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Review Article

Effectiveness of school-based nutrition interventions in sub-Saharan Africa: a systematic review

Paul Kyere†, J Lennert Veerman, Patricia Lee and Donald E Stewart*
School of Medicine, Griffith University, Southport, Gold Coast 4222, Queensland, Australia

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Abstract

Objective: To evaluate the effect of school-based nutrition interventions (SBNI) involving schoolchildren and adolescents in sub-Saharan Africa (SSA) on child nutrition status and nutrition-related knowledge, attitudes and behaviour.
Design: A systematic review on published school nutrition intervention studies of randomised controlled trials, controlled clinical trials, controlled before-and-after studies or quasi-experimental designs with control. Nine electronic bibliographic databases were searched. To be included, interventions had to involve changes to the school's physical and social environments, to the school's nutrition policies, to teaching curriculum to incorporate nutrition education and/or to partnership with parents/community.
Setting: Schools in SSA.
Participants: School-aged children and adolescents, aged 5–19 years.
Results: Fourteen studies met our inclusion criteria. While there are few existing studies of SBNI in SSA, the evidence shows that food supplementation/fortification is very effective in reducing micronutrient deficiencies and can improve nutrition status. Secondly, school nutrition education can improve nutrition knowledge, but this may not necessarily translate into healthy nutrition behaviour, indicating that nutrition knowledge may have little impact without a facilitating environment. Results regarding anthropometry were inconclusive; however, there is evidence for the effectiveness of SBNI in improving cognitive abilities.
Conclusions: There is enough evidence to warrant further trials of SBNI in SSA. Future research should consider investigating the impact of SBNI on anthropometry and nutrition behaviour, focusing on the role of programme intensity and/or duration. To address the high incidence of micronutrient deficiencies in low- and middle-income countries, food supplementation strategies currently available to schoolchildren should be expanded.

Keywords
School children
Nutrition intervention
Anthropometry
Micronutrients
Food fortification
Sub-Saharan Africa

Childhood and adolescence are extremely important developmental stages in life. These early years are when key foundations are laid for adult health and economic well-being(1,2). The influence of childhood experiences on later adult life is well documented(1,3–5). Therefore, developing healthy nutrition behaviours in childhood may help to prevent not only under-nutrition, stunting and acute child nutrition problems but also chronic, long-term health challenges such as obesity, CVD, type 2 diabetes and stroke(3,6,7). Further, there is increasing evidence of a double burden of malnutrition, characterised by the co-existence of under-nutrition/micronutrient deficiencies along with energy overnutrition or diet-related non-communicable diseases(8). Encouraging healthy nutrition among children and adolescents can be an effective primary prevention strategy for reducing the risk of many non-communicable diseases. Poor child nutrition creates economic and social challenges among the vulnerable(9).

[†] Deceased author.

**Corresponding author:* Email Donald.Stewart@griffith.edu.au

Particularly, under-nutrition has been linked to suboptimal brain development, which negatively affects educational performance and economic productivity(10–12). Child malnutrition has been a major health problem in many low- and middle-income countries (LMIC). To reduce global health inequities, the WHO has emphasised the key role of establishing positive early childhood experiences in health and in education(13). Consequently, at the World Education Forum in Dakar, a framework that aimed at Focusing Resources on Effective School Health was launched in recognition of the importance of School Health and Nutrition (SHN) as a priority area for education sector plans(14). Since then, the presence and scope of SHN have grown widely globally(15). Specifically, between 2000 and 2015, SHN grew substantially in Education Sector Plans in sub-Saharan Africa (SSA) with school enrolment also rising from 83 % in 2000 to 91 % in 2015(15).

Since children spend a substantial proportion of their lives in the school setting, from a public health perspective, it makes sense to make schools as healthy as possible. Schools can offer an optimal setting to promote healthy eating habits(16–20). They can provide a unique system for the delivery of cost-effective public health interventions since they have a large reach over the child population(21). More importantly, in LMIC with limited resources, the evidence indicates that effective school health promotion can offer a strong return on investment(22). Investment in these formative years in childhood can reduce health inequity and create healthy adults. Indeed, schools are an obvious place to facilitate this social investment given the inextricable relationship between education and health(23).

According to the 2015 Millennium Development Goals report, the prevalence of stunting among children has fallen in all regions except SSA, where the numbers increased by about one-third between 1990 and 2013(24). Thus, while in 2015, 24·5 and 15 % of children globally were stunted and underweight, respectively, the African region and South East Asia recorded the highest prevalence of under-nutrition, with the former accounting for 39·4 % of the stunted and 24·9 % of the underweight(24). This clearly indicates that malnutrition remains a major public health concern in the sub-region(8,24–26). In addition, whereas the average consumption of fruit and vegetables was below the WHO recommendations in all WHO regions, African, South East Asian and South American countries reported the least intake, where schoolchildren typically consumed <300 g/d(27). These statistics show that investigating and promoting child nutrition in SSA must be a public health priority, especially if the region is to meet the WHO global nutrition target of improving child nutrition by 2025. As a mediating measure for poor child nutrition in the sub-region, WHO and UN have implemented the Renewed Efforts Against Child Hunger and undernutrition, Scaling Up Nutrition(8) and Accelerating Nutrition Improvement(26) initiatives.

