	Explicit Hypothesis	Study Design, Follow-up	Participants (Groups, Age and sample size)
7. [42]	To increase children's liking for FV by offering them repeated opportunities to taste these items.		Non-randomized trial. Non- controlled trial. Follow-up: at 4th and 10th post intervention months.	Two intervention groups: 1) Children who disliked the targeted FV before the intervention. 2) Children who liked the targeted FV before the intervention. No control group. 6-9 years. *n* = 379.
8. [43]	To examine the impact of a multi-component, theory-based intervention in children's FV consumption, preferences, knowledge and body mass index.	Children exposed to the intervention would show an increased FV knowledge, preferences and lunch time consumption as well as lower BMIs, in comparison to the control group.	Randomized trial. Controlled trial. Follow-up: at the first-3th post-intervention years.	One intervention group. These children were exposed to the intervention. One control group. These children were not exposed to the intervention. Mean age: 6.2 years. *n* = 149.
9. [44]	To examine the effects of exposure to vegetables of different liking levels on children's liking for and intake of vegetables.	1) Exposure to vegetables would increase children's preferences for and intake of vegetables. 2) Changes in liking, derived from exposure to vegetables, would be transferred to similar non-exposed vegetables. 3) Children would show increases and decreases in liking for and intake of neutrally liked vegetables paired with liked and non-liked vegetables, respectively.	Randomized trial. Controlled trial. Follow-up: at the first-post-intervention day.	Three intervention groups: 1) These children received a mixture of a neutrally liked vegetable and a liked vegetable. 2) These children received only a neutrally liked vegetable. 3) These children received a mixture of a neutrally liked vegetable and a disliked vegetable. One control group. These children did not receive any exposure intervention. 9-11 years. *n* = 345.
10. [45]	To evaluate the effects of a multi-component nutrition education program on children's knowledge, attitudes and behaviours related to consumption of FV.		Non-randomized trial. Controlled trial. No follow- up.	Two intervention groups: 1) Children received an educational program. Teachers and parents were involved in the intervention as role models for behaviour change. 2) Children received an educational program, but teachers and parents were not involved in the intervention. One control group. These children did not receive the educational program. 8-11 years. *n* = 399.
11. [46]	To examine the impact of an educational program together with repeated food exposures on children's ability to identify FV and willingness to try FV.	Children who received the nutritional education program together with food exposures would be better at identifying and more willing to try FV, compared to other children.	Non-randomized trial. Non-controlled trial. No follow- up.	Two intervention groups: 1) Children who received the educational program plus repeated FV exposures. 2) Children who only received the educational program. No control group. 5-6 years. *n* = 88.

(Table 3). Continued.

Reference	Objectives	Explicit Hypothesis	Study Design, Follow-up	Participants (Groups, Age and sample size)
12. [47]	To examine the impact of the so called CHANGE intervention on children's diet quality, thus preventing children's unhealthy weight gain.	Children exposed to the intervention would improve their diet quality, in comparison with other children.	Randomized trial. Controlled trial. No follow- up.	One intervention group. These children were exposed to the intervention. One control group. These children were not exposed to the intervention. 6-12 years. *n* = 432.
13. [48]	To examine the effects of chefs going into schools to teach children to prepare and taste healthy food on children's food preparation and consumption as well as cooking confidence.		Randomized trial. Controlled trial. No follow- up.	One intervention group. These children were exposed to the intervention. One control group. These children were not exposed to the intervention. 9-11 years. *n* = 169.
14. [49]	To examine the effectiveness of the choice strategy on children's vegetable consumption.	Children provided with choice would consume more vegetables than children not provided with choice. Children having choice availability continuously during the meal would show a higher vegetable intake than those who had choice availability only once.	Randomized trial. Controlled trial. No follow- up.	Two intervention groups: 1) Children chose the vegetable to ingest once before the meal. 2) Children chose the vegetable during the meal, whenever they made a bite. One control group. These children could not choose the vegetable. 4-6 years. *n* = 150.
15. [50]	To examine the effectiveness of adult modelling (the teacher being the exposure model) on children's fruit intake.		Randomized trial. Controlled trial. Follow-up: at the first post-intervention year.	Two intervention groups: 1) Children were exposed only to an educational program. 2) Children were exposed only to adult modelling. One control group. These children were not exposed to any intervention. 9 years. *n* = 184.
16. [51]	To examine the effectiveness of integrating animal cartoon characters into a comprehensive nutritional education program in children's FV consumption and physical activity.		Non-randomized trial. Non-controlled trial. No follow-up result assessment.	One intervention group. These children were exposed to the intervention. 8-11 years. *n* = 4,128.
17. [52]	To examine the effectiveness of peer modelling combined with rewarding in children's FV.		Non-randomized trial. Non-controlled trial. No follow-up result assessment.	Three intervention groups: 1) Children who consumed no fruit at pre-intervention base line. 2) Children who consumed no vegetable at pre-intervention base line. 3) Children who consumed FV at pre-intervention base line. All these children were exposed to the intervention. No control group. 6-11 years. *n* = 253.

