The impact of complex school nutrition programmes on the nutritional status of school-aged children: A review of Asian countries' experiences and lessons from a case study in Thailand

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Declaration of own work

I, Suladda Pongutta, confirm that the work presented in this thesis is my own. Where information has been gathered from other sources, I confirm that this has been indicated in the thesis.

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Date: 10th July 2023

Abstract

Malnutrition, characterised by the imbalanced intake of nutrients or impaired nutrient utilisation, is a leading health risk factor among children globally. The double burden of malnutrition among children is prevalent in Asia including Thailand. The effectiveness of school nutrition interventions in reducing this problem in Asia remains unclear. Limited information exists regarding why and how school nutrition interventions are effective/ineffective. This lack of evidence hinders the advancement of nutrition policy in Asia.

My PhD research assessed the impact and factors influencing the impact of school-based nutrition programmes on over- and undernutrition in school-aged children in Asia, focused specifically on Thailand. I conducted a systematic review and meta-analysis to examine school nutrition interventions in Asia. I subsequently did impact and process evaluations of a complex school nutrition intervention in Thailand, using a quantitative analysis of the data obtained from a quasi-experiment and qualitative methods, respectively. My meta-analysis indicated that school nutrition interventions in primary schools across Asia focused primarily on and were effective in reducing Body Mass Index (BMI) and BMI-for-age z-scores. The impact evaluation of the intervention in Thailand demonstrated lowered risks of overweight and obesity and an increase in height-for-age Z-scores among young school children, but no significant impact on wasting. My process evaluation revealed perceived strengths, which included its multi-component design and its multi-sectoral support system to facilitate the implementation of the intervention. Perceived limitations were the lack of specific services for

addressing wasting and suboptimal fidelity. The findings also underscored the importance of having supportive education and health policies and establishing an enabling school context (i.e., policy, leadership, capacity, external support, social and physical environments).

My thesis suggests that complex school nutrition interventions are effective in reducing overnutrition and more evidence regarding the impact on undernutrition is needed in Asia. In Thailand, the intervention has the potential to reduce overnutrition and stunting; however, specific services for addressing undernutrition are required. Additionally, supportive national policies and school contexts are crucial for ensuring effective implementation and maximum impacts.

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List of Abbreviations

BMI	Body Mass Index
BAZ	Body Mass Index for-age z-score
CI	Confidence interval
CMOC	Context-Mechanism-Outcome pattern Configuration
DALY	Disability-Adjusted Life Year
GDP	Gross Domestic Product
GNP	Gross National Product
HAZ	Height-for-age Z-score
HPS	Health promoting school
IHPF	International Health Policy Programme Foundation
IRR	Incidence rate ratio
LMICs	Low- and middle-income countries
MRC	Medical Research Council
NCDs	Non communicable diseases
PRISMA-P	Preferred Reporting Items for Systematic review and Meta-Analysis Protocols

RCT	Randomised Control Trial
SDG	Sustainable Development Goal
TSL	Thai School Lunch
UK	United Kingdom
UNSCN	United Nations System Standing Committee on Nutrition
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations International Children's Emergency Fund
WFP	United Nations World Food Programme
WHO	World Health Organization

Chapter 1

Background to the thesis

1.1 Introduction

The double burden of malnutrition in children, which is defined as the coexistence of over- and undernutrition, is a leading cause of global disability-adjusted life years (DALYs) (1). This threat hinders the global capacity to achieve the United Nations' Sustainable Development Goals (SDGs). This is because: 1) Nutrition is a part of SDG2 (End hunger, achieve food security and improved nutrition and promote sustainable agriculture), and 2) Nutrition is a precondition for achieving SDGs1-5, 8 and 16 and a consequence of achieving SDGs 6,7,9-13, 15,17 (2, 3).