Poor nutrition of schoolchildren can be an important barrier affecting their health status and thus access to education and academic achievements(15,17,28). While the first 1000 d of a child's life remain crucial, school-aged children have the potential for catch-up growth(11) making them a suitable age group to target with well-designed nutrition interventions(17). As a result, a number of initiatives have been promulgated globally to improve SHN, including but not limited to the Focusing Resources on Effective School Health approach(20), Health Promoting Schools(23) and Nutrition Friendly School Initiatives(29). Several studies and reviews have evaluated the effectiveness of SHN programmes globally(16,21,30–33). Findings appear to support the effectiveness of multi-component, school-based nutrition interventions (SBNI) in improving nutrition status and nutrition-related Knowledge, Attitude and Behaviour (KAB)(16,18,21); however, evidence is inconsistent in terms of the impact of SBNI(16,30,31,34). A preliminary review indicated that no systematic review that evaluates the effectiveness of SBNI in SSA has been published. Therefore, this review aims to evaluate the effectiveness of SBNI involving schoolchildren and adolescents in SSA on child nutrition status and nutrition KAB outcomes.

Methods

The reporting style of this review is based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) Guidelines(35).

Eligibility criteria

Inclusion criteria: Studies were included based on:

- Setting: Schools in SSA.
- Type of interventions: SBNI involving at least one of the following: (a) changes to the school's physical and social environments; (b) changes to school's nutrition policies; (c) changes to teaching curricula to incorporate nutrition education and (d) partnership with parents/community.
- Participants: Schoolchildren and adolescents, aged 5–19 years.
- Study design: Randomised controlled trials (RCT, including cluster RCT), controlled clinical trials, controlled before-and-after studies or quasi-experimental designs with control.
- Outcomes of interest: (a) changes in physical indicators/anthropometry; (b) changes in nutrition KAB; (c) biochemical outcomes and (d) psychosocial outcomes. Assessment of measures did not form part of eligibility criteria for initial screening of studies during the electronic search.
- Period: No date limit was set. Our last search was done on 20 January 2019.
- Language: Studies reported in English.
- Publication status: Published.

Exclusion criteria:

- Surveys, observational or case studies, theses, policies and commentaries.
- Government school feeding interventions which also met the 'type of study/intervention' criteria.
- Other research reports of included studies.

Information sources

The following electronic bibliographic databases were searched: Cochrane Library, MEDLINE, Embase, PubMed, CINAHL plus, PsycINFO and ProQuest. In addition, Informit, Health Collection and Scopus were searched. We also hand-searched reference lists of previously published systematic reviews on SHN(16,21,30–33). Reference lists of included studies and the Public Health Nutrition Journal were also hand-searched. Corresponding authors of included studies, which required further clarification, were contacted through email to find out if the articles we forwarded to them were 'twin' reports or if they knew of similar studies to theirs that they could recommend. Authors of six studies(28,34,36–39) were contacted, and four of them(34,36–38) responded.

Search

All available literature on SBNI in SSA was screened independently by two members of the review team (P.K. and D.E.S.) using study titles and abstracts. The systematic search started in November 2018 and ended on 20 January 2019. Where reviewers were not sure of the eligibility of a study for inclusion, the entire document was downloaded for a full-text screening. The Boolean search terms 'AND', 'OR' and '*' (for truncation) were applied: '*school-based nutrition*' or '*school nutrition intervention**' or '*school nutrition program**' or '*school meals*' or '*school breakfast*' or '*school lunch*' or '*school diet*' or '*school food*' or '*school nutrition education*' AND *Sub-Saharan Africa* or *SSA or Angola,* or *Benin or . . . Zimbabwe* (all SSA countries were listed, see Supplemental Table 1 in the appendix).

Study selection

Both quantitative and qualitative studies were searched for during the initial search, and no language limit, date limit or design limit was set during the screening stage, although some of those restrictions were applied later using the inclusion criteria. Search strategies were created by a university librarian with expertise in systematic review researching. For transparency and inter-rater reliability, two of the review team members independently screened study titles and abstracts against the inclusion criteria. Full reports for all titles that appeared to meet the inclusion criteria were retrieved. During the electronic database search stage, consensus meetings were held by two of the reviewers (P.K. and D.E.S.) to discuss eligibility of studies about which they had a divergent view. In such cases, a third review team member (J.L.V. or P.L.) was consulted for an opinion.

Data collection process

Data extraction matrix was developed with Microsoft Excel by P.K. and verified by D.E.S. The reliability of the extraction matrix was tested by piloting data entry of the first 10 % of included studies. Data extracted were information on authors' names, title of study, study aims, participants, intervention, comparators, outcomes, demographics, design, intervention duration and authors' conclusions. To avoid double counting and to synthesise data from multiple reports on the same intervention ('companion' reports), we juxtaposed names of authors, sample size, the outcomes and comparisons used. We considered all reports on a single intervention, but we did not include all companion reports. Only one of such reports was included. The final decision for inclusion or examining the full-text report to determine eligibility was not done by one reviewer but independently by three review members (D.E.S., J.L.V. and P.L.) representing public health physicians, epidemiologists, methodologists and content area experts.