Country, City, School physical space	Procedures	Results (they are significant)	Limitations
USA; Southeast Louisiana. Classrooms of different public schools.	Provision of nutritional knowledge aimed to learn the physiology of digestion and the importance of consuming healthy foods, such as FV. Modification of children's social environment leading to encourage to consume FV.	In comparison to control children, children of the intervention group showed an increase in their healthy nutritional knowledge, and the psychosocial variables associated with eating FV were improved. However, their preferences for FV did not change.	The program had a relatively short, 12-week duration. This may be insufficient time for changing children's food preferences. Follow-up assessment of the program was not examined, so long-term effects of the program are unknown. The majority of children were black and resided in low-income households, so results cannot be generalized to other socioeconomic groups and ethnicities.
USA; Rural Kentucky. One school cafeteria.	The kitchen staff was asked to serve whole and sliced apples and oranges in the usual manner. On day 1, children could choose the sliced fruits among other food options. On day 2, children could choose the whole fruits among other food options.	Slicing fruit encouraged children's fruit selection and consumption, only in the case of oranges. The greatest slicing effect was observed among the younger children.	There were no independent subject and food samples, so different factors from slicing may have (also) influenced the results. Results cannot be generalized to other populations.
USA; Southeastern. Classrooms and garden of one school.	Provision of nutritional and gardening education.	The first hypothesis was fulfilled. However, the intervention group and the first control group showed, with no significant differences between both groups, greater improvements in nutrition knowledge than the second control group. There was no impact on children's fruit-related knowledge, preferences and consumption.	The study did not use a randomized design. The sample size was not as large as desirable. The study did not include a follow-up assessment to determine long-term results. Participants were predominantly white, second-grade population, and results should not be generalized to other populations.
USA; South-eastern Louisiana. The cafeterias and classrooms of four low-income public schools.	Provision of a vegetable tasting program combined with a nutritional education program.	Liking for the majority of the targeted vegetables was increased in the first group of children. No changes in liking for the vegetables were observed in the other two groups.	Children were 9-11 year old and attending low-income schools of South-eastern Louisiana. The 80% of them were black, so results should not be generalized to other populations. Questionnaires were used to collect information on children, and social desirability might have biased the results. There was no control group. A random design was not used. Lower rate of participation of children of the first group.
USA; California. Classrooms; dining halls and gardens of different schools.	A combined provision of nutritional lessons, cooking and garden classes, as well as exposure to FV.	There was no difference in nutritional knowledge nor attitudes toward healthy eating behaviours by intervention degree. The most increases in preferences for FV were found in the children of the high-degree intervention development. These children also showed significant increases in FV consumption, but only at the school, while children of the low-degree intervention development showed a decrease in this variable.	Nor control nor random design was used. Some schools had advantage over other schools in implementing the intervention because of their greater experience in this program. The youngest children had difficulties in providing researchers the information required. Some of the information was collected only in working days, weekends having been omitted. The intervention was not applied at home.

(Table 3). Continued.

