Public Health Nutrition: 18(13), 2358–2367 doi:10.1017/S1368980015000221

Review Article

Sustenance and sustainability: maximizing the impact of school gardens on health outcomes

Jaimie N Davis[1], Mackenzie R Spaniol[1] and Shawn Somerset[2,*]
[1]Department of Nutritional Sciences, The University of Texas at Austin, Austin, TX, USA: [2]School of Allied Health, Australian Catholic University, Virginia, QLD 4014, Australia

Submitted 18 March 2014: Final revision received 22 November 2014: Accepted 23 December 2014: First published online 23 February 2015

Abstract

Objective: School garden programmes have become popular action-oriented learning environments in many countries, often driven by converging priorities of environmental sustainability and healthful diets. Many of these programmes have assessed the impact on dietary intake, specifically fruit and vegetable intake, and related dietary behaviours, such as knowledge, preference, motivation, intention and self-efficacy to eat and prepare fruit and vegetables. The objective of the present study was twofold: (i) to review published garden-based programmes conducted in schools targeting dietary intake and/or determinants of dietary behaviour in children; and (ii) to identify similar strategies and components employed by these garden-based programmes.

Design: The review included thirteen studies that have examined the impact of garden-based programmes conducted in school, either during school hours or in after-school settings, on dietary behaviours in children (kindergarten through 8th grade students).

Results: Three of the reviewed studies did not have a comparison or control group and simply evaluated within-group changes after a garden intervention. None of the reviewed studies were randomized, but were assigned based on school's interest and timing of new school gardens being built. Out of the eleven programmes that examined dietary intake, six found that the programme resulted in increased vegetable intake, whereas four showed no effect. Seven of the eight studies that measured preference found that the programmes resulted in increased preference for vegetables. Gardening programmes also resulted in improved attitudes towards, willingness to taste, identification of and self-efficacy to prepare/cook fruit and vegetables. Similar strategies/components employed by the majority of the programmes included: 'hands on' curriculum, incorporation of a cooking component, providing the instructors, parental and stakeholder support, food provision and using the garden as the focal point for media promotion.

Conclusions: Some of the garden programmes resulted in increased vegetable intake, which has positive implications for both environment sustainability and health-related outcomes. Further, the majority resulted in some improvement in behaviour determinants more generally. However, more research is warranted to understand how to achieve long-term improvements in dietary behaviours and how to sustain the garden-based programmes in schools.

Keywords
School gardens
Sustainability
Fruit intake
Vegetable intake

School gardens are an interesting and potentially useful interface between health promotion and local community-based measures towards environmental sustainability. First, school gardens have become a prevalent approach to school-based strategies to enhance dietary and physical activity behaviours in many countries[1–4]. Interest in school gardens has emerged from previous observations that community gardening was associated with a range of putative health benefits across the physical, psychological and social dimensions of health[5]. However, there is also a well-established underlying emphasis on environmental issues such as sustainable living, organic food production, waste minimization and permaculture associated with school gardens. Many of these latter themes have been identified as initial drivers for the establishment of a large proportion of school-based community gardens[3]. Inherent within these themes is the

