School-Based Interventions Targeting Double Burden of Malnutrition and Educational Outcomes of Adolescents in Low- and Middle-Income Countries: Protocol for a Systematic Review

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Protocol

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Abstract

Background

Adolescence is a period of rapid physical growth and transition between childhood to adulthood. However, in many developing countries, nutritional and epidemiological transitions are contributing to surging overnutrition, which, together with prevalent undernutrition, is resulting in the double burden of malnutrition (DBM) among adolescents. Schools as social systems have tremendous but mostly underutilized capacity to facilitate change and address a range of nutritional and associated educational concerns of adolescents and young people. The main objective of this systematic review will be to synthesize the evidence on school-based nutrition interventions that aimed to address the DBM, and the associated educational outcomes among adolescents from low- and middle-income countries (LMICs).

Methods

Comprehensive literature searches will be conducted in multiple electronic databases, including the Medline (through PubMed), Embase, CENTRAL (through Cochrane Library), CINAHL, and Google Scholar. We will include randomized controlled trials (RCTs), controlled before-after studies, and non-randomized controlled trials examining the effects of nutrition interventions on DBM and educational outcomes among adolescents (10–19–years–old) in LMICs. Two reviewers will independently screen all citations and full-text articles and abstract data. The quality of the included studies will be assessed with the Cochrane Collaboration's tool for assessing the risk of bias for RCTs and the Risk Of Bias In Non-randomized Studies of Interventions tool for controlled before-after studies and non-randomized controlled trials.

Discussion

To maximize the power of schools as a platform to reinforce the mutually beneficial relationship between adolescent nutrition and education, it is imperative to develop and implement integrated interventions connecting schools, adolescents, parents, communities, and the health care system. The results of this systematic review will provide a comprehensive state of current knowledge on the effectiveness of school-based interventions to enable future research that maximizes the impact and efficiency of integrated approaches to tackle multiple forms of malnutrition among school-going and out-of-school adolescents.

Systematic review registration

PROSPERO ID: 211109 (under review)

Background

Low- and middle-income countries (LMICs) formerly that suffer from a high prevalence of undernutrition ing) are now facing the additional burden of overnutrition (i.e.

overweight or obesity). This is referred to as the “double burden of malnutrition” (DBM). Originally identified in adults, the DBM is now affecting children, and adolescents across LMICs [1].

Approximately 1.2 billion adolescents aged 10 – 19 years today make up 16% of the world’s population, of which 90% live in LMICs [2]. The Global School-based Student Health and Health Behaviour Survey between 2003 and 2013, in 129, 276 school-aged adolescents (aged 12 – 15 years) from 57 LMICs estimated the prevalence of stunting as 10.2%, the prevalence of thinness as 5.5%, the prevalence of overweight or obesity as 21.4% and the prevalence of concurrent stunting and overweight or obesity as 2.0% [3]. Thus, DBM in adolescents in LMICs is considered to be a significant public health concern. The consequences of concurrent undernutrition and overnutrition in adolescents and later in adulthood are associated with poor muscle strength, reduced bone density, delayed onset of puberty, poor cognitive development and academic performance, early onset of adult chronic diseases (type 2 diabetes, hypertension), poor work capacity and reproductive outcomes in adulthood, particularly for females because of the heightened obstetric risks [4]. In this perspective, changes in diet and health behaviors are likely to have major effects on the individual’s current and future health [5, 6].

Education is one of the most powerful determinants of adolescent health and a driver of economic progress to a successful transition to adulthood. Given the bidirectional relationship between health and nutrition on the one hand, and educational outcomes on the other [5], schools offer a promising platform for addressing nutritional issues of adolescents. Furthermore, schools and peers have a central role in adolescents’ social lives, thus influencing multiple health behaviors, diet habits, and educational outcomes [7]. This is particularly the case given the global expansion of school attendance [8]. Because schools are at the heart of all communities, there is an opportunity to use the school as a sustainable, scalable option to reinforce health messages and address malnutrition for both school-going and out-of-school adolescents.

Several systematic reviews suggest promising but modest evidence of benefit from addressing the single form of malnutrition through discrete school – based nutrition interventions (e.g., nutrition education, physical activity, and micronutrients through fortification and targeted supplementation, school feeding, school gardens, and access to a safe environment and hygiene) [9 – 19]. These food supplementations and/or fortification interventions are effective in reducing micronutrient deficiencies and can improve nutrition status [9, 17]. Evidence on school-based nutrition education interventions suggests that these interventions can improve nutrition knowledge, but this may not necessarily translate into healthy nutrition behavior, indicating that nutrition knowledge may have little impact without a facilitating environment [15, 19]. Also, single-domain adolescent nutrition interventions target either undernutrition or overnutrition and function in *silos*. Hence, there is increasing interest in schools addressing health and nutrition behaviors through multi-component integrated interventions, generally called “double-duty actions” [4], to target all forms of malnutrition and non-communicable diseases. The linchpin of this proposition is the no harm notion that addressing one form of malnutrition should not be detrimental to subsequently tackling another form of malnutrition. Evidence on integrated interventions is promising in

improving the nutritional status of school-going children and adolescents. However, it comes largely from high-income countries and hence has limited generalizability [20–27].