Country, City, School physical space	Procedures	Results (they are significant)	Limitations
USA; rural East Tennesee. Classrooms of different schools.	Provision of taste-related FV experiences by child peers and/or adults.	The first intervention group showed an increased fruit consumption. The second intervention group showed a reduced energy intake.	The second intervention group showed a reduced fruit and vegetable intake, due to problems related to the measurement of dietary consumption.
USA; Southeast Louisiana. Cafeteria of low-income schools.	Repeated exposure to FV during 8 weeks.	Children of the first group showed an improvement of their liking for FV after the intervention and maintained this improvement at both follow-up assessments. There were some gender and grade differences at each assessment time. The number of exposures required for observing these increases in liking for FV were two and three, respectively. Children of the second group maintained their liking status at each assessment time, and there were no gender or grade differences.	Participants were first, 2th and 3th graders from low-income schools, so results should not be generalized to other populations. Social desirability could have influenced children's responses. There was no control group.
USA; North-eastern. Classrooms, lunchrooms of different schools and children's homes.	Provision of the following components for promoting FV consumption: 1) Loudspeaker announcements. 2) Instructional material (DVD). 3) Contingent rewarding on a bite of FV. 4) Take-home activity books.	In comparison to the control group, the intervention group increased the FV consumption, although this effect declined across time. Preferences for FV and BMIs did not change between groups. There were persistent increases on children's FV knowledge.	The sample size was not as large as desirable, which may affect results' generalization.
Denmark; Copenhagen. Classrooms.	Repeated exposure to vegetables in the context of an evaluative conditioning.	In comparison to the control group, liking for most vegetables decreased after the intervention, but tended to recover somewhat during the follow-up. Vegetable intake decreased after the intervention. Intake quantity varied across the type of vegetable servings. Indeed, children consumed more of neutrally liked vegetables when these items were paired with a liked vegetable than when served alone or together with a disliked vegetable.	Most of the children were Caucasian and middle class, so results should not be generalized to other populations. All classes received similar, but alternating serving orders of vegetables at liking test days, thus leading to confounding between serving order and intervention group. There could have been peer influences affecting the data. There could have been some overestimations of the intake data, in the case of children who dropped their vegetables on the floor.
USA; Los Angeles. Classrooms.	Adult modelling. Nutrition education sessions. Interactive activities.	Neither of the 2 intervention groups showed an increased FV consumption. Neither of the 2 intervention groups showed an increased availability of FV at home. Only children of the first intervention group showed increases in knowledge, attitudes and beliefs toward vegetables. The parent/teacher influence on children's FV attitudes increased only in the first group.	Participant groups represented only a few of some specific ethnic groups, so results should not be generalized to other populations. The small size of the firs intervention group was to small to observe changes in FV consumption. There was no follow-up result assessment. There was no intervention on the school food environment, this resulting in no behavioural change in vegetable consumption.