*Corresponding author: Email Shawn.Somerset@acu.edu.au

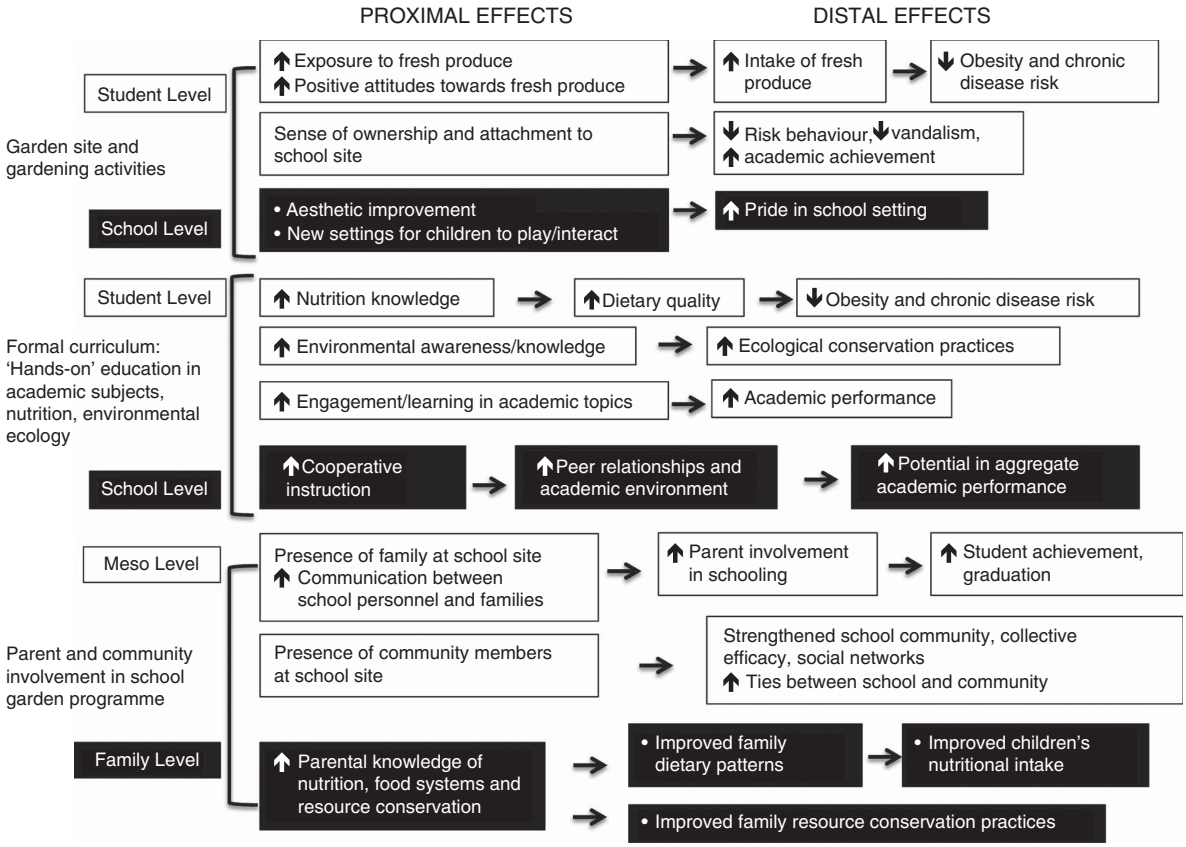

Fig. 1 Conceptual model of the impact of school garden programmes (adapted from Ozer[11])

maintenance of agricultural biodiversity, particularly by expanding the range of varieties of fruit and vegetables (F&V)[6] beyond that commonly available through mainstream supermarkets. These reported motives are consistent with enhanced self-fulfilment, life satisfaction, sense of belonging and community contribution reported previously[7].

School gardens epitomize the tenants of success for nutrition interventions in children outlined by Lytle and Achterberg, being activity based, theory driven, implemented in the school environment and involving parents and the wider community[8]. One of the earliest formal studies on school gardens by Cason, albeit in kindergarten children, set the scene for subsequent work by showing that as little as 30 min each week in a vegetable garden can improve vegetable and fruit identification, identification of 'best' snack choices and increased willingness of children to taste new vegetables and fruits[9].

Most of the early studies on school gardens focused on process issues, including in-school support for garden initiatives. In 2005, Graham and Zidenberg-Cherr published two such studies in California schools, reporting that teachers generally were supportive of school gardens and believed that their use enhanced academic performance, language, arts and healthful eating[10]. Thus the advocacy for school gardens drifted ahead of supporting evidence of effectiveness for improving health or determinants thereof.

At about the same time, the paucity of empirical evidence on effectiveness of school gardens was revealed in a systematic review by Ozer[11], which found only five separate studies on the health impacts of school gardens. Ozer recognized the emergence of school gardens as 'learning laboratories' in the USA and the need for a conceptual framework upon which to evaluate their impact on health. The resulting conceptual model (summarized in Fig. 1) comprised a matrix of both proximal and distal effects on the health and well-being of various stakeholder groups (students, school, family, community).

Given the increasing popularity of school gardens as a health promotion resource, the objective of the present review was twofold: (i) to review the garden-based programmes conducted in schools targeting dietary intake and/or related behaviours in children; and (ii) to identify similar strategies and components employed by these garden-based programmes.

Research methods

We searched Medline and Embase for garden-based school interventions. Studies were eligible if they were: (i) in the English language; (ii) taught in school settings; (iii) included a school garden component; and (iv) had a baseline and post-intervention dietary measure (including dietary intake and/or determinants of dietary behaviour).

https://doi.org/10.1017/S1368980015000221 Published online by Cambridge University Press

Sixteen studies were initially identified. However, two of these studies, although they included school-age children, were taught in community settings[12,13] and were therefore excluded. Another study was excluded because there was no main outcome analyses of the intervention[14]. Therefore, thirteen studies remained, including one prospective study[15] (where level of implementation among schools was evaluated), three quasi-experimental design studies[16–18] (with no comparison group) and nine non-randomized controlled trials[2,19–27].

Results

Table 1 represents the characteristics of each study reviewed, including the reference, location, study population, design, outcome measures and results[2,15–28]. Ten of the garden interventions were conducted during school hours, whereas three were conducted during after-school hours. The duration of the interventions varied widely, from 10–12 weeks (four studies) to 4–7 months (four studies), one school year (two studies), 12 months (one study) and two school years (two studies). The populations also varied widely, with children ranging from kindergarten through 8th grade students; however, nine of these studies were conducted in elementary or primary schools. The studies represented students from a wide range of ethnicities and socio-economic backgrounds, with at least half of the studies targeting minority and low socio-economic students. The intervention components varied widely as well among the garden programmes, such as differences in who taught the lessons (paid instructors *v.* schoolteachers), where the lessons were taught (actual garden *v.* in the classroom) and incorporation of nutrition and cooking components.

The outcomes and evaluation tools reported also varied widely by study. Table 2 outlines the determinants of behaviour and the actual behaviours measured in the garden programmes reviewed. Ten of the studies examined the effect of the garden programme on students' reported dietary intake, as measured by questionnaire, screener, diet recalls or diet records. Six of these interventions resulted in increased vegetable intake, whereas four studies showed no change in dietary intake.