Given the limited systematic reviews of evidence particularly from LMICs, we aim to conduct a comprehensive review of the published literature to characterize school-based nutrition interventions that focused on addressing multiple forms of malnutrition and educational outcomes of adolescents (aged 10 to 19 years) in LMICs. We will emphasize findings generated from effectiveness studies of nutrition interventions such as focusing on individuals as well as school environment and policies to improve the nutritional status and educational outcomes of adolescents with the involvement of parents and wider communities, and provision of school-based health services. We will include findings generated from randomized controlled trials (RCTs) and other rigorously designed interventional studies, including controlled before-after studies (CBAs) and non-randomized controlled trials that accounted for the baseline differences between intervention arms.

Conceptual framework

The newly developed agenda for Sustainable Development 2030 has recognized a need for greater accountability especially for the Global Strategy for Women's, Children's and Adolescents' Health [28]. It has called for increased participatory frameworks across a range of areas relevant to young people including non-communicable disease risks and nutrition. We developed a conceptual framework based on existing conceptual frameworks and the recommendations [29, 30]. We identified a set of interventions to be incorporated in our review process. These interventions are chosen from the existing work based on proven and potential effectiveness to address malnutrition in adolescents (aged 10–19 years).

Well-nourished adolescents protected from disease, infection, and early pregnancy are less likely to develop malnutrition in all its forms during adolescence and adulthood and are more likely to avoid non-communicable diseases, have optimal maternal and birth outcomes, and enjoy increased work capacity and productivity. Various individual and general risk factors throughout the life cycle including adolescence can have implications for the nutritional status of adolescents. These risk factors are not independent of each other and impact the adolescence stage, the next stage of life as well as can also have intergenerational effects. We will not divulge further into this as the purpose of this study is to review the potential interventions which could address the multiple forms of malnutrition in adolescents. Figure 1 shows the conceptual framework focusing on adolescent-specific nutrition interventions to guide our review. To organize and synthesize the existing body of knowledge on interventions addressing multiple forms of malnutrition in adolescents, our conceptual framework revolves around risk factors, potential interventions to prevent malnutrition and manage risk factors, and outputs and impacts at the individual, community, and societal levels.

Methods/design

Aims of the Review

We aim to address the following points through the review of school-based interventions focusing on the DBM, and educational outcomes of adolescents in LMICs.

1. Characterize the interventions that have been carried out
2. Ascertain the effectiveness of these interventions in addressing specific outcomes of interest
3. Identify factors that contribute to the success or failure of the interventions, including the potential barriers to their successful implementation in the context of LMICs

Eligibility criteria

1. We will include randomized controlled trials, with the intervention randomized to individuals or in clusters (including classes, schools, and groups/clubs). We will also include controlled before-after studies as they are non-randomized studies with a relatively rigorous design and occupy a non-negligible proportion of the relevant literature. Non-randomized controlled trials will also be eligible for inclusion as long as the baseline differences between study arms are accounted for in the analysis.
2. Studies involving adolescents (boys and girls) aged 10 to 19 years.
3. Studies conducted in LMICs—as defined by the World Bank in the year 2020 [31].
4. Studies involving interventions for one or more of the following: interventions to promote healthy diets, interventions promoting physical activity, nutrition education, school feeding, micronutrient supplementation, managing acute nutrition problems, prevention, and management of overweight, obesity, or anemia, school gardens, and access to safe environment and hygiene including WASH interventions.
5. Studies addressing the following outcomes:

   For DBM: Change in nutritional status measured by anthropometry (e.g., physical activity, height-for-age z scores, weight-for-age z scores, weight-for-height z scores, skin-fold thickness measures, stunting, underweight, wasting, body mass index, overweight, obesity, waist-to-height ratio, and central obesity), and knowledge of and practices related to diet.

   For educational difficulties: school enrolment, school completion, school attendance, prevention of school absenteeism and/or drop-out, and cognitive, maths, and/or language skills
6. The control (comparison) in each included study can be participants who did not receive any intervention or received general health education intervention.
7. We will include published articles and ongoing studies for which preliminary findings are available.
8. We will not place any restrictions in terms of the year of publication, language, sample size of the study, or duration of the intervention provided.

Exclusion criteria

We will not consider the following studies:

1. Non-randomized controlled trials that did not account for the baseline differences between the study arms;
2. Studies without a proper control (comparison) group/arm; e.g., uncontrolled before-after studies,
3. Observational studies including cohort, case-control, and cross-sectional designs,
4. Editorial commentaries, opinions, and review articles,
5. Clinical treatments/interventions targeted towards individuals with specific medical conditions such as programs intended for underweight, overweight, or obese adolescents,
6. Studies describing nutrition and/or educational interventions without linkage to specific outcome/s, and
7. Studies of educational interventions focusing *only* on educational outcomes (e.g., school or classroom participation, classroom environment, teacher performance, and so on).

Information sources

The following principal sources of electronic reference libraries will be searched: Medline (through PubMed), Embase, CENTRAL (through the Cochrane Library), CINAHL (Cumulative Index to Nursing and Allied Health Literature), and Google Scholar. All databases will be searched for eligible studies from the inception of each database through September 2020. Detailed examination of cross-references and bibliographies of available publications to identify additional sources of information will also be performed. This search of studies will be supplemented by reviewing organizational websites such as the World Food Programme, World Bank, Food and Agriculture Organization, United Nations Children's Fund, and United Nations Population Fund. Articles written in languages other than English will be translated by colleagues who are native speakers, whenever possible. Studies that cannot be adequately translated will be excluded.