Assessment of risk of bias within studies

To assess studies for risk of bias, we extracted information using the Cochrane 'Risk of bias' tool (described in chapter 8 (section 8·5) in the Cochrane Handbook for Systematic Reviews of Interventions(40)): that is, random sequence generation, allocation concealment, blinding, incomplete outcome data such as dropouts, and selective outcome reporting. In addition, we assessed study quality using the Effective Public Health Practice Project Quality Assessment Tool for Quantitative Studies(41). Due to the public health nature of the review topic, we only report methodological rigour of studies based on the EPHPP tool (Appendix, Supplemental Table 2). For each included study, each criterion was rated as either '*strong*', '*moderate*' or '*weak*' and then summed up to obtain an overall score (termed as 'global rating') for each paper.

Results

Study selection

After initial screening of titles and abstracts, 1041 records were identified through database searching. Sixteen papers were further identified through other sources, such as from reference lists of included studies. The records were exported to EndNote^{x9} software where duplicates were removed; 602 records remained. After further analysis, 558 records were considered not relevant based on the eligibility criteria and were excluded. Following an assessment of study titles and abstracts, full texts of seventy-six studies were retrieved for further review for eligibility. Out of these, two reviewers (D.E.S. and P.K.) agreed that forty-four studies were potentially eligible for full-text analysis. Subsequently, only fourteen studies(34,36–39,42–50) met our pre-specified inclusion criteria; thirty of the potentially eligible articles were excluded as those studies were either 'companion' reports of studies already included (*n* 7); school nutrition surveys/case studies (*n* 14) which mainly involved assessments of anthropometry and/or nutrition KAB(51–53); analyses of perception and practice of healthy eating among teachers and parents, and development of school food gardens as nutrition tools(54–56); RCT of government school feeding initiatives (*n* 4)(28,57,58); or SBNI on pre-schoolers aged <5 years (*n* 5), these consisted mainly of school-and-community nutrition interventions with parental involvement(59–62). Figure 1 presents a flow chart of the review process.

Interventions that were evaluated in our analysis were mainly school-based nutrition programmes focusing on supplementation of school meals with micronutrients and/or assessment of the effects of micronutrients on nutrition status of schoolchildren(36–38,42,43,45,46). Others assessed the impact of school nutrition education with/without physical activity programmes on nutrition knowledge, dietary intake patterns and nutrition status(34,44,47–49). Some papers also focused on promoting healthy dietary choices(36,38,42,44,48,49). None of the included papers specifically provided details on educational, policy or SBNI involving partnership with parents/community in their results. Consequently, we were unable to abstract some of these issues for discussion since they were absent in the original papers.

Study characteristics

Of the fourteen studies, half took place in South Africa and the other seven were from Botswana, Burkina Faso, Kenya, Nigeria and Tanzania. Three were controlled before and after trials(44,45,47), and 11 (78·6 %) were RCT with three double-blind controlled trials(39,43,46). All included studies assessed child nutrition status or nutrition KAB, either as primary or secondary outcomes. All but four of the studies(44,47–49) reported on anthropometric status. Three studies assessed cognitive outcomes through cognitive tests(37,43,50). Nutrition behaviour outcomes were assessed in seven studies(34,42,44,47–50), and nutrition knowledge