The double burden of malnutrition is a major health burden among children (4-6). A worrying trend is found among children age 5 -19 years old due to the greatest increase in overweight and obesity (1.4 times from 2010 to 2019) and persistently high prevalence of wasting (8.1% and 11.6% in girls and boys in 2019) (5), but school children are not prioritised in the nutrition global agenda (7). By geographical contexts, children over five years old in Asian and African countries are suffered from the double burden of malnutrition (overweight boys: 21.0% and 18.9%, overweight girls: 15.4 and 11.8%, wasted boys: 16.6% and 12.4%, and wasted girls:12.4% and 4.8% in 2019), while children of these ages in the rest of the world are suffered primarily from overweight (ranged from 25.5% to 44.5%) not wasting (ranged from 0.4% to 2.1%)(8).

On the solution side, prior to my studies, there had been meta-analyses indicating that school nutrition interventions implemented in high-income western countries reduced children's Body Mass Index-for-age Z-score (BAZ) up to -0.12 (9-12). However, based on previous systematic reviews (9-20), the impacts of school nutrition interventions on undernutrition among

school-aged children had been rarely reported, even in an Asian context where the double burden of malnutrition is prevalent.

Similar to other Asian countries, Thailand has been affected by the double burden of malnutrition in school-aged children for decades, with an increase of overweight and obesity from 5.8% to 18.1% between 1995 and 2014 together with a persistent trend of wasting (15.0% to 14.4%) and low levels of stunting (6.6% to 2.9%) (21, 22). To address the problem, a free school lunch scheme was implemented in all public primary schools in Thailand in 1999 (23). However, the increasing rates of overnutrition and the persistent undernutrition among primary school-aged children indicate that providing free school lunch alone is not effective in tackling malnutrition. In 2014, a school intervention called the "*Dekthai Kamsai* Programme" was first developed by a non-governmental multi-disciplinary working group. It was financially supported by an autonomous Thai government agency with an intention to promote child development, while addressing the double burden of malnutrition in school-aged children. It was a multi-purpose, multi-component, and multi-actor school nutrition intervention implemented on a yearly basis (24). Before my studies, there had been no evidence indicating 1) its effectiveness in reducing the double burden of malnutrition, as well as 2) the process underpinning its outcomes. This evidence is crucial for policy decisions on school nutrition interventions in Thailand.

In conclusion, given the negative impacts of over- and undernutrition on children, it is crucial to have evidence-based interventions to effectively address the problem. Previous literature indicated school-based nutrition interventions have the potential to address childhood overweight and obesity in western countries. However, there is limited evidence on whether

school nutrition interventions implemented in Asia, including Thailand, can reduce the double burden of malnutrition among school-aged children and factors contributing to the effectiveness.

My thesis research was undertaken to help address these evidence gaps through three interlinked studies. The first one was a systematic review and meta-analysis to describe characteristics of school nutrition interventions implemented in Asian countries and to quantify the effects of the interventions on the nutritional status of school-aged children's, including both over- and undernutrition. The second study was an analysis of data obtained from a 2-year quasi-experimental impact evaluation of a complex school nutrition intervention implemented in Thai primary schools to assess the impact on over- and undernutrition. The third study was a process evaluation conducted to identify internal and external factors affecting the impact of the school nutrition intervention implemented in Thailand. These three studies were guided by an evaluation framework, which I adapted from the realist evaluation (25), RE-AIM framework (26), and UK Medical Research Council (MRC) process evaluation (27). The findings from these three studies were synthesised to address the evidence gaps.

1.2 Thesis Roadmap

The thesis, which is a paper-based thesis, has seven chapters. **Chapter one** is the thesis's background, which outlines its introduction, roadmap, evidence gaps and rationale, and aim and objectives. It also outlines my contribution to both the research undertaken and the securement of project funding. **Chapter two** describes the evaluation framework used to guide the three studies of my thesis and the methods used for the studies. **Chapter three** presents the systematic review and meta-analysis done to achieve the first objective of the thesis. It was