Search strategy

Guided by the conceptual framework, a broad search strategy (e.g. type of study [randomized controlled trial OR controlled before-after studies OR quasi-experimental studies] AND intervention domain [nutrition] AND population [adolescents] AND setting [low- and middle-income countries]) will be performed in PubMed without time restrictions. We consulted with a health science librarian to develop the PubMed search strategy, which is provided in Additional File 1. The sensitivity of the search strategy will be examined by confirming that several sentinel articles are identified. The PubMed strategy will be adapted to the syntax appropriate for other databases. The following details will be documented for each search: [illegible]ted on, search strategy (i.e., subject headings and keywords

used, including whether terms are exploded, truncated and how terms are combined), years searched, filters used, number of results retrieved for each search, the total number of records, duplicates identified, and numbers pre- and post-screening. Also, all publications identified through hand searching will be noted with a source (i.e., name of journal/website, conference proceedings, etc.) and the years.

Data Management

EndNote X9 (Clarivate Analytics, PA, USA) will be used to store the records retrieved from searches of electronic databases. The records will also be imported into Covidence (Veritas Health Innovation, Melbourne, Australia), an internet-based program that facilitates the streamlined management of the systematic review. Duplicate records will be detected and removed first by EndNote and then by Covidence.

Two reviewers will independently assess the search results based on the inclusion and exclusion criteria. First, all searched titles and abstracts will be reviewed to exclude irrelevant studies. Disagreements between the two reviewers will be resolved by discussion or by a third reviewer, if necessary.

The interrater agreement will be quantified by calculating the raw percentage of agreement and Cohen's κ coefficient. A study flow diagram will be maintained as recommended by the PRISMA statement (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) [32], with the specific reasons for excluding studies. Neither of the reviewers will be blind to journal titles or the names of the authors.

Data extraction

Two reviewers will independently extract and enter the data of studies included in the review. A data extraction form provided as Additional File 2, will be developed and then pilot-tested on five randomly selected studies. The following information will be extracted for each selected study: title, authors (first author and corresponding author), contact information of corresponding author, journal (or source for reports), year of publication, year of intervention implementation, country and geographical setting, study design, sample size (if a cluster randomised trial, number of clusters and average cluster size), sample characteristics (e.g., age, sex, and socioeconomic status of the participants), intervention (including duration, intervention type, guiding theory/framework, intervention description, delivery mechanisms and agents, and procedures employed for selection, training and supervision of delivery agents, intervention coverage and fidelity information, and challenges and barriers encountered in intervention delivery), measure of adherence, information on control/comparison intervention, outcomes assessed, time-points, main findings with point estimates and measures of variance (standard errors, 95% CI and/or *p*-values), and reasons provided for success/failure. Multiple reports of a single study will be collated as additional results may be provided in different reports. In case of missing information or inconsistent results across reports of a single study, we will contact the corresponding author via email to obtain more accurate [illegible] of two contact attempts will be made.

Quality assessment

For the assessment of the risk of bias of the selected studies, we will use the Cochrane Collaboration's tool for assessing the risk of bias in randomized trials [33, 34]. Two reviewers will independently evaluate methodological quality. Any uncertainties or disagreements will be resolved by discussion or by a third reviewer, whenever needed. The tool is a domain-based evaluation, in which critical assessments will be made separately for the bias arising from the randomization process, the bias due to deviation from intended interventions, the bias due to missing outcome data, the bias in the measurement of the outcome, and selective outcome reporting. The judgment for each entry will involve assessing the risk of bias as "low risk," as "high risk," or as "some concerns," with the last category indicating either lack of information or uncertainty about the potential for bias.

We will use the Risk of Bias in Non-randomized Studies of Interventions (ROBINS-I) tool [35], to assess the risk of bias for controlled before-after studies and non-randomized controlled trials. This tool considers biases from confounding, the bias in selection of participants into the study, the bias in classification of interventions, bias due to deviations from intended interventions, the bias due to missing data, the bias in the measurement of outcomes, and the bias in selection of the reported results. Each domain will be judged as "low risk of bias," "moderate risk of bias," "serious risk of bias," "critical risk of bias," or "no information." Based on the domain-specific judgments, we will consider a non-randomized study (a) at low risk of bias if it is judged to have a low or moderate risk of bias for all domains; or (b) at high risk of bias if it is judged to have a serious or critical risk of bias in one or more domains; or (c) have some concerns if the assessment is unclear for one or more domains but low or moderate for all other domains. We will contact the corresponding authors of the reports to obtain more information, when necessary. We will summarize the results of the assessment of the risk of bias in a table, in which the judgment for each domain will be presented with a justification.

Synthesis of evidence

A systematic and narrative synthesis of all included studies will be presented in the text as well as in a table. Based on our conceptual framework, the interventions will be identified by an iterative process of data collating and key findings will be broken down into specific categories, derived from the articles. We will not conduct the meta-analyses given the considerable heterogeneity of both the interventions and outcomes.

We will follow the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist and guidelines to ensure a robust and replicable process [36]. Effect estimates for continuous outcomes will be expressed as mean differences (with 95% CI) comparing the intervention group with the control group; effect estimates for dichotomous outcomes will be expressed as risk ratios, rate ratios, hazard ratios, or odds ratios (all with 95% CI), comparing the intervention group with the control group.