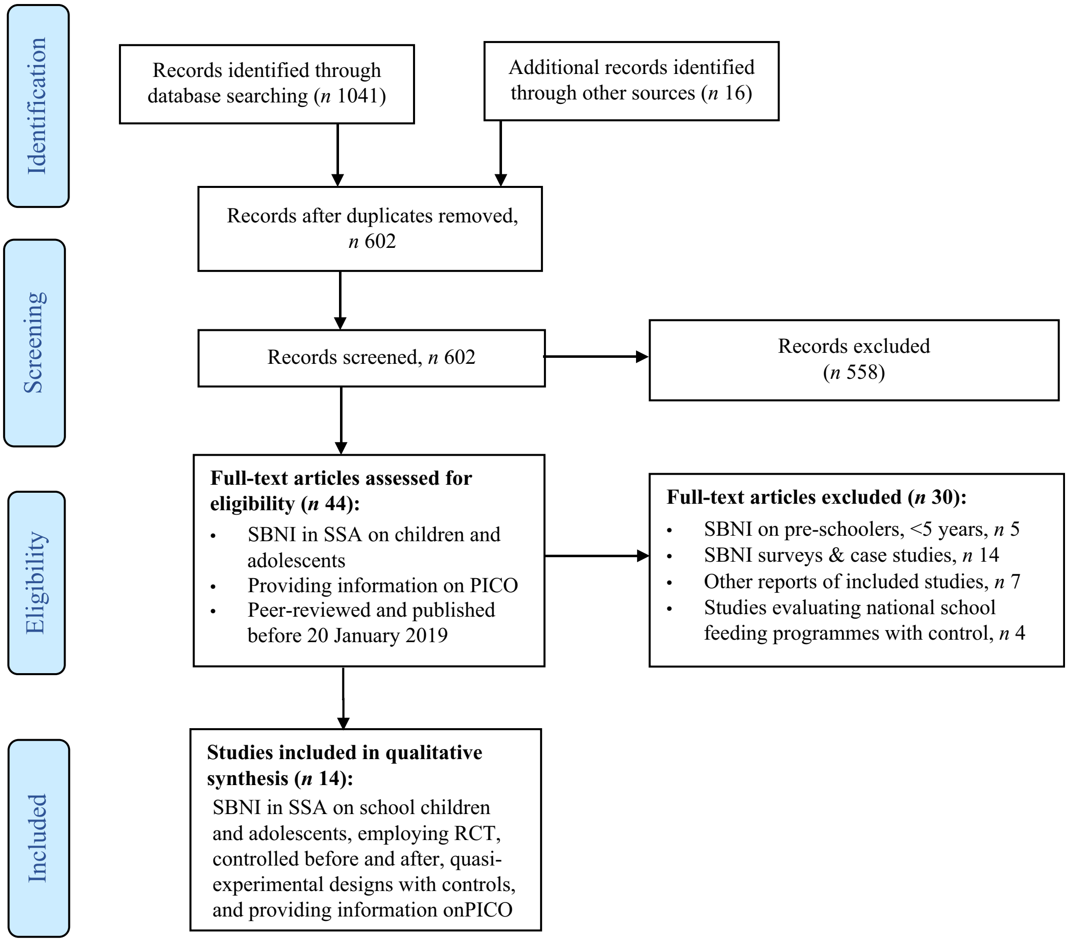

Fig. 1 (colour online) Flow chart of the review process. SBNI, school-based nutrition interventions; SSA, sub-Saharan Africa; RCT, randomised controlled trials; PICO, participants, intervention, comparators, outcomes

was reported by only three[34,44,47]. Intervention duration varied from 3 weeks[47] to 3 years[34]. All studies were conducted within the last two decades. Specifically, seven were published after the year 2010; only one was conducted before the year 2000[37]. The total number of participants involved in our analysis of this review was 6837 schoolchildren, aged 5–19 years, from 121 schools. In fact, the age group we considered was very wide; however, thirteen out of the fourteen included studies recruited schoolchildren who were aged ≤13 years. Only one study (Jemmot *et al.*)[48] included participants who were older than 13 years. A majority of the participants (4847 out of 6837 pupils, or 71 %) were aged 6–12 years. The implication is that our analysis was mainly on children aged 6–12 years. Consequently, disaggregating results by age (e.g. 5–10 years representing school age and 11–19 years representing adolescents) could not have changed our results significantly, since there was only one study which recruited participants who were older than 13 years. There was a minimum of one school in a study[37] to a maximum of thirty-nine schools[36]. The average number of pupils per study was 488; only two of the studies[44,47] had fewer than 200 participants. See Supplemental Table 3 in the appendix for details on the characteristics of included studies.

Risk of bias within studies

Ten papers (71·4 %) were rated as being of '*strong*' methodological quality, three (21·4 %) were rated as '*moderate*', while one (7·2 %) was rated as '*weak*'. Thus, the quality of the evidence of included studies varied, both between studies and across the different domains of potential bias within studies. Many of the studies were rated as being susceptible to *'high risk of bias'* on the *'blinding'* criterion. Only six studies stated explicitly that outcome assessors were not aware of the intervention status of participants. Although, as noted above, it was undoubtedly difficult to totally blind outcome assessors and participants since these were public health interventions. Dropout rates varied from 0[44,47] to 43 %. The dropouts were mostly reported in terms of numbers and/or reasons per group in all cases except one[50]. One study lost nearly 50 % of participants to dropouts[44]. Supplemental Table 2 presents details on the '*risk of bias*' within individual studies.

Intervention effects

Physical outcomes/Anthropometry

Weight and height gains were measured in kilograms and in centimetres, respectively. Study children were classified as stunted, underweight or overweight if their '*z*' score of height-for-age, weight-for-age and BMI-for-age, respectively, was ±2 SD from the mean of the WHO reference population[63]. Of the studies which assessed anthropometric status, eight specifically reported on the prevalence of child stunting[36–38,42,43,45,46,50], six reported on wasting[37,38,42,43,45] and seven on BMI[34,36,39,42,43,45,46]. Although Kugo *et al.*[39] did not assess prevalence of stunting and wasting, their study and that of Abrams *et al.*[45] added mid-upper arm circumference and triceps skin-fold assessment[39] to their measures.

In terms of intervention effects on outcomes, Stuijvenberg *et al.*[37] presented evidence that fortification of biscuits with Fe, iodine and β-carotene (vitamins) had no favourable effect on anthropometric measures. Other results[45] indicated that compared with a control beverage, children who consumed fruit-flavoured Beverage Fortified with Micronutrients (BeForMi) of 240 ml servings/week for 8 weeks had significant changes ($P = 0{\cdot}01$) in BMI, mid-upper arm circumference, weight-for-age and total weight. In addition, at a follow-up, mean incremental changes in weight (1·79 *v.* 1·24 kg), height (3·2 *v.* 2·6 cm) and BMI (0·88 *v.* 0·53 kg/m^2) were also significantly higher in an orange-flavoured BeForMi group than in a non-fortified group[46]. Moreover, micronutrients fortification or sugar alone in a beverage had a relative lowering effect on weight-for-age relative to controls (micronutrients −0·08; 95 % CI −0·15, −0·01; sugar −0·07; 95 % CI −0·14, −0·002), but when given in combination, the lowering effect was reduced[43]. Presenting results contrary to the above evidence[37,43,45,46], analysis from the other studies which assessed anthropometric status observed no significant differences between intervention and control groups on BMI/BMI-for-age[34,36,39,43,50] or mid-upper arm circumference[39] even after 3 years of school nutrition intervention[34].