The majority of studies showed significant improvements in determinants of dietary behaviours, such as preference, attitudes towards, willingness to taste, identification, knowledge, self-efficacy and variety consumed of fruit and/or vegetables. Seven of the eight studies that measured preference found that the gardening programme resulted in increased preference for vegetables. Out of the four studies that measured attitudes, all showed that the programme resulted in improved attitudes towards F&V. Out of the three studies that measured willingness and identification all found that the gardening programme resulted in improved willingness to taste and identification of fruits and/or vegetables. Three studies also measured self-efficacy to prepare/cook F&V and/or to garden, all of which resulted in improvements in these self-efficacy skills.

There were several common strategies and components described in the programmes that likely contributed to the improved diet behaviours. Common strategies that were mentioned in at least three of the studies are included in Table 3, resulting in seven strategies. All of the studies referred to the 'hands on' experience of planting, caring for and harvesting produce as a key reason why gardening programmes were effective at improving dietary behaviours. Eight of the studies included cooking activities/lessons in their programmes[15,17,19–21,23,24,27]. In seven of the programmes, instructors were actually provided to teach the garden lessons[2,15–17,20,22,23]. Six of the studies mentioned that stakeholder involvement in the development, planning and implementation was a key aspect of the programme[2,17,19–21,25]. Five of studies included a parental component in the programme, although only a few examined the impact of the programme on parental outcomes[2,17,19,23,25]. Four of the programmes included some kind of food provision[17,19,20,26]. Finally, three of the programmes included media promotion occurring in or around the garden[16,19,20].

Discussion

Thirteen studies were identified and reviewed that evaluated the effects of gardening programmes on dietary behaviours and/or determinants of dietary behaviour. Although all studies differed in evaluation measures, the majority of the programmes that measured dietary intake resulted in increased vegetable intake, whereas some showed no effect. Gardening programmes also resulted in improved preferences for, attitudes towards, willingness to taste, identification of and self-efficacy to prepare/cook F&V. In general, the gardening programmes reviewed showed healthier dietary intake and improved determinants of dietary behaviour.

There appeared to be many common core strategies employed by the school garden programmes to improve dietary behaviours. All of the reviewed studies emphasized the 'hands on' experience of planting, caring for and harvesting produce as a key reason why gardening programmes were effective at improving dietary behaviours. When children are actively involved in all aspects from planting the seed, nurturing the growing of the plants to harvesting the produce, and in some cases preparing/cooking the produce, they are truly invested in the process. When children have the opportunity to use their hands they become active participants instead of passive learners[12,29].

Another key strategy employed by eight of the garden programmes was the inclusion of cooking/food preparation activities in various or all lessons. Teaching cooking/food preparation to children is another example of a

Table 1 Studies included in the present review of school garden-based programmes on health outcomes in children

Reference	Location	Population	Design	Outcome measures	Results
Wright and Rowell (2010)[16]	Green Bay, WI, USA	K–5th grade students (*n* 234) > 70 % Caucasian > 50 % low SES	Quasi-experimental design: • One intervention school Intervention details: • 10 weeks of a salad bar in school • 3 weeks of in-class gardening lessons	Vegetable selection and intake from salad bar	Increased selection of vegetables from the salad bar
Hermann *et al.* (2006)[17]	Stillwater, OK, USA	K–8th grade students (*n* 43) > 70 % Native American No data on SES	Quasi-experimental design: • One intervention school Intervention details: • One 90 min lesson per week for all grades for one school year; taught during after-school hours	Vegetable intake Physical activity	Increases in vegetables intake Increases in physical activity
Lineberger and Zajicek (2000)[18]	College Station, TX, USA	3rd–5th graders (*n* 111) No data on ethnicity or SES	Quasi-experimental design: • Five intervention schools Intervention details: • Ten units taught in-class over one school year • Nutrition education + gardening and cooking activities	F&V attitudes and preferences Dietary intake (via 24 h recall workbooks)	Attitudes towards vegetables and preferences for vegetables improved F&V intake did not change significantly
Ratcliffe *et al.* (2011)[19]	San Francisco, CA, USA	6th grade students (*n* 320) > 90 % minority > 60 % low SES	Non-randomized intervention: • Intervention (two schools; *n* 170) • Control (one school; *n* 150) Intervention details: • Weekly lessons for 4 months taught during school hours • Included taste testing and cooking components, and a 'salad day' at school with harvested vegetables	Vegetable variety and intake Identification, attitudes, preferences and willingness to taste vegetables	Improved identification, attitudes, preferences and willingness to taste vegetables Increased vegetable variety consumed Vegetable intake did not increase
Somerset and Markwell (2009)[20]	Brisbane, Australia	4th–7th grade students (*n* 252) Primarily low SES Indigenous and migrant populations	Non-randomized intervention: • Historical control (*n* 132) • Intervention (one school; *n* 120) Intervention details: • Weekly garden in-class lessons over 12 months • Included food production and preparation	Identification, attitudes and self-efficacy towards F&V	Increased ability to identify F&V Greater attention to origins of produce Increased attitudes towards F&V Changes to perceived F&V consumption Enhanced confidence in preparing F&V snacks
Gibbs *et al.* (2013)[21]	Victoria, Australia	3rd–6th grade students (*n* 764) 562 parents > 50 % low SES No data on ethnicity	Non-randomized intervention: • Programme schools (six schools) • Comparison schools (six schools, matched on SES and size) Intervention details: • Weekly in-class garden + kitchen lessons taught for two school years	Willingness, attitudes and preference to eat F&V Student and parent dietary intake Teacher surveys (*n* 45)	Students reported: (i) enjoyment of trying new foods; (ii) willingness to try new foods; (iii) eating more vegetables; (iv) increased perception of healthy foods; (v) enjoyment of cultural food; (vi) ability to taste the 'freshness' Teachers reported an increase in good quality of school snacks and lunches Parents reported children were more willing to try new foods Classroom observations revealed children were willing to try more foods No change in student/parent dietary intake