Country, City, School physical space	Procedures	Results (they are significant)	Limitations
USA; Williamsburg James City. The classrooms of two different schools.	An educational program, which included interactivities about healthy eating and physical activity. Repeated exposure to FV.	All children were better able to identify FV. Only the children of the first intervention group were more willing to try FV. There were no changes in children's identification abilities or willingness to try vegetables.	Children may have had insufficient opportunities to learn to like the flavour of the vegetables, due to the small number of vegetables offered. There was no follow-up result assessment, so effects of the intervention over the long-term are unknown.
USA; rural areas of California, Kentucky, Mississippi and South Carolina. Classrooms and cafeterias of different schools; children's homes.	Changes in the foods offered in the cafeteria: more FV and whole grains and less added-sugar and saturated-fat products. Educational program based on the social-cognitive theory. Parent and community outreach components.	In comparison to the control group, children of the intervention group showed an increased consumption of vegetables and combined FV, as well as a trend to consume more fruits. They also showed a reduced average daily dietary glycaemic index. There were no differences in children's consumption of whole grains.	Results are not generalizable to other populations. Many children who agreed to participate in the study failed to complete a second survey at the end of the intervention.
England; Est London, West London, North West England (near Manchester and Liverpool) and Midlands. Classrooms of different schools.	Instructional lessons. Sensory experiences focused on taste. Practical cooking sessions with a chef.	In comparison to the control group, the intervention group showed gains in skills and confidence to prepare and ask for the ingredients to be purchased for use in home. These children also showed an increased vegetable consumption.	There was no follow-up result assessment, so it is not known, whether the results found are sustained in the long-term.
Spain; Granada. Dining halls of different schools.	Provision of choice availability at the lunch time.	Children of both intervention groups ate more vegetables than the control group. There were no differences between both choice conditions.	There was no follow-up assessment, so it is not known, whether the results found are sustained in the long-term. Children's motivation (liking or preference) for the targeted vegetables during and after the meal was not measured. Children's attentional focus during the meal was neither measured.
Greece; Chipre. Classrooms.	Provision of a nutritional educational program. Adult modelling.	In comparison to the control group, both intervention groups exhibited a higher fruit intake. At 1-year follow-up, that increase remained only for the children of the 2th intervention group.	The misreported food information: food record during weekends was omitted. Parents reported information for their children, but they may not know exactly what their children ate outside the school. The results were obtained from a single school district, so results are not generalizable to other populations.
USA; Minessota. Classrroms and cafeteris.	Children's exposure to animal cartoon characters. Provision of nutritional lessons. Addition of FV to the menus offered in the cafeterias.	Self-reported consumption of FV was improved. The number of sessions attended and improvements in fruit consumption was weakly but yet significantly related.	No control group was used. The survey used self-reported dichotomous questions.
USA; Northen Utah. Cafeteria.	Children watched videos in which heroic peers were eating FV, and received a reward for eating FV.	Children's FV intake increased after the intervention. This effect was more discriminable among children of the first intervention group.	No control group was used. Only one school participated in the study, which may affect the generalization of results. The socioeconomic status or ethnicity in schools with more cultural diversity may impact the results. No follow-up assessment was carried out to check the stability of results in the long-term.

meta-analysis, was conducted because of the marked heterogeneity in the types of school-based interventions carried out. Furthermore, the studies used a wide range of methods and outcomes to assess effects on children's nutritional outcomes. The included studies were analyzed according to the three research questions formulated in the introductory section: which school-based interventions executed during that period may be effective in increasing these healthful nutritional outcomes in children? What limitations do these studies present? How would it be possible to overcome these limitations in future investigations of viable strategies for promoting child healthy nutritional outcomes? (Table **3**).

DISCUSSION AND IMPLICATIONS FOR FUTURE RESEARCH

Based on the review of the included studies, the answers to the three questions formulated in the introductory section are presented below, along with several implications for future research.

School-Based Interventions Executed During the Compulsory Education Period that may be Effective in Increasing Healthful Nutritional Outcomes in Children

School-based interventions focused, at least partially, on providing children with nutritional education programs are effective in increasing healthful nutritional outcomes. Indeed, it has been demonstrated that children provided with nutritional and gardening education are more likely to choose and eat a variety of V (i.e. carrots, broccoli, cabbage and zucchini) during lunch time. This strategy also increases their preferences for these items. Their nutritional knowledge also improves if they are exposed to this combination of strategies, but to the same extent as when children only receive nutritional education [38]. Furthermore, this type of intervention does not impact children's selection, consumption or preferences for F, when only one F (i.e. blueberry) is offered [38]. Therefore, these authors recommend that future research should examine the same intervention, but using a variety of F. Providing children with nutritional knowledge, such as the physiology of digestion and the need for consuming healthy foods, using a language adapted to their age, together with modification of the social environment by, for instance, encouraging children to participate in school assemblies where the message to consume FV is delivered, also result in an increase in healthy nutritional knowledge. Improvement

of the psychosocial variables associated with eating FV is also found, but there were no changes in preferences for FV [36]. These authors therefore recommend that future research should identify ways to increase children's tasting and exposure to these healthy foods, in addition to those strategies, in order to change their preferences for FV. Following this research line, at least three studies have obtained positive results. Wang *et al*. [40] found that provision of nutritional lessons, combined with cooking and gardening classes, as well as exposure to FV, increases children's consumption of and preferences for FV. Nutritional knowledge or attitudes toward healthy eating are not affected by this intervention, however. The authors of this study suggest that the potential advantage of some of the schools over others in the implementation of the intervention (because of previous relevant experience) may have distorted children's post-intervention data related to their knowledge and attitudes toward healthy eating. That is, this previous experience could have resulted in a ceiling effect. Therefore, future school-based interventions should also control this variable. Secondly, a school-based intervention that combined an educational program and repeated exposure to FV improves children's ability to identify FV as well as willingness to try FV [46]. These variables are likely to promote FV consumption in children, a hypothesis that should be tested in the future. Thirdly, exposing children to animal cartoon characters within a comprehensive nutritional education program consisting of the provision of nutritional lessons, plus addition of FV offered in the school cafeterias, improves children's self-reported FV and F consumption [51].