Nutrition-related Knowledge, Attitude and Behaviour

Nutrition knowledge. All the three studies that reported on nutrition knowledge[34,44,47] gave evidence in favour of the positive impact of nutrition education on nutrition knowledge. For instance, De Villiers *et al.*[34] found intervention significance ($P = 0{\cdot}02$) in an intervention group, both at first and second follow-ups ($P = 0{\cdot}031$). In another study aimed at improving dietary intake patterns, correlations linked protein intake to knowledge of proteins, and vitamin C intake to knowledge of fruits and vegetables[44]. The nutrition knowledge of the intervention participants improved significantly ($P < 0{\cdot}001$) from a total of 45·4 to 58·8 % for all nutrition knowledge questions. Even a long-term measurement still reflected retention of nutrition knowledge, except for topics related to variety in a diet (23·8 %), serving size of specific foods (34·9 %), required daily allowance of specific foods (42·9 %), and fat intake and classification (42·9 %). The results[44] must be interpreted with caution, however, since there was a significant dropout rate (43 %) in this study making the results difficult to generalise. After investigating the effect of school nutrition education programme on nutrition knowledge, Ebo's study[47] corroborated the evidence presented above. They also observed greater increase in nutrition knowledge ($P = 0{\cdot}001$) for the intervention group. Regarding the impact of nutrition education on nutrition knowledge, the evidence was gathered from 650 intervention and

620 control participants from twenty-one different schools (Supplemental Table 4 of the appendix).

Nutrition behaviour. Of the seven studies[34,42,44,47–50] on this outcome, only two[47,48] reported a positive impact of SBNI on nutrition behaviour. Improvement in nutrition behaviour such as less sugar intake or more consumption of fruits and vegetables was primary measures in studies that assessed this outcome. Results from one of the nutrition education programmes suggested that nutrition behaviour did not change significantly after 9 weeks of intervention; legumes, fruits and vegetable intake remained low, while refined sugars and fat were still consumed among the intervention group, although mean intake for protein improved significantly[44]. Dietary intake analysis by Van der Hoeven *et al.*[42] of the efficacy of green leafy vegetable consumption on micronutrient status also showed no significant differences in energy intake at any of the follow-ups. The median energy intake was 7291 (5768–9960) kJ and 6493 (5258–8457) kJ in the intervention and in the control groups, respectively. Although their 'HealthKick' was able to improve nutrition knowledge and self-efficacy significantly, it also had little impact on nutrition behaviour[34].

It appears, however, that theory-based and contextually appropriate school health promotion intervention may improve nutrition behaviours. Participants in a cognitive-behavioural nutrition intervention were significantly more likely to have met 5-a-day fruit and vegetable guidelines compared with HIV/STD risk reduction intervention participants in a control group ($\mathrm{OR} = 1·30$, $P = 0·008$)[48]. They reported eating approximately 0·54 more servings of fruit ($P < 0·05$) and 0·77 more servings of vegetables ($P < 0·05$) than the controls after 12 months. The estimated effect sizes were 0·19 and 0·24 for fruit and vegetables, respectively[48]. After introducing an orange-fleshed sweet potato meal rich in vitamin A on five occasions for 4 weeks to 3rd and 4th grade intervention participants from twelve schools, their study demonstrated that specific goal setting may help promote nutrition behaviour change[49]. Thus, directing children to state their intentions to eat a meal could increase the actual proportion of this meal consumed. Besides, the effect on a child's capability to make changes to their diet (self-efficacy) was found to be significant in a nutrition and physical activity intervention that sought to determine whether nutrition KAB improved after 3 years[34]. In fact, the study that presented the most favourable results to show evidence of effectiveness of school nutrition education on nutrition behaviour was Ebo's study[47]. They found a significant change in compliance in meeting a dietary guideline as well as in meeting food pyramid's recommendations ($P = 0·001$). This evidence must also be interpreted with caution, since the methodological rigour of the paper was rated as '*weak*'. So far, the evidence gathered on this outcome point to the conclusion that SBNI do not necessarily influence nutrition behaviour positively.

Biochemical outcomes

The four studies on the BeForMi project included in this review[39,43,45,46] assessed changes in several micronutrient status indicators, including Hb, Fe, serum retinol (vitamin A_1), plasma vitamin B_{12}, riboflavin and serum Zn. Kugo *et al.*[39] tested the efficacy of grounded dried *Carica* papaya seed mixed with maize porridge on malnutrition and deworming. Their results indicated that a 300 ml maize BeForMi, which contained 10 g of the papaya seed, increased Hb counts of the intervention group (7·14–8·38 mmol/l, $P = 0·001$). There was also a significant reduction of *Ascaris lumbricoides* (large round worm) egg count by 63 % (mean 209·7 epg to 75·7 eggs per gram $P = 0·002$) and Tinea capitis/ringworm infestation (from 54·4 to 34 %, $P = 0·002$) after 2 months in the intervention group compared with the control that received a one-time 400 mg dosage of albendazole, which is conventionally used for deworming. Evidence from the other food supplementation studies also showed that a BeForMi significantly increased Hb concentration, Fe status indicators (serum ferritin and zinc protoporphyrin) concentrations and vitamin A status[43]. Using binary logistic regression, controlling for age, sex and baseline Fe deficiency status, they demonstrated that their BeForMi significantly decreased the OR for Fe deficiency (OR 0·20; 95 % CI 0·07, 0·53). The prevalence of Fe deficiency significantly decreased from 29·2 to 5·5 % in children who received the BeForMi[43].