Table 1 *Continued*

Reference	Location	Population	Design	Outcome measures	Results
Parmer *et al.* (2009)[22]	Auburn, AL, USA	2nd grade students (*n* 115) No data on ethnicity or SES	Non-randomized intervention: • Nutrition education + gardening (NE + G; *n* 39) • Nutrition education only (NE; *n* 37) • Control group (C; *n* 39) Intervention details: • Bimonthly (every other week) in-class lessons taught for 28 weeks	F&V knowledge, preference and intake Lunchroom observation	NE + G and NE, compared with C, had improvements in nutrition knowledge and preferences Students in NE + G (compared with either NE or G alone) more likely to consume vegetables in lunchroom
Morris and Zidenberg-Cherr (2002)[23] Morris *et al.* (2008)[28]	Davis, CA, USA	4th grade students (*n* 213) > 65 % Caucasian, 17 % Hispanic	Non-randomized intervention: • Control (C; *n* 49) • Nutrition education only (NE; *n* 60) • Nutrition education + gardening (NE + G; *n* 63) Intervention details: • Nine in-class lessons taught over 17 weeks	Students and parents: Nutrition/gardening knowledge Vegetable preference	NE and NE + G compared with C increased nutrition and gardening knowledge and vegetable preference Vegetable preference increased the most in the NE + G group and was retained at 6 months Parents increased knowledge and vegetable preference
McAleese and Rankin (2007)[24]	Pocatello, ID, USA	6th grade students (*n* 99) No data on ethnicity or SES	Non-randomized intervention: • Control (*n* 25) • Experimental School 1: nutrition/ garden weekly lessons (*n* 25) • Experimental School 2: nutrition/ garden weekly lessons + garden hands-on activities (*n* 45) Intervention details: • 12-week after-school programme	Student dietary intake (via three 24 h food recall workbooks)	Increased F&V consumption, vitamin A, vitamin C and fibre intakes in Exp School 2 only No significant changes in Exp School 1 or control
Morgan *et al.* (2010)[25]	New South Wales, Australia	5th–6th grade students (*n* 127) No data on ethnicity or SES	Non-randomized intervention: • Nutrition education (NE; *n* 35) • Nutrition education + gardening (NE + G; *n* 35) • Control (*n* 57) Intervention details: • 10 weeks, taught by classroom teachers	F&V identification, knowledge and willingness to taste Vegetable preference Dietary intake (via 24 h diet recalls)	NE and NE + G, compared with Control, had increases in willingness to taste vegetables and preferences for vegetables NE + G compared with Control had increases in F&V knowledge NE + G compared with other groups had greater ability to identify vegetables No change in dietary intake
Evans *et al.* (2012)[26]	Austin, TX, USA	6th–7th grade students (*n* 246) Ethnically diverse schools Primarily low SES	• Non-randomized intervention: • Intervention (four schools; *n* 176) • Control (one school; *n* 70) Intervention details: • Twelve in-class lessons and once weekly after-school gardening component over 5 months • Components included: (i) farm-to-school; (ii) farmers visit to school (twice in 5 months); (iii) taste test activities; (iv) field trips to farms	F&V intake (via FFQ) Preference, knowledge, self-efficacy and motivation for F&V	Students exposed to ≥2 *v.* < 2 components: had higher F&V intake, self-efficacy, knowledge and lower preference for unhealthy foods

Table 1 *Continued*

Reference	Location	Population	Design	Outcome measures	Results
Gatto *et al.* (2012)[27] Davis *et al.* (2011)[2]	Los Angeles, CA, USA	4th–5th grade students (*n* 104) >93 % Hispanic Primarily low SES	Non-randomized intervention: • Control (delayed intervention; *n* 70) • Intervention (*n* 34) Intervention details: • Weekly after-school lessons for 12 weeks • Included cooking components and farmers' market visits	Motivation to eat F&V Self-efficacy to garden, cook and eat F&V Dietary intake (via screener) BMI, body fat, waist circumference, BP	Intervention group compared with Control had: (i) increases in preferences for vegetables, self-efficacy to cook and garden and dietary fibre intake; (ii) decreases in diastolic BP; (iii) decreases in BMI and weight gain (in overweight subsample only)
Wang *et al.* (2010)[15]	Berkeley, CA, USA	4th and 5th grade students (*n* 179) Ethnically diverse 39 % low SES	Prospective design: • Two schools with HIGH garden intervention development (*n* 72) • Two schools with LOW intervention (*n* 107) Intervention details: • Weekly in-class lessons taught over two school years (instruction hours ranged from 0 to 24 h over 2 years)	F&V knowledge, attitudes and preferences	Students with HIGH exposure had increases in F&V intake inside and outside school and increases in F&V preference

K, kindergarten; SES, socio-economic status; F&V, fruit and vegetables; BP, blood pressure.