Registration and reporting

This protocol is submitted for registration with the International Prospective Register of Systematic Reviews (PROSPERO) on September, 24 2020 (ID 211109). In the event of protocol amendments, the date of each amendment will be accompanied by a description of each change and the rationale on PROSPERO.

This protocol is written following the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) [36]. The PRISMA-P checklist can be obtained from Additional File 3. We will report this systematic review following the *Cochrane Handbook for Systematic Reviews of Interventions* [37] and the PRISMA guidelines [32, 36].

Discussion

Combating malnutrition in all its forms is one of the greatest global health challenges influenced by economic and income growth, urbanization and globalization, and related shifts in the quality and quantity of human diets. In 2016, the United Nations Decade of Action on Nutrition for the period 2016 – 2025 came to life [38], which calls for specific coordinated actions through cross-cutting and coherent policies, programs, and initiatives to address increasing DBM. As the global community transitions from a predominant focus on the eradication of severe and acute undernutrition within the framework of the Millennium Development Goals to the broader nutrition focus of the Sustainable Development Goals, including all forms of malnutrition and noncommunicable diseases, addressing DBM offers an unexplored window of opportunity for integrated actions. The agenda for Sustainable Development 2030 has also identified a need for tracking indicators to meet targets, especially for the Global Strategy for Women's, Children's and Adolescents' Health [28]. The major causes of deaths, disabilities, illnesses, and social problems among adolescents and young people are established during childhood and adolescence. In this review, we will focus on DBM in adolescents for multiple reasons. First, adolescence is a critical period for growth and development, with higher nutritional demands placing adolescents at greater risks of malnutrition. Malnutrition during adolescence manifests in three broad groups of conditions: undernutrition (wasting, stunting or chronic undernutrition and thinness or underweight): micronutrient deficiency or excess (inadequate or excessive intake of vitamins or minerals); and overweight and obesity. Among adolescents, undernutrition and micronutrient deficiencies are associated with poor physical growth, impaired cognitive and motor development, delayed maturation, impaired school achievement, reduced economic productivity, and poor reproductive health outcomes in females [39, 40]. Obesity and overweight in adolescence have been associated with an increased risk of early onset of adult chronic diseases such as type 2 diabetes, heart disease, stroke, hypertension, some cancers, and mortality in adult life [41, 42]. Second, the DBM can manifest at three levels for adolescents: 1) it occurs at the individual level through the simultaneous development of two or more forms of malnutrition (e.g., obesity with nutritional anemia or any vitamin or mineral deficiencies); 2) the DBM can occur at the household level (e.g., nutritional anemia in an adolescent with an overweight parent and

be observed in the same community, region or country [4].

Especially, the stable rates of undernutrition in many LMICs coupled with the dramatic increases in overweight, obesity, and associated NCDs are placing heavy tolls on individuals, families, economies, and health-care systems [43]. Third, after infancy, growth during adolescence is faster than any other period of life. On the one hand, there is an increase in height, peak bone mass, and body weight while on the other hand, the adolescent brain undergoes tremendous growth and development. Often referred to as the second window of opportunity for growth and development in the lifecycle, the adolescence offers a unique chance to address nutritional problems and develop healthy and long-lasting dietary and lifestyle habits [5]. Fourth, given that approximately 16 million girls between the ages of 15 and 19 years enter motherhood every year across the globe, their nutritional status is important not only for their health but also for the health of their new-born as well as the family [44]. Finally, good nutrition is one of the prerequisites for effective learning and vice versa [5, 6]. During the past two decades, public health research has shown the effects of social determinants of health, especially about the powerful and interactive effects of nutrition on one hand and brain functions, cognitive development and educational performance on the other hand, about disparities in each of these exacerbating the other, and how these disparities accumulate over life-cycle and generations [45].

Several evidence-informed actions exist to address adolescent nutrition. The school-based adolescent nutrition interventions can be broadly identified as 1) promoting healthy diets through education; 2) providing additional micronutrients through fortification of staple foods and targeted supplementation; 3) managing acute malnutrition; 4) promoting physical activity; and 5) providing access to a safe environment and hygiene [44, 45]. These interventions can be broadly classified into two categories: 1) discrete single-component interventions; and 2) multi-component interventions with a focus on one or more determinants of nutrition status. Single-component interventions include obesity prevention, anemia prevention, and micronutrient supplementation whereas the multi-component interventions integrate multiple aspects of adolescent nutrition into a single intervention. The most widely recognized example of the multi-component school-based health and nutrition intervention is WHO's Health Promoting Schools (HPS) framework [46] which recognizes the link between health, nutrition, and education and encourages a whole school approach to improving health and educational outcomes. This framework describes six key pillars of HPS: 1) healthy school policies; 2) healthy school physical environments; 3) healthy school social environments; 4) health skills and education curriculum; 5) links with parents and school community, and 6) access to school health services. Individual countries have also developed their interpretation of the HPS concept and adapted it to their own needs and resources. For example, in Canada and the USA, the HPS is known as the 'Comprehensive School Health Program' model [47 – 49]. In many LMICs, school-based nutrition programs, consisting of multi-component interventions including promoting healthy eating, less sedentary behavior, and more physical activity have been increasingly implemented worldwide since WHO launched the Nutrition-Friendly School Initiative in 2006 to address the multiple forms of malnutrition among school-aged children [50].