Presenting further evidence, Abrams *et al.*[45] demonstrated that fruit-flavoured BeForMi with 419 kJ/240 ml blend of twelve micronutrients significantly improved hematologic measures. Fe and vitamin B status were also significantly better, and serum Zn was significantly higher at endpoint in the intervention group. The last BeForMi study also presented similar results. Thus, data from a double-blind placebo efficacy trial of an orange-flavoured BeForMi indicated that among children with anaemia (Hb < 110 g/l) at baseline, there was a significantly larger increase in Hb concentration among participants in the intervention group than those in the control (+9·2 and +0·2 g/l, respectively). In addition, the prevalence of children with vitamin A deficiency dropped from 21·4 to 11·3 % compared with the non-fortified group (20·6–19·7 %)[45].

Apart from the BeForMi studies, other SBNI have presented similar evidence that food supplementation can improve micronutrient status. To assess the impact of red palm oil (RPO) on vitamin A status, 15 ml RPO was added to school lunch in two test zones. Using HPLC to assess retinol levels, vitamin A status was found to have improved significantly in the RPO group, just as in a positive control that received a single vitamin A capsule of 60 mg (0·77 ± 0·28 to 0·98 ± 0·33 μmol/l). The observed intervention effect was more significant in the RPO group (0·82 ± 0·30 μmol/l to 0·98 ± 0·33 μmol/l) than in a negative control consuming the regular school lunch without RPO ($P = 0·001$). The efficacy of RPO in addressing vitamin A deficiency was again observed to be more significant in another test zone of the same study, where serum retinol levels increased from 0·77 ± 0·37 μmol/l at baseline to 1·07 ± 0·40 μmol/l one year later ($P < 0{\cdot}001$)(36). Further evidence showed that biscuit with RPO as a vitamin A fortificant can also be as effective as biscuit with synthetic β-carotene in improving vitamin A status(50). The estimated treatment effect for the synthetic β-carotene biscuit was 2·88 μg/dl (95 % CI 1·75, 4·00) and that of the RPO biscuit was 2·26 μg/dl (95 % CI 1·14, 3·37). A related study also found a significant between-group treatment effect on vitamin A status, Hb, Fe and urinary iodine in favour of participants who received biscuits fortified with micronutrients(37).

While it appears that green leafy vegetables such as *Amaranthus cruentus*, *Cleome gynandra*, *Cucurbita maxima* and *Vigna unguiculate* added to a school meal may help address vitamin A deficiency, their effects on other micronutrients have been unclear(42). Although a green-leafy vegetable dish contributed 11·6–15·8 mg Fe and 1·4–3·7 mg Zn, no significant intervention effect was found for the dish on micronutrient status. It is important to add that two of the five SBNI among the thirty potentially eligible articles which were excluded in the review process for not meeting the age inclusion criteria(59,60) had however found that intake of dark green, leafy vegetables with fat significantly increased retinol levels (vitamin A) ($P < 0{\cdot}05$) among intervention participants(59), and sun-dried cowpeas with amaranth leaves recipe also enhanced vitamin A status and Hb concentration(60) among preschool children. In sum, our analysis of the biochemical indicators as study outcomes showed that all the studies on BeForMi and other SBNI included in this review have presented evidence of the effectiveness of SBNI in improving the micronutrient status of schoolchildren and adolescents.

Psychosocial outcomes

Our analysis also involved assessment of the relationship between SBNI and cognitive performance. Cognitive outcomes comprised: general intelligence (two studies(43,50)), change in arithmetic test scores (three studies(37,43,50)) and verbal comprehension tests involving reading/spelling (three studies(37,43,50)). Findings of Whaley *et al.*(50) showed that supplementation with animal source food plays a key role in the optimal cognitive performance of children. Using the Raven's Coloured Progressive Matrices to measure general intelligence, they found a 'most striking' (sic) significant impact ($P = 0{\cdot}01$) of supplementation of a staple diet with meat on general intelligence among Grade One intervention participants, compared with a control after 21 months. Significant group differences were also observed in arithmetic test scores on an adapted version of the Wechsler Intelligence Scales for Children-Revised. However, the effects were neither equivalent across all domains of cognitive functioning nor did different forms of animal source foods produce the same benefits. The study showed no significant difference in verbal meaning test scores(50).