'hands on' learning experience and also enables children to acquire necessary self-efficacy skills involved in eating and enjoying vegetables and fruits[12,29]. Many of the programmes divided the children into smaller groups (four to six children) for the cooking component, so that each child got the chance to wash, cut and mix the produce[2]. In addition, several of the programmes had the children sit down together to share and enjoy the meal or snack they prepared, which encouraged the children to taste but with no pressure to eat[2,21,27].

Seven of the programmes provided an educator/gardener to teach all or some of the garden and nutrition lessons in the programme; this was another key strategy used. Providing instructors may be an integral step in programme initiation and reduces the initial burden of teaching the programme within existing resources. It is unclear how long these educators must be provided to ensure maintenance and sustainability of the programme. More research is required to understand the underlying conditions by which the school community can assume garden maintenance after an initial start-up phase concludes. There is some evidence that not all schools have the capacity and/or volition to do so[3] and it is clear that both teacher and parent engagement and involvement are critical[30].

The above observations highlight the general importance of recognizing links with pedagogical frameworks, in particular careful integration of garden activities into the curriculum. Previous findings indicate that school gardens can be integrated into diverse curriculum areas such as Mathematics, Literacy, Science and Art[3,30]. The above observations also highlight previously recognized benefits of expanding the reach of school gardens through combinations with other hands-on experiences such as cooking, tasting and marketing. For example, school gardens can be incorporated effectively into Health Promoting School settings through attachment to a kids' café, as a commercially viable means of food provision[31].

Six of the programmes mentioned the importance of enlisting stakeholder input (i.e. children, teachers, principals, school staff, parents, community groups) in the development, implementation and maintenance of the programme[2,17,19–21,25]. Many studies discussed holding focus groups or meetings with stakeholders to enlist their help in various aspects of the programme including: (i) the design of the garden; (ii) the build-out/initial planting of the garden; (iii) development of the curriculum and in-class activities; (iv) the selection of the recipes used; (v) what to do with the harvested produce; and (vi) which community/family garden activities to incorporate. These aspects may also enhance the sustainability of the programme after the research project has concluded. However, further research is warranted to assess how initial and continued stakeholder input is needed to sustain school gardens and gardening programmes.

Five of the programmes involved parents and families in some way. Several studies sent home newsletters to the

Table 2 Summary of determinants of behaviour and actual behaviours measured in the garden programmes reviewed

Determinants of behaviour	References	Behaviour	References
Attitudes	15, 18–20, 21	F&V intake	17, 18, 21, 22, 24–27
Recognition/identification	19, 20, 25	Physical activity	17
Preferences	15, 18, 19, 21–23, 25–27	Snack intake	21
Knowledge	15, 22, 23, 25–27	Nutrient intake	24, 27
Self-efficacy	2, 20, 26, 27	Vegetable intake variety	16,19
Motivation	2, 26		
Willingness to taste (lack of neophobia)	19, 21, 25, 27		

F&V, fruit and vegetables.

Table 3 Effective strategies to improve health outcomes highlighted in reviewed studies. Strategies listed were included if they were mentioned in at least three studies, and are ranked in decreasing frequency of mention

Strategy	Description	Number of programmes	References
1. 'Hands on'	Children's hands-on experience planting, caring for and harvesting their own produce	13	2, 15–22, 24–28
2. Cooking component	Children participated in cooking and preparing the produce from the garden	8	15, 17, 19–21, 23, 24, 27
3. Instructor provided	Garden and/or nutrition lessons were taught by paid educators, provided by the research programme	7	2, 15–17, 20, 22, 23
4. Stakeholder involvement	Involved teachers, principals, community leaders in the development, dissemination and maintenance of the garden and garden activities	6	2, 17, 19–21, 25
5. Parental involvement	Included community workshops where parents could participate, newsletters and specific parental lessons	5	2, 17, 19, 23, 25
6. Food provision	F&V harvested from school garden were sold in farmers' markets or used in school cafeterias	4	17, 19, 20, 26
7. Media promotion	Garden became focal point for whole-school activities, such as fundraising, media promotion and meal sharing	3	16, 19, 20

F&V, fruit and vegetables.

parents, some conducted parent/family classes separately and many involved community garden events, where parents/family were invited to attend[2,19,21]. Parental support, modelling, parenting styles and the family environment are well established as important components supporting the adoption and sustainability of healthy eating behaviours, which are essential in the prevention and management of childhood obesity[32,33]. Although few of the studies reviewed measured parental outcomes, those that did found that a garden programme improved parental dietary behaviours[21,28].