Several systematic reviews of single-component interventions on high-income and/or LMICs suggest promising but modest evidence of an effect, with these reviews examining a range of interventions such

ty prevention, physical and activity [9 — 19]. For example, a

systematic review of 50 school-based obesity prevention interventions found significant differences between groups on BMI and BMI z – score [15]. A systematic review of 18 studies on school feeding interventions found beneficial effects in terms of gained weight among the participants from lower-income countries, and improved performances in cognitive tasks [9]. On the other hand, a systematic review of six school-based nutritional supplements interventions found no evidence for reducing the re-infection rates of species-specific soil-transmitted helminth infections and physical wellbeing of school-age children between the age of 4 and 17 years [18]. These single risk domain interventions fail to recognize that multiple lifestyle risk behaviors in adolescents co-occur as clusters and track into adulthood [51]. It is also possible that discrete interventions that are not coordinated could be ineffective [52]. Furthermore, when interventions operate in isolation they often lack sufficient buy-in, training, and fidelity and are less likely to be sustained [53]. Given the limited availability of funding for prevention and treatment interventions for adolescents, the Lancet Commission on Adolescent Health [5] and WHO's Global Accelerated Action for the Health of Adolescents guideline [47] highlight the necessity of synchronized prevention efforts to target multiple health risk behaviors in adolescents.

Several literature reviews and systematic reviews published in the last two decades examine the effectiveness of multi-component school-based health and nutrition interventions [20 – 27]. A cross-national Cochrane review of 67 clustered randomized control trial (CRCT) studies on the effectiveness of HPS initiatives observed positive improvements in BMI, physical activity, and nutrition of the participants in a few studies [23]. In another systematic review of 11 multi-strategy nutrition education interventions, four studies reported significant improvements in anthropometric measures and nine studies showed significant changes in dietary intakes [26]. In a scoping review of seven studies on DBM, two school-based DBM intervention studies reported a modest reduction in thinness and no impact on overweight [54]. Furthermore, recent research on interventions targeting multiple risk behaviors in school settings also suggests that by improving health outcomes, these programs can also enhance educational outcomes such as student attendance, school engagement, classroom behavior, mood, concentration, memory, standardized test scores, grade point average, grade advancement, and high school completion [55 – 59]. However, the impact of multi-component school-based nutrition interventions on academic outcomes and cognitive development is modest [22]. Evidence on the involvement of family or community in school-based health interventions is mixed [23]. Overall, evidence suggests that comprehensive, multicomponent school-based interventions hold greater potential in promoting and supporting positive health behavior changes in the long-term than single-component nutrition interventions.

Although multi-component school-based nutrition interventions are promising, there are several gaps in the available evidence. First, most of the multi-component school-based health and nutrition interventions focused on general health and wellbeing, healthy eating, and physical activity and lacked attention to multiple forms of malnutrition [23]. Second, these reviews have not examined which components of the package or the characteristics of the context that contributed to the reported effect. Third, many of the above-mentioned literature on multi-component school-based health intervention does not focus only on

inomial. This is a problem because it combines the two life

stages into one and tends to neglect the unique health and development challenges of adolescents. Fourth, most of the studies included in these reviews come from high-income countries. Thus, little is known about the impacts of multi-component interventions on specific nutrition and educational outcomes of adolescents in LMICs. Finally, previous reviews of multi-component school-based interventions are out-dated, with the most recent review published in 2015 [23], thus do not reflect all of the currently available evidence. Therefore, an updated and refined synthesis of evidence on school-based nutrition interventions that target multiple forms of malnutrition and educational outcomes of adolescents, engage students, families, and communities and enable education, health and nutrition, and other agencies to synergistically improve nutritional status and education outcomes of all adolescents, is warranted.

In this context, our review will help advance the application of recommendations noted in the Lancet Commission on Adolescent Health [5], WHO's Global Accelerated Action for Health of Adolescents [47], and Child and Adolescent Health Volume of the third edition of Disease Control Priorities [6] advocate for integrated multi-component school-based health and nutrition approaches. Our review will contribute to the formulation of future programs to address the immediate and growing needs of school-going children as well as approaches to link schools, families, and the wider community through such interventions. Further, the findings of this review should help policy- and program-makers, researchers and practitioners, government and non-government agencies operating in health and education domains, to develop and implement interventions that effectively promote integrated health, address multiple forms of malnutrition, and education interventions, maximize efficiencies, and increase the scale and impact of school-based health and nutrition interventions for the health and educational benefits of millions on school-age children in LMICs.

Abbreviations

BMI: Body Mass Index

CBA: Controlled before-after study

CI: Confident interval

CINAHL: Cumulative Index to Nursing and Allied Health Literature

CRCT: Clustered randomized control trial

DBM: Double burden of malnutrition

HPS: Health Promoting Schools

LMIC: Low- and middle-income country

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses

PRISMA-P: Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols

PROSPERO: International Prospective Register of Systematic Reviews

RCT: Randomized controlled trial

ROBINS-I, Risk of Bias in Non-randomized Studies of Interventions

WHO: World Health Organization

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

All data that will be generated and analyzed during this study will be included in the published article or its supplementary information files.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

SS is the guarantor. SS and WWF developed the research questions and methodology. All the authors contributed to developing the search strategy, the risk of bias assessment strategy, and the data extraction form. SS drafted the manuscript. All the authors read, provided feedback, and approved the final manuscript.