Other findings showed that a BeForMi had beneficial effects on cognitive test scores(43). A BeForMi improved general intelligence (intervention effect: 0·76; 95 % CI 0·10, 1·42) on the Kaufman Assessment Battery for Children version II test and verbal meaning test scores (1·00; 95 % CI 0·01, 2·00) on an adapted version of the Hopkins Verbal Learning Test. Specifically, there was improvement in planning abilities, number recall, word order, short-term memory recall, story completion and ability to discriminate among words in a familiar setting(43). Further evidence confirmed these findings; biscuits fortified with micronutrients (not a BeForMi) resulted in a significant between-group treatment effect in cognitive function tasks such as digit copying, counting letters, reading numbers, counting backwards and verbal fluency(37). In sum, all three studies of SBNI on cognitive performance found a significant positive impact(37,43,50). Due to differences in data collection methods and measurements, meta-analysis was not feasible in this study.

Discussion

This is the first systematic review of RCT and controlled before-and-after studies to assess the effectiveness of SBNI among schoolchildren and adolescents in SSA. A total of fourteen studies met our inclusion criteria. Duration and complexity of SBNI in SSA over the past two decades have varied. With regard to the impact of SBNI on micronutrient status, studies on beverages fortified with micronutrients (BeForMi)(39,43,45,46), and other SBNI on food supplementation/fortification(36–38,42) involving 1699 intervention participants, presented evidence of effectiveness of SBNI in improving child micronutrient status. There is sufficient evidence to confirm that food fortification can play a vital role in reducing micronutrient deficiencies. In addition, all studies that assessed cognitive outcomes(37,43,50), involving a total of 738 and 443 intervention and control participants, respectively, from sixteen different schools, showed effectiveness of SBNI in improving cognitive performance. More specifically, food supplementation with animal source food(50) or RPO(36,38) or micronutrients(43) significantly improved general intelligence, verbal learning and arithmetic performance of schoolchildren and adolescents. While few nutrition interventions have used comprehensive neuropsychological tests, results from previous systematic reviews corroborate the evidence from our review on assessments of cognitive performance outcome(12,33). For instance, Kristjansson *et al.*(33) noted in their review that early micronutrient deficiencies can negatively affect physical, mental and social aspects of child health.

Of the fourteen included studies, only two(45,46) observed intervention effect on anthropometry in favour of intervention groups. Thus, although there was evidence to show that SBNI can have a positive impact on anthropometric status(45,46), the majority of studies included in our analysis found no intervention effect(34,36,37,39,43,50). Specifically, regarding intervention effects on BMI/BMI-for-age, six(34,36,37,39,43,50) out of nine studies which reported on this outcome(34,36–39,42,43,45,46) found that SBNI had no significant effect on BMI. This finding is consistent with a previous review of diet interventions on weight status, which found that interventions did not have a significant effect on BMI outcomes(31). On the contrary, of the two studies in the current review that reported an effect on anthropometry, Ash *et al.*(46) observed significant differences between groups for all anthropometric measures; the intervention group gained 0·55 kg more weight, 0·57 cm more height and 0·32 more BMI units. Similarly, Abrams and colleagues(45) observed significant change in weight, weight-for-age, BMI and mid-upper arm circumference, for the intervention group. Regarding intervention effect on height status/height-for-age, four studies(36,37,43,50) reported no intervention effect. The inconclusive evidence of SBNI impact on anthropometry reflects evidence from prior reviews(21,23,31,33). In their Cochrane systematic review and meta-analysis, Kristjansson *et al.*(33) found significant effects of school feeding on weight gain (kg) in lower-income countries but inconsistent results in higher-income countries. For height gain (cm), results from lower-income countries were inconsistent, but in higher-income countries, results were moderate and positive. Further evidence from subgroup analyses indicated that in lower-income countries, height gain was significantly greater for younger children than for older age groups(33). In another meta-analysis on physical activity and nutrition outcomes, the evidence indicated that interventions showed an average reduction in BMI of 0·11 kg/m^2, yet the only nutrition study included in the review did not show any intervention effect on BMI(23). As has been noted in previous reviews, the inconsistent evidence of intervention effect on anthropometry may be attributed to baseline malnutrition status or to the short duration of many of the interventions(18,33). Thus, we might expect to see effects on outcomes such as weight gain even with shorter study durations and on height gain with longer durations(33).

Regarding nutrition behaviour, our analysis suggests that nutrition education may have little impact on nutrition behaviour(34,42,44) but can improve nutrition knowledge significantly(34,44,47). Thus, even though there was an improvement in nutrition knowledge, results from other included studies(34,42,44,50) indicated that SBNI could not change dietary intake patterns of participants, and very little variety occurred in diet choices. However, in a health promotion intervention aimed at encouraging health behaviours, the intervention increased fruit and vegetable consumption of adolescents by 1·3 servings/d, compared with the control group(48), while specific goal setting also promoted nutrition behaviour change. Similarly, Ebo *et al.*(47) observed that school nutrition education programme improved nutrition behaviour. Our evidence on nutrition behaviour outcome is inconsistent with results of other reviews, which observed significant improvement in nutrition behaviour outcomes(16,30); however, it is consistent with results of other meta-analyses which observed moderate improvement in nutrition behaviour(21,23,32). Even if potential gains appear modest due to small effect size, small intervention effects scaled up to large population can produce large public health benefits(23). Evidence from prior studies suggest that although nutrition knowledge may exist, the level of poverty, lack of influence that children have on their food choices(44), food poverty and accessibility could make a complete change to healthier diets somehow difficult(58,64,65). In sum, a possible explanation for the inconclusive results regarding intervention effectiveness on nutrition behaviour and anthropometry might be a duration factor as well as the complex nature of eating behaviour, along with limited statistical power(6,21). Nutrition behaviour is complex, and it may take time to change dietary habits.