Other effective school-based interventions are those focused on repeated exposure to FV as the only strategy applied. Repeated exposure increases liking for V and FV in children who did not like the targeted items before this repeated taste-related experience [39, 42]. This result was constant across time (four and ten months later) and subject to gender and grade variables [42]. In the case of F, fewer exposures –two times- are required for observing an increase in liking for these items, in comparison to the number of exposures required to increase liking for V –three times- [42]. The authors attribute this effect to children's innate liking and rejection for the sweet and bitter tastes of F and V, respectively. In contrast, repeated exposure does not change liking for V and FV in children who already liked V before the repeated

tastings [39, 42]. Therefore, it is suggested that future research should examine whether adding to the targeted V some sweetener or even a sweet F, that is, using the so-called evaluative conditioning experimental paradigm –within this paradigm, a neutral or even rejected stimulus is paired with an already liked stimulus- (see Gast, Gawronski and De Houwer [53] for a review) might increase children's liking for V that is already liked (but see Olsen *et al*. [44] for a different point of view). Indeed, as it is have been pointed out in a previous section, these authors found no increases in liking for or intake of already liked V motivated by evaluative conditioning. Authors of this study attribute this result, either to children's limited attention focused on the targeted V, due to peer influence, or to children's V-related boredom sensation or the large size of V servings. Future research should examine evaluative conditioning related to child V consumption under more appropriate experimental conditions.

In addition to the strategies that have been discussed so far in this section, there are four more that deserve readers' attention. The first involves manipulation of the food environment at schools. For example, offering sliced F in the cafeteria has been shown to encourage children's F selection and consumption of oranges, especially among younger children, but does not impact consumption of apples [37]. Therefore, future research should develop additional age- and F-specific strategies to encourage child F consumption. Similarly, offering children more FV and whole grains with less added-sugar and saturated-fat products in the school cafeteria has been found to increase children's V and FV consumption while reducing dietary glycaemic index [47]. Furtheremore, providing children with the opportunity to choose the V to ingest once before the meal or whenever they take a bite during the meal has been demonstrated to increase their V intake [49]. The second strategy refers to others' influence. Provision of a FV snack stand in classrooms by peers increased children's F consumption [41]. Furtheremore, peer modeling has been observed to increase children's FV intake [52], and adult modeling also increased children's knowledge, attitudes and beliefs toward FV, although it did not increase their FV consumption nor availability of FV at children's home [45]. Such modelling also increases children's F consumption, with this effect remaining across time (one year later) [50]. The third strategy is associated with the influence of chefs. School programs in which chefs teach children to prepare and taste healthy food has been

demonstrated to increase children's V intake as well as their skills and confidence to prepare and ask for the ingredients to be purchased for use at home [48]. Finally, promotion of FV consumption by means of loudspeaker announcements, instructional material (DVD), contingent rewards, and take-home activity books has been found to increase children's FV consumption, although this effect declines across time (three months later) [43]. This kind of intervention has also demonstrated increases in children's FV knowledge, but does not change their preferences for FV, however [43]. These authors attribute this result to the fact that they did not make the FV more palatable. Therefore, the effectiveness of increased palatability of the FV served in enhancing children's preferences for those food items should be tested in the future.

As can be seen, the effectiveness of a school-based intervention in increasing healthful nutritional outcomes in child population relies on the specific strategy or strategies used. Across the included studies, fourteen strategies have been used (Table **4**).