References

1. Wells JC, Sawaya AL, Wibaek R, Mwangome M, *et al*. The double burden of malnutrition: aetiological pathways and consequences for health. Lancet 2020; 395 (10217): 75–88.
2. United Nations Population Funds. Adolescent and youth demographics: a brief overview. 2013.

3. Caleyachetty R, Thomas GN, Kengne AP, Echouffo-Tcheugui JB, *et al*. The double burden of malnutrition among adolescents: analysis of data from the Global School-based Student Health and Health Behaviour in school-aged children in 57 low– and middle–income countries. American Journal of Clinical Nutrition 2018; 108: 414–424.
4. World Health Organization. The double burden of malnutrition. Policy brief WHO/NMH/NHD/17.3. Geneva: World Health Organization; 2017.
5. Patton C, Sawyer S, Santelli JS, Ross DA, et al. Our future: a Lancet commission on adolescent health and wellbeing. Lancet 2016; 387: 2423–78.
6. Bundy D, de'Silva N, Horton S, Hamison DT, Patton GC. Child and adolescent health development. Disease Control Priorities 3rd Washington DC: World Bank, 2017. ISBN (electronic): 978-1-4648-0439–7.
7. Awartani M, Whitman VC, Gordon J. Developing instruments to capture young people's perceptions of how school as a learning environment affects their well-being. European Journal of Education 2008; 43: 51–70.
8. Roser M, Ortiz-Ospina E. Global Education. Published online at org, 2020. Available at: https://ourworldindata.org/global-education
9. Kristjansson B, Petticrew M, MacDonald B, Krasevec J, *et al*. School feeding for improving the physical and psychosocial health of disadvantaged students. Cochrane Database Systematic Review 2007; 1.
10. Eilander A, Gera T, Sachdev HS, Transler C, *et al*. Multiple micronutrient supplementation for improving cognitive performance in children: systematic review of randomized controlled trials. The American Journal of Clinical Nutrition 2010; 91 (1): 115–130.
11. Kriemler S, Meyer U, Martin E, van Sluijs EMF, *et al*. Effect of school-based interventions on physical activity and fitness in children and adolescents: a review of reviews and systematic update. British Journal of Sports Medicine 2011; 45:923–30.
12. Silveira JAC, Taddei JA, Guerra PH, Nobre MR. Effectiveness of school-based nutrition education interventions to prevent and reduce excessive weight gain in children and adolescents: a systematic review. Jornal de Pediatria 2011; 87(5): 382–
13. Watson A, Timperio A, Brown H, Best K, Hesketh KD. Effect of classroom-based physical activity interventions on academic and physical activity outcomes: a systematic review and meta-analysis. International Journal of Behavioral Nutrition and Physical Activity 2017; 14 (114); doi:10.1186/s12966–017–0569–9.
14. Liu Z, Xu HM, Wen LM, Peng YZ, *et al*. A systematic review and meta-analysis of the overall effects of school-based obesity prevention interventions and effect differences by intervention components. International Journal of Behavioral Nutrition and Physical Activity 2019; 16(1): 95.
15. Tallon JM, Dias RS, Costa AM, Leitao JC, *et al*. Impact of technology and school-based nutrition education programs on nutrition knowledge and behavior during adolescence–a systematic review. esearch 2019; 1–12.

16. Vaquero-Solis M, Gallego DI, Tapia-Serrano MA, Pulido JJ, Sanchez-Miguel PA. School-based physical activity interventions in children and adolescents: a systematic review. International Journal of Environmental Research and Public Health 2020; 17(3):999.
17. Adom T, Villiers AD, Puoane T, Kengne AP. School-based interventions targeting nutrition and physical activity and body weight status of African Children: a systematic review. Nutrients 2020; 12, 95. doi: 10.3390/nu12010095.
18. Isah AUJ, Ekwunife OI, Ejie IL, Mandrik O. Effects of nutritional supplements on the re-infection rate of soil-transmitted helminths in school-age children: a systematic review and meta-analysis. PLoS ONE 2020; 15(8): e0237112. doi:10.1371/journal.pone.0237112.
19. Leis R, de Lamas C, de Castro MJ, Picans R, *et al*. Effects of nutritional education interventions on metabolic risk in children and adolescents: a systematic review of controlled trials. Nutrients 2020; 12(1): 31. doi:10.3390/nu12010031.
20. Lister-Sharp D, Chapman S, Stewart–Brown S, Sowden A. Health Promoting Schools and Health Promotion in Schools: Two Systemic Reviews. Health Technology Assessment 1999; 3 (22). ISSN 1366–
21. Stewart-Brown, S., 2006. What is the evidence on school health promotion in improving health or preventing disease and, specifically, what is the effectiveness of the health promoting school's approach? Health Evidence Network report; WHO Regional Office for Europe. Available at: http://www.euro.who.int/document/e88185.pdf.
22. Murray NG, Low BJ, Hollis C, Cross AW, Davis SM. Coordinated school health programs and academic achievement: a systematic review of the literature. Journal of School Health 2007; 77 (9): 589-600.
23. Langford R, Bonell C, Jones H, Pouliou T, *et al*. The World Health Organization's Health Promoting Schools framework: a Cochrane systematic review and meta-analysis. BMC Public Health. 2015;15(1). doi:10.1186/s12889-015-1360-y.
24. World Health Organization. Improving nutrition outcomes with better water sanitation and hyginene: practical solutions for policies and programmes. Geneva: WHO; 2015. ISBN 978–92–4–156510–3.
25. Guerra PH, da Silveira JAC, Salvador EP. Physical activity and nutrition education at the school envirtonment aimed at preventing childhood obesity: evidence from systematic reviews. Jornal de Pediatria 2016; 92(1) 15–23.
26. Meiklejohn S, Ryan L, Palermo. A systematic review of the impact of multi-strategy nutrition education programs on health and nutrition of adolescents. Journal of Nutrition Education and Behaviour 2016; 48(9): 631-646.
27. Xu T, Tomokawa S, Gregorio Jr ER, Mannava P, *et al*. School-based interventions to promote adolescent health: a systematic review in low-and middle-income countries of WHO Western Pacific Region. PLoS ONE 2020. doi:10.1371/journal.pone.0230046.
28. Kuruvilla S, Bustreo F, Kuo T, Mishra CK, *et al*. The Global strategy for women's children's and lmap based on evidence and country experience. Bulletin of