Four of the studies mentioned how they used the harvested vegetables and fruit from the garden[17,19,20,26]. One garden programme had the children and their families sell the produce at a local farmers' market[20]. Another study made salads from the harvested F&V and served them to the entire study body during lunch[19]. More research is needed to understand if and how this strategy impacts student dietary behaviour as well as school, family and community outcomes and how this strategy aids in the sustainability of the programmes.

Having media events or promotional activities (such as fundraising events and meal-sharing occasions) occur in the garden is also a viable strategy to highlight the garden and associated programmes[16,20]. Several studies made the garden the focal point for whole-school activities, which helped students, parents, teachers and school staff take ownership and pride in their school garden. The garden can also be very aesthetically pleasing, which can encourage school community support and investment in the garden. Several studies emphasized the importance of teaching the programme in the actual garden[2,20,28]. School gardens are ideal settings for experiential (hands-on) learning and give children the opportunity to learn outside the traditional classroom setting. Teaching in the garden allows educators to explore children's senses, which play a significant role in the development of dietary preferences, including the smell, sight, texture and taste of the growing produce[34].

Despite the substantial uptake of school gardens to promote health, the evidence underpinning this is limited. The majority of the studies reviewed are 'proof of concept' studies and more rigour and well-designed experimental studies are warranted. Ozer's framework assumed school gardens as systemic interventions, using ecological theory to conceptualize outcomes that might arise from their implementation. However, many school gardens have emerged spontaneously as an outcome of a complex set of needs unique to each school community, making it impractical to design and evaluate the effect of the garden programme with a well-designed randomized control trial. In addition, the randomized control trial design is challenging because control communities are reluctant to

participate unless they also receive benefit. Further development and use of suitable experimental and quasi-experimental designs will assist in developing a better evidence base for school gardens and other community-based health interventions.

The length of the studies reviewed varied substantially from 10 weeks to two school years. In general, studies in the present review measured impact immediately after intervention cessation, thus reflecting only short-term changes in diet-related behaviours. There is no clear direction on the optimal duration of interventions which effectively induce long-term dietary behaviour change. Sustainability (i.e. longevity) of garden programmes remains a continuing challenge and it is important to identify factors that drive it. Many of the interventions analysed in the present review acknowledged the importance of parent, teacher and community involvement and ownership as being a critical determinant of success and sustainability of the programmes. Further research on how to support and extend these aspects is warranted.

School gardens have an inherent complexity in terms of their origins, composition and how they are used. Their origins within individual schools and indeed their sustained longevity are driven by a mix of factors unique to each school, comprising factors such as climate, school size and parent/teacher capacity to participate[3]. Both US[35] and Australian[30] studies have identified multiple curriculum areas other than health that drive garden establishment. The mechanisms by which each garden is integrated into school life are also complex and varied. One potential pathway to understanding the role of school gardens is to consider them as part of a continuum extending from community need to enhanced health, rather than a specific intervention *per se*. This is consistent with the proposal by French and Weschler[36] that school gardens are but one of a range of food-based interventions suitable for enhancing dietary behaviours in school-aged children, providing useful insight into the conceptualization of school gardens.

The surge in interest towards school gardens has been associated with an apparent commodification of the concept in both the USA and Australia. The California 'garden in every school'[10] and Australian public–private partnership[37] initiatives tend towards a generic 'one size fits all' approach. There is some indication from the literature that this top-down approach has limitations. One study[38] reported that a large proportion of schools would not apply for funding to initiate a school garden. Those schools that did apply for funding had greater access to financial and human resources, confirming the importance of individual school environments as a determinant of suitability for garden establishment and sustainability. Such top-down approaches may undermine grass-roots capacity-building initiatives[39].

A substantial limitation across the studies was the lack of consistent evaluation measures. Almost every study used a different measure to evaluate dietary intake and determinants of dietary behaviour. In addition many of the questionnaires/surveys used were not validated. While constructs measured were similar (i.e. preference to eat, willingness to taste, self-efficacy to eat F&V), the actual questionnaire or survey used varied substantially. In order to better understand the effect of school garden programmes on dietary behaviours, garden programmes should use similar and consistent evaluation tools. However, this is challenging given the different age ranges, cognitive capabilities and cultures of the populations tested. In addition, none of the reviewed studies examined the mediatory/mediational effects of changes in dietary determinants on actual changes in dietary intake or any other related health outcomes, such as obesity. More research is warranted to understand how improvements in behavioural determinants actually impact dietary intake. Understanding the most influential determinants of behaviour would provide valuable information in designing garden-based programmes and nutrition interventions more generally.

Another limitation is that only one of the programmes examined a health outcome beyond dietary behaviours. The 12-week gardening, nutrition and cooking programme called LA Sprouts, which was taught during an after-school programme to low-income, primarily Hispanic, 3rd–5th grade students, found that the garden programme resulted in reductions in BMI, waist circumference and blood pressure. While substantial research has been conducted to show that healthy diets, specifically diets high in F&V, are linked to reductions in obesity and obesity-related diseases such as type 2 diabetes and cardiovascular risk factors[40,41], more studies examining the direct impact of a garden-based programme on obesity and related diseases are warranted.