Table 4: Essential Strategies Used by School-Based Interventions Identified

1. Provision of nutritional knowledge combined with modification of children's social environment.
2. Slicing F.
3. Provision of nutritional and gardening education.
4. Repeated exposure to V.
5. Provision of nutritional lessons, combined with cooking and gardening classes, and exposure to FV.
6. Provision of a FV snack stand in classrooms by peers.
7. Peer modelling.
8. Adult modelling.
9. Provision of loudspeaker announcements, instructional material (DVD), contingent rewarding on a bite of FV, and take-home activity books.
10. Provision of an educational program combined with repeated exposure to FV.
11. Offering more FV in the school cafeteria.
12. Chefs going into schools to teach healthy nutritional issues.
13. Provision of the opportunity to choose the V to ingest.
14. Exposure to animal cartoon characters within a comprehensive nutritional education program.

Limitations of these Studies and ways to Overcome them in Future Research

Limitations of these studies can be placed into four categories.

1. Limitations derived from the experimental designs used. The most common of this type of limitation

concerns the lack of follow-up assesments to check whether the intervention remains effective in the long-term. This limitation affects the studies by Tuuri, *et al.* [36], Prelip *et al.* [45], Schindler *et al.* [46], Caraher *et al.* [48], Rohlfs Domínguez *et al.* [49] and Wengreen *et al.* [52]. Future research should therefore examine the effectiveness of these interventions in the long-term by adding at least one follow-up assesment at any post-intervention month or even year. A second limitation relates to the lack of control groups with which to compare the results of the experimental groups. This limitation is found in the studies by Swanson *et al.* [37], Lakkakula *et al.* [39], Leines *et al.* [51], Wengreen *et al.* [52], and Wang *et al.* [40]. These comparisons are essential for ascertaining whether the effectiveness of a school-based intervention may be exclusively attributed to manipulation of the independent variable, in this case, the type of strategy used for improving children's healthy nutritional outcomes. Consequently, a better examination of the efectivenness of these school-based interventions by adding control groups is warranted. The third limitation involves the lack of randomized experimental designs. This limitation exists in the studies by Parmer *et al.* [38], Lakkakula *et al.* [39], and Wang *et al.* [40]. Randomized experimental designs also ensure attribution of the effectiveness of a school-based intervention to the strategy used. To better examine the effectiveness of these school-based interventions randomized designs are thus necessary. Finally, short durations of the interventions may limit their effectiveness. Tuuri *et al.* [36] argue that the relatively short duration of their program - 12-weeks - was insufficient to change children's outcomes. It is therefore recommended to test their intervention in the future, but with a longer duration.

2. Limitations derived from the experimental procedures used. Within such limitations, Wang *et al.* [40] highlight that their intervention was not applied at home, thus the resulting increases in FV consumption observed among some students concern only foods eaten during school hours, and cannot be generalized to foods consumed at home. None of the studies described here targeted the home food environment, so this limitation also affects them. Prelip *et al.* [45] highlight, in turn, that their intervention did not target the school food intervention, which may explain the lack of changes in children's V consumption. Future studies should combine both home and school food environments. Thatchildren might have had insufficient opportunities to learn to like the flavor of the V during the intervention that included only 4 V offerings, is another limitation hypothesized by Schindler *et al.* [46].

Hence, this hypothesis should be tested in the future. Olsen *et al.* [44], on their part, affirm that all participants received similar, but alternating servings of V at liking test days, thus leading to confounding between serving order and intervention group, which has to be avoided in future studies. Finally, Rohlfs Domínguez *et al.* [49] underline that they did not assess children's motivation (liking or preference) for the targeted stimuli, nor attentional focus during and after their intervention, and therefore endorse the need to assess these variables in the future, to determine why children eat more V under choice conditions.

3. Limitations affecting participant samples. The most common of this type of limitation concerns the limited generalization of the results due to the fact that participants were mostly of one ethnicity (i.e. white or black) or socioeconomic group (i.e. low-income families). This limitation affects the interventions by Tuuri, *et al.* [36], Swanson *et al.* [37], Parmer *et al.* [38], Lakkakula *et al.* [39], Lakkakula *et al.* [42], Olsen *et al.* [44], Prelip *et al.* [45], Cohen *et al.* [50], Perikou *et al.* [53], and Wengreen *et al.* [52]. Consequently, the effectiveness of these interventions should be examined in different ethnic and socioeconomic groups in the future. The second most common limitation of this type is related to the participant sample size. This was not as large as desirable in several studies, such as those by Parmer *et al.* [38], Lakkakula *et al.* [39], Hoffman *et al.* [43], Prelip *et al.* [45], and Cohen *et al.* [47]. Finally, previous experience of some schools with these interventions may have resulted in advantages over other schools in implementing the intervention, for example, in the study by Wang *et al.* [40]. Hence, this variable should be controlled in future school-based interventions.