Quality of the evidence

Risks for participants receiving the control intervention or adverse outcomes were generally not reported. In addition, none of the studies explicitly indicated the percentage of relevant confounders which were controlled (either in the design or analysis). As stated earlier, since these were public health and health promotion interventions, total blinding was impossible in many of the studies. In addition, few of the studies discussed existing school nutrition policies or direct parental/community involvement in the development and implementation of the SBNI(34,39,42,59). Notwithstanding the above limitations, food supplementation/fortification was generally described as very effective and free of adverse effects. Secondly, all included studies had comparators since they were either controlled before-and-after studies or RCT. Thirdly, all the fourteen studies were rated as '*strong*' on the '*data collection method*' criterion on the EPHPP risk of bias assessment tool (Supplemental Table 2 of appendix). This indicated that the data collection tools employed by the primary studies were shown to be both valid and reliable. Moreover, three of the studies(39,43,46) employed double blinding, while the methodological quality of ten of them (70·4 %) was rated as 'strong'. This makes the risk of bias across these studies low; hence, their evidence can be said to be more reliable.

Implications for health practice, policy and future research

To contextualise these findings, it is important that results from this review be read alongside evaluations of SBNI from other regional contexts which employed different evaluations of study designs other than RCT or controlled before-and-after studies. To address the high incidence of micronutrient deficiencies in LMIC and/or the high incidence of anaemia in SSA in particular(8), the WHO and health professionals may have to intensify food supplementation strategies currently available to schoolchildren in LMIC. Globally, it is important that in countries where schools provide meals to schoolchildren, such meals should be supplemented with vital micronutrients or animal source food to help prevent the double burden of malnutrition. Food and drink fortification with appropriate micronutrients may have double benefits of improving both cognitive performance and nutrition status of schoolchildren. In addition, our findings imply that to effectively design SBNI in the future, policymakers in the education sector planning may need to consider enhancing formal school curricula to include nutrition education since it can positively improve nutrition knowledge.

We recommend that future research should consider investigating the true impact that school nutrition programmes may have on anthropometry and nutrition behaviour, focusing on whether programme intensity and/or duration play any significant role. Specifically, future research must help to find out the impact that nutrition education has on nutrition behaviour since current results on their potential impact are inconclusive. Indeed, the existence of few RCT and controlled before-and-after studies of SBNI in SSA indicates that there might be insufficient evidence from high-quality and analytical school nutrition studies in SSA, and in LMIC in general. This view has also recently (2019) been expressed in a systematic review of food environment research in LMIC(66). This is a challenge, suggesting that there is an urgent need to improve research designs and methods to better understand the effectiveness of public health nutrition programmes in LMIC(66). The implication is that public health researchers and health professionals need to improve the quality of not only school food environment research but also that of the community and national nutrition research. Doing so will undoubtedly be crucial to the design of effective interventions to improve public health nutrition globally.

Limitations

The review process was presented with some methodological challenges. We included only studies published in English, and we also included in our analysis one study with 'weak' methodological rigour. Unlike clinical control trials which present more homogenous populations, public health interventions display more heterogeneity. Consequently, the variability among the included studies limited the possibility of meta-analysis on the effect of each factor on child nutrition status. Our reason was that since the factors were measured differently in each study, reporting an estimate for the pool effect would misrepresent the impact of the factors on child nutrition. There was also the possibility of publication bias in the primary studies: studies showing 'negative' results are less likely to be written up and submitted, and less likely to be published. Methodological strengths of this review were the use of the PRISMA guidelines(35) in our reporting, as well as the use of the EPHPP tool(41) to assess the methodological rigour of included studies. This form of assessment has a proven content and construct validity. Our search from more than seven highly recognised electronic databases presents a high level of methodological rigour to the review process. It is also important to note that our review is the first systematic review of RCT and controlled before-and-after studies to assess the effectiveness of SBNI among schoolchildren and adolescents in SSA. Therefore, it provides the best summary to date of the likely average effect of SBNI on nutrition status of schoolchildren and adolescents in the sub-region.

Conclusions

When addressing child malnutrition, evidence from RCT and controlled before-and-after studies of school nutrition interventions in SSA generally confirms the view that the school setting is a very important place to start from. There is strong evidence that supports the positive impact that SBNI can have on cognitive abilities, nutrition knowledge and improved micronutrient status of schoolchildren. There are few existing studies of SBNI in SSA; however, evidence from such studies supports the view that food supplementation is very effective in addressing micronutrient deficiencies in schoolchildren and can improve their overall nutrition status. Secondly, nutrition education may enhance nutrition knowledge, but this may not necessarily translate into healthy nutrition behaviour. This could mean that nutrition knowledge simply has little impact without a facilitating environment. In sum, there is strong evidence to show that SBNI can positively enhance the nutrition status of school-aged children and adolescents. Some evidence also exists to show that SBNI may positively enhance growth and cognitive development. The key conclusion is that there is enough evidence of promise to warrant further trials in these areas.

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Supplementary material

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