World Health Organization 2016; 94:398-400.

29. Salam RA, Hooda M, Das JK, Arshad A, *et al*. Interventions to improve adolescent nutrition: a systematic review and meta-analysis. Journal of Adolescent Health 2016; 56: S29-S39.
30. World Health Organization. Implementing effective actions for improving adolescent nutrition. Geneva: WHO, 2018. ISBN: 978–92–4–151370–
31. World Bank. World bank country and lending groups-country classification 2020. Available at: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519.
32. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Annals of internal medicine. 2009; 151(4):264–26
33. Higgins JPT, Green S. Cochrane handbook for systematic reviews of interventions version 5.1.0 [updated March 2011]: The Cochrane Collaboration; 2011.
34. Sterne JA, Savović J, Page MJ, Elbers RG, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. British Medical Journal 2019; 366.https://doi.org/10.1136/bmj.l4898.
35. Sterne JA, Hernán MA, Reeves BC, Savović J, *et al*. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. British Medical Journal 2016; 355: i4919.
36. Moher D, Shamseer L, Clarke M, Ghersi D, Liberati A, Petticrew M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Systematic Reviews 2015; 4(1):1.
37. Chandler J, Cumpston M, Li T, Page MJ, Welch VA. Cochrane handbook for systematic reviews of interventions: John Wiley & Sons; 2019.
38. United Nations. United Nations decade of action on nutrition 2016-2025. un.org/nutrition.
39. Grantham-McGregor S, Cheung YB, Cueto S, Glewwe P, *et al*. Developmental potential in the first 5 years for children in developing countries. Lancet 2007; 369:60–70.
40. Patton C, Sawyer S, Santelli JS, Ross DA, *et al*. Our future: a Lancet commission on adolescent health and wellbeing. Lancet 2016; 387: 2423–78.
41. Dewey KG, Begum K. Long-term consequences of stunting in early life. Maternal and Child Nutrition 2011; 7(S 3):5–18.
42. Reilly JJ, Kelly J. Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: a systematic review. International Journal of Obesity 2011; 35:891–898.
43. Nugent R, Levin C, Hale J, Hutchinson B. Economic effects of the double burden of malnutrition. Lancet 2019; 395 (10218): 156–
44. World Health Organization. Adolescent pregnancy: key facts. Available at: who.int/news-room/fact-sheets/detail/adolescent-pregnancy.
45. Braveman P, Egerter S, Williams DR. The social determinants of health: Coming of age. Annual Review of Public Health 2011; 32: 381–

noting Schools – Concept Note. WHO; 2018.

47. WHO. Global Accelerated Action for the Health of Adolescents (AA-HA!): guidance to support country implementation. Geneva: World Health Organization; 2017. Licence: CC BY–NC–SA 3.0 IGO.
48. Division of Population Health, National Center for Chronic Disease Prevention and Health Promotion. Whole school, whole community, whole child. CDC; 2020. Available at: https://www.cdc.gov/healthyschools/wscc/index.htm.
49. Veugelers PJ, Schwartz ME. Comprehensive school health in Canada. Canadian Journal of Public Health 2010; 101 (S2): 5-8.
50. Delisle, HF, Receveur O, Agueh V, Nishida C. Pilot project of the Nutrition-Friendly School Initiative (NFSI) in Ouagadougou, Burkina Faso and Cotonou, Benin in West Africa. Global Health Promotion 2013; 20: 39–49.
51. Jacob CM, Baird J, Barker M, Cooper C, Hanson M. The importance of a life-course approach to health: chronic disease risk from preconception through adolescence and adulthood. White paper, World Health Organization, 2017. Available at: https://www.who.int/life-course/publications/importance-of-life-course-approach-to-health/en/.
52. Domitrovich CE, Bradshaw CP, Greenberg MT, Embry D, *et al*. Integrated models of school-based prevention: logic and theory. Psychology in the Schools 2010; 47(1):71–
53. Herlitz L, MacIntyre H, Osborn T, Bonell C. The sustainability of public health interventions in schools: a systematic review. Implementation Science 2020; 15 (4). doi:10.1186/s13012-019-0961-8.
54. Menon S, Penalvo JL. Actions targeting the double burden of malnutrition: a scoping review. Nutrients 2020; 12: 81.
55. Basch CE. Healthier students are better learners: a missing link in school reforms to close the achievement gap. Equity Matters Research Review 2010; 6, Columbia University Teaching College Centre for Educational Equity, New York.
56. Michael SL, Merlo CL, Basch CE, Wentzel KR, Wechsler H. Critical connections: health and academics. Journal of School Health 2015; 85:740–58.
57. Kase C, Hoover S, Boyd G, West KD, et al. Educational outcomes associated with school behavioral health interventions: a review of the literature. Journal of School Health 2017; 87:554–62.
58. Rasberry CN, Tiu GF, Kann L, McManus T, *et al*. Health-related behaviors and academic achievement among high school students—United States, 2015. Morbidity and Mortality Weekly Report 2017; 66:921–927.
59. Snilstveit B, Stevenson J, Phillips D, Vojtkova M, *et al*. Interventions for improving learning outcomes and access to education in low-and middle-income countries: a systematic review. The Campbell Collaboration 2015.