Considering Ozer's evaluation framework in 2007[11], there are multiple pathways by which school garden programmes may potentially strengthen the healthy development of students, including dietary intake, academic achievement/engagement and a sense of connection to schools, while enhancing the relationship of the school to the family and broader community. However, the majority of the garden programmes have primarily focused on the student outcomes, mainly dietary behaviours. Impacts on other important stakeholders such as parents, teachers and the wider community have been less reported, but are equally important since they have implications both for persistence of health effects in children and on the sustainability of the garden within the school. Research examining how garden programmes impact student outcomes beyond dietary intake, and how they impact the family and broader community, is needed.

It is clear from the present review that studies which focus on health outcomes associated with school gardens pay only minor attention to impacts on factors affecting environmental sustainability, despite the apparent duality of purpose behind the establishment of many gardens[3]. Interest in and volition to produce foods locally via

community gardens may be a sentiment that is determined by early-life experience[42] and is linked to connections with agriculture and community belonging[43]. Thus, an important potential direction for impact measurement of school gardens is in relation to factors that can enhance capacity of communities to assure their own local food security. Such measures might include reflections on self-efficacy and knowhow, strengthening of traditional/local food culture and food sovereignty.

Conclusion

The present analysis showed clear and consistent effects of school gardening programmes on improving dietary behaviours linked to increases in F&V intake, while half of the studies showed actual increases in vegetable intake. The contextualization of gardens within pedagogical frameworks is an ongoing challenge towards a better understanding of the potential for school gardens to enhance health.

The broader impacts of school gardens on parents, teachers and the wider school community need further analysis. The transition from the start-up phase to long-term maintenance of garden initiatives is also an important area for further work to enhance sustainability of gardens and thus the duration of effects on determinants of health.

Acknowledgements

Financial support: This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors. *Conflict of interest*: None. *Authorship:* S.S. and J.N.D. were involved equally in the conception and design of the review, involved in drafting and revising the manuscript, had final approval of the version to be published, and agree to be accountable for all aspects of the work. M.R.S. was involved in the conception and design of the review as well as drafting and revising the manuscript. *Ethics of human subject participation:* Ethical clearance was not sought for this review article.

References

1. Bhutta ZA, Salam RA & Das JK (2013) Meeting the challenges of micronutrient malnutrition in the developing world. *Br Med Bull* **106**, 7–17.
2. Davis JN, Ventura EE, Cook LA *et al.* (2011) LA Sprouts: a gardening, nutrition and cooking intervention for Latino youth improves diets and attenuate weight gain. *J Am Diet Assoc* **111**, 1224–1230.
3. Somerset S & Bossard A (2009) Variations in prevalence and conduct of school food gardens in tropical and subtropical regions of North-Eastern Australia. *Public Health Nutr* **12**, 1485–1493.
4. Christian MS, Evans CE, Hancock N *et al.* (2013) Family meals can help children reach their 5 a day: a cross-sectional survey of children's dietary intake from London primary schools. *J Epidemiol Community Health* **67**, 332–338.
5. Armstrong D (2000) A survey of community gardens in upstate New York: implications for health promotion and community development. *Health Place* **6**, 319–327.
6. Guitart DA, Pickering CM & Byrne JA (2014) Color me healthy: food diversity in school community gardens in two rapidly urbanising Australian cities. *Health Place* **26**, 110–117.
7. Blair D, Giesecke C & Sherman S (1991) A dietary, social and economic evaluation of the Philadelphia Urban Gardening Project. *J Nutr Educ* **23**, 161–167.
8. Lytle L & Achterberg C (1995) Changing the diet of America's children: what works and why? *J Nutr Educ* **27**, 250–257.
9. Cason K (1999) Children are 'growing healthy' in South Carolina. *J Nutr Educ* **31**, 235–236.
10. Graham H & Zidenberg-Cherr S (2005) California teachers perceive school gardens as an effective nutritional tool to promote healthful eating habits. *J Am Diet Assoc* **105**, 1797–1800.
11. Ozer EJ (2007) The effects of school gardens on students and schools: conceptualization and considerations for maximizing healthy development. *Health Educ Behav* **34**, 846–863.
12. Heim S, Stang J & Ireland M (2009) A garden pilot project enhances fruit and vegetable consumption among children. *J Am Diet Assoc* **109**, 1220–1226.
13. Lautenschlager L & Smith C (2007) Understanding gardening and dietary habits among youth garden program participants using the Theory of Planned Behavior. *Appetite* **49**, 122–130.
14. Jaenke RL, Collins CE, Morgan PJ *et al.* (2012) The impact of a school garden and cooking program on boys' and girls' fruit and vegetable preferences, taste rating, and intake. *Health Educ Behav* **39**, 131–141.
15. Wang M, Rauzon S, Studer N *et al.* (2010) Exposure to a comprehensive school intervention increases vegetable consumption. *J Adolesc Health* **46**, 1–9.
16. Wright W & Rowell L (2010) Examining the effect of gardening on vegetable consumption among youth in kindergarten through fifth grade. *WMJ* **109**, 125–129.
17. Hermann JR, Parker SP, Brown BJ *et al.* (2006) After-school gardening improves children's reported vegetable intake and physical activity. *J Nutr Educ Behav* **38**, 201–202.
18. Lineberger S & Zajicek J (2000) School gardens: can a hands-on teaching tool affect students' attitudes and behaviors regarding fruit and vegetables? *HortTechnology* **10**, 593–597.
19. Ratcliffe MM, Merrigan KA, Rogers BL *et al.* (2011) The effects of school garden experiences on middle school-aged students' knowledge, attitudes, and behaviors associated with vegetable consumption. *Health Promot Pract* **12**, 36–43.
20. Somerset S & Markwell K (2009) Impact of a school-based food garden on attitudes and identification skills regarding vegetables and fruit: a 12-month intervention trial. *Public Health Nutr* **12**, 214–221.
21. Gibbs L, Staiger PK, Johnson B *et al.* (2013) Expanding children's food experiences: the impact of a school-based kitchen garden program. *J Nutr Educ Behav* **45**, 137–146.
22. Parmer SM, Salisbury-Glennon J, Shannon D *et al.* (2009) School gardens: an experiential learning approach for a nutrition education program to increase fruit and vegetable knowledge, preference, and consumption among second-grade students. *J Nutr Educ Behav* **41**, 212–217.
23. Morris JL & Zidenberg-Cherr S (2002) Garden-enhanced nutrition curriculum improves fourth-grade school children's knowledge of nutrition and preferences for some vegetables. *J Am Diet Assoc* **102**, 91–93.
24. McAleese JD & Rankin LL (2007) Garden-based nutrition education affects fruit and vegetable consumption in sixth-grade adolescents. *J Am Diet Assoc* **107**, 662–665.
25. Morgan PJ, Warren JM, Lubans DR *et al.* (2010) The impact of nutrition education with and without a school garden on