4. Limitations concerning data collection. In some studies, questionnaires were used to collect information on children (i.e. Lakkakula *et al.* [39]); thus social desirability might have biased the results [39]. Moreover, in the study by Leines *et al.* [51], the survey used self-reported dichotomous questions, which limits children's provision of information. As Wang *et al.* [40] have argued, young children have difficulties in providing researchers with required information because of their still limited language capacities. For these reasons, development of methods of data collection adapted to children's age and language are warranted. In some studies (i.e. Wang *et al.* [40]; Perikkou *et al.* [50]), information on children's nutritional outcomes was collected only on working days, hence information should also be collected on weekends in

future studies. Results reported by Olsen *et al.* [44] could have reflected peer influences and the fact that some children dropped the targeted items on the floor. Finally, Perikkou *et al.* [50] affirm that in their study parents reported information for their children, but they may not have known exactly what their children ate outside the school. Therefore, peer influences, parents' ignorance regarding what their children eat outside the school and data loss due to children's actions associated with dropping the targeted stimuli should be avoided or compensated in future school-based interventions. Ways to overcome these limitations are summarized in Table **5**.

Table 5: Strategies for Overcoming the Research Limitations of School-Based Interventions Identified

1. Add at least one post-intervention follow-up assessment.
2. Add control groups.
3. Use randomized designs.
4. Apply the intervention during longer time intervals.
5. Include the home and school food environments.
6. Offer children a higher number of V.
7. Assess children's motivation (liking or preference) for the targeted stimuli and attentional focus during and after the intervention.
8. Examine the effectiveness of these interventions in different ethnicities and socioeconomic groups.
9. Include larger participant samples.
10. Control schools' previous experience with interventions.
11. Use data-collection methods suited to children.
12. Collect information related to children's nutritional outcomes also in weekends.
13. Control peer influences on children's nutritional outcomes.
14. Avoid children's actions associated with dropping the targeted stimuli on the floor.
15. Avoid parents' ignorance regarding what do their children eat outside the school.

Based on this discussion, I propose several new working hypotheses (Table **6**).

Table 6: New Hypotheses Derived from the Targeted School-Based Interventions for Future Research

1. The provision to children of nutritional and gardening education might increase their F selection, consumption and preferences.
2. Schools' previous experience with these interventions might distort children's post-intervention data related to their nutritional outcomes.
3. Application of evaluative conditioning under more appropriate experimental conditions might increase child V consumption.
4. Development of age- and F-specific strategies might encourage child F consumption.
5. Increasing the palatability of the FV served might increase children's preferences for FV.
6. A small number of V offered might lead to insufficient opportunities to learn to like the flavour of V.

CONCLUDING REMARKS

The present review aimed to identify school-based interventions executed during the compulsory education period that may be effective in increasing healthful nutritional outcomes in children, along with their associated limitations and implications for future research. Seventeen different school-based interventions that are effective in increasing children's nutritional outcomes during this period were identified. Taken as a whole, these school-based interventions vary according to the specific strategy used to promote healthy nutritional outcomes in children and evidence four types of limitations.

I recommend fifteen ways to overcome the limitations described above, and present six new hypotheses to be assessed in the future.

The principal contribution of this review is to enhance awareness within the scientific community of the need to conduct further research on strategies that promote children's healthy nutritional outcomes as well as to overcome research-related limitations, even if this is not possible currently.

Finally, the suggestions for the future presented here are probably not viable currently, but they may inspire other researchers to find solutions in the future for the obstacles that hinder viability of these suggestions currently.

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CONFLICT OF INTEREST

There is no conflict of interest to declare.

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