Figures

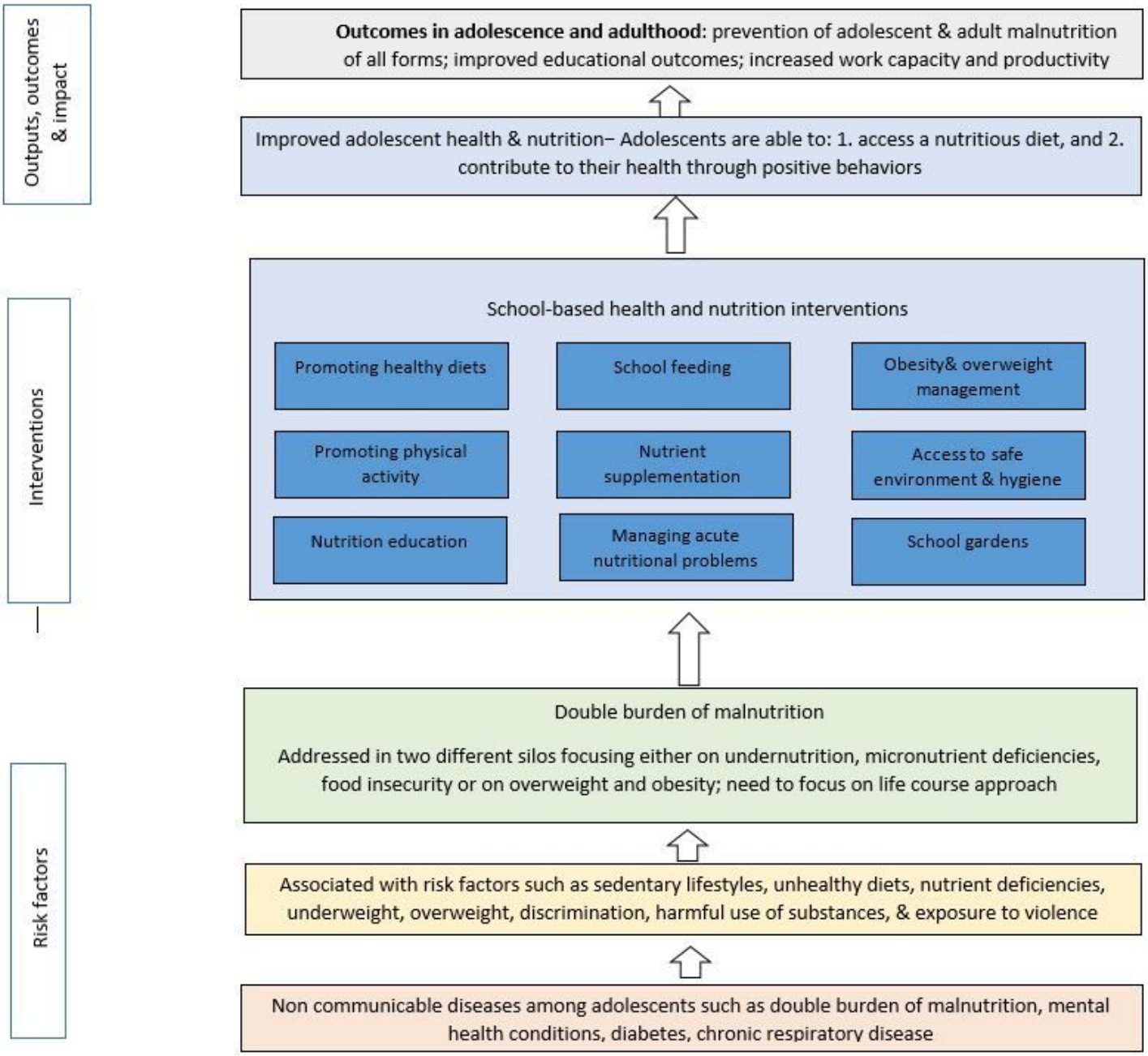

Figure 1

Framework for evidence synthesis of school-based interventions of adolescent double burden of malnutrition

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