knowledge, vegetable intake and preferences and quality of school life among primary-school students. *Public Health Nutr* **13**, 1931–1940.
26. Evans A, Ranjit N, Rutledge R *et al.* (2012) Exposure to multiple components of a garden-based intervention for middle school students increases fruit and vegetable consumption. *Health Promot Pract* **13**, 608–616.
27. Gatto NM, Ventura EE, Cook L *et al.* (2012) LA Sprouts: a garden-based nutrition intervention impacts motivation and preferences for fruits and vegetables in Latino youth. *J Acad Nutr Diet* **112**, 913–920.
28. Morris JL, Koumjian KL, Briggs M *et al.* (2002) Nutrition to grow on: a garden-enhanced nutrition education curriculum for upper-elementary schoolchildren. *J Nutr Educ Behav* **34**, 175–176.
29. Beets MW, Swanger K, Wilcox DR *et al.* (2007) Using hands-on demonstrations to promote cooking behaviors with young adolescents: the Culinary Camp summer cooking program. *J Nutr Educ Behav* **39**, 288–289.
30. Somerset S, Ball R, Flett M *et al.* (2005) School-based community gardens: re-establishing healthy relationships with food. *J Home Econ Inst Aust* **12**, 25–33.
31. Rowe F, Stewart D & Somerset S (2010) Nutrition education: towards a whole of school approach. *Health Educ* **110**, 197–208.
32. Golan M & Crow S (2004) Targeting parents exclusively in the treatment of childhood obesity: long term results. *Obes Res* **12**, 357–361.
33. Epstein LH (1996) Family-based behavioral intervention for obese children. *Int J Obes Relat Metab Disord* **20**, Suppl. 1, S14–S21.
34. Dazeley P, Houston-Price C & Hill C (2012) Should healthy eating programmes incorporate interaction with foods in different sensory modalities? A review of the evidence. *Br J Nutr* **108**, 769–777.
35. Graham H, Beall DL, Lussier M *et al.* (2005) Use of school gardens in academic instruction. *J Nutr Educ Behav* **37**, 147–151.
36. French SA & Wechsler H (2004) School-based research and initiatives: fruit and vegetable environment, policy, and pricing workshop. *Prev Med* **39**, Suppl. 2, S101–S107.
37. Block K, Gibbs L, Staiger PK *et al.* (2012) Growing community: the impact of the Stephanie Alexander kitchen garden program on the social and learning environment in primary schools. *Health Educ Behav* **39**, 419–432.
38. Hazzard EL, Moreno E, Beall DL *et al.* (2012) Factors contributing to a school's decision to apply for the California Instructional School Garden Program. *J Nutr Educ Behav* **44**, 379–383.
39. Liberato SC, Brimblecombe J, Ritchie J *et al.* (2011) Measuring capacity building in communities: a review of the literature. *BMC Public Health* **11**, 850.
40. Wosje KS, Khoury PR, Claytor RP *et al.* (2010) Dietary patterns associated with fat and bone mass in young children. *Am J Clin Nutr* **92**, 294–303.
41. Mikkila V, Rasanen L, Raitakari OT *et al.* (2005) Consistent dietary patterns identified from childhood to adulthood: the Cardiovascular Risk in Young Finns Study. *Br J Nutr* **93**, 923–931.
42. Pereira C, Larder N & Somerset S (2010) Food acquisition habits in a group of African refugees recently settled in Australia. *Health Place* **16**, 934–941.
43. Harris N, Rowe-Minniss F & Somerset S (2014) Refugees connecting with a new country through community food gardening. *Int J Environ Res Public Health* **11**, 9202–9216.