published as a paper entitled “Impacts of school nutrition interventions on the nutritional status of school-aged children in Asia: A systematic review and meta-analysis” (published in *Nutrients*). **Chapter four** presents the impact evaluation of the Dekthai Kamsai programme, which is a complex school-based nutrition intervention programme in Thai primary schools, that was done to achieve the second objective of the thesis. This manuscript, which is entitled “The impact of a complex school nutrition intervention on double burden of malnutrition among Thai primary school children: a 2-year quasi-experiment” has been published in *Public Health* journal. **Chapter five** presents the process evaluation undertaken of the Dekthai Kamsai programme, that was done to achieve the third objective of the thesis. This manuscript, which is entitled “Addressing the double burden of malnutrition among Thai school-aged children with a complex school nutrition intervention: A process evaluation” is currently being reviewed by a peer-review journal. **Chapter six** discusses the findings presented in chapter three, four, and five in relation to their contribution to the current body of evidence regarding the impacts of school nutrition interventions on the anthropometric status of school-aged children. It also discusses the limitations of the studies done for this thesis, and the methods used to minimise these limitations. **Chapter seven** concludes the thesis and provides the policy and research recommendations based on it. The last two sections are the **References** and **Appendices**.

1.3 Literature review

1.3.1 Nutrition: a key pillar for sustainable development

Nutrition is a key pillar for sustainable development because it influences the health and well-being of the global population. The interlinkages between nutrition and all aspects of

sustainable development are described below to highlight the importance of addressing malnutrition in child populations.

Nutrition and health

Nutrition can be referred to as "a characteristic of the quality of an individual's diet in relation to their nutrient needs"(28). Diet quality influences human physical and mental health, and well-being throughout the life cycle (29). A poor quality diet can lead to malnutrition, which refers to deficiencies, excesses or imbalances in a person's intake of energy and/or nutrients, which results in stunting, wasting, underweight, micronutrient deficiencies, overweight, obesity and diet-related non-communicable diseases (30). Malnutrition can affect every organ and body system, including the brain and nervous system, cardio-respiratory function, gastrointestinal function, muscle and bone, and immunity and wound healing (29, 31). Apart from physical health, an imbalanced diet can lead to cognitive impairment and mental disorders such as depression since inadequate intakes of some nutrients will affect brain composition, neurodevelopment, and the level of neurotransmitters (32, 33).

Malnutrition is a major global health risk factor (1, 5). In 2019, maternal and child malnutrition accounted for 11.6% of global disability-adjusted life years (DALYs), while dietary risk was the 6th and the 5th ranks of the global attributable DALYs for females and males(1). Malnutrition is also recognised as an intergenerational health risk factor (34), which can be determined by both individual factors (such as genetic and epigenic factors) and socio-cultural factors (such as poverty and fear of giving birth to a large child) (35).

Nutrition and education

As described earlier, nutrition contributes to the development of physical and mental health. It therefore plays a significant role on cognition and academic achievement. Evidence for the link between various forms of childhood malnutrition and low academic achievement is well-established. Numerous studies demonstrated that severe wasting in children under the age of five is associated with impaired neurodevelopment, cognition, and academic achievement (33). Poor cognitive function due to malnourishment can persist throughout the primary school years, irrespective of child's psychosocial status (36). Early-onset persistent stunting was found to be associated with lower cognitive development in preschool children across multiple countries (37). Child stunting was reported to be associated with lower cognitive scores in the Philippines (49.6 versus 56.4), lower reasoning and arithmetic scores in Indonesia (9.7 versus 11.2), lower attained grades in Brazil (6.5 versus 8.1), and lower WISC IQ in Peru (79.2 versus 92.3) (38). Deficiencies in iron and vitamin B were shown to be associated with cognitive performance (39) and attention-deficit/hyperactivity disorder (ADHD) and autism (40) even in the absence of anemia (41). Furthermore, overnutrition was also found to be associated with lower academic performance in school-aged children (42). Food insecurity was reported to be associated with school absenteeism (43).

Nutrition and socio-economic development

The physical and cognitive impairment due to malnutrition undermines human capital and economic development (44). An analysis of multiple longitudinal datasets (1982-2020) from 123 low- and middle-income countries (LMICs) estimated that childhood stunting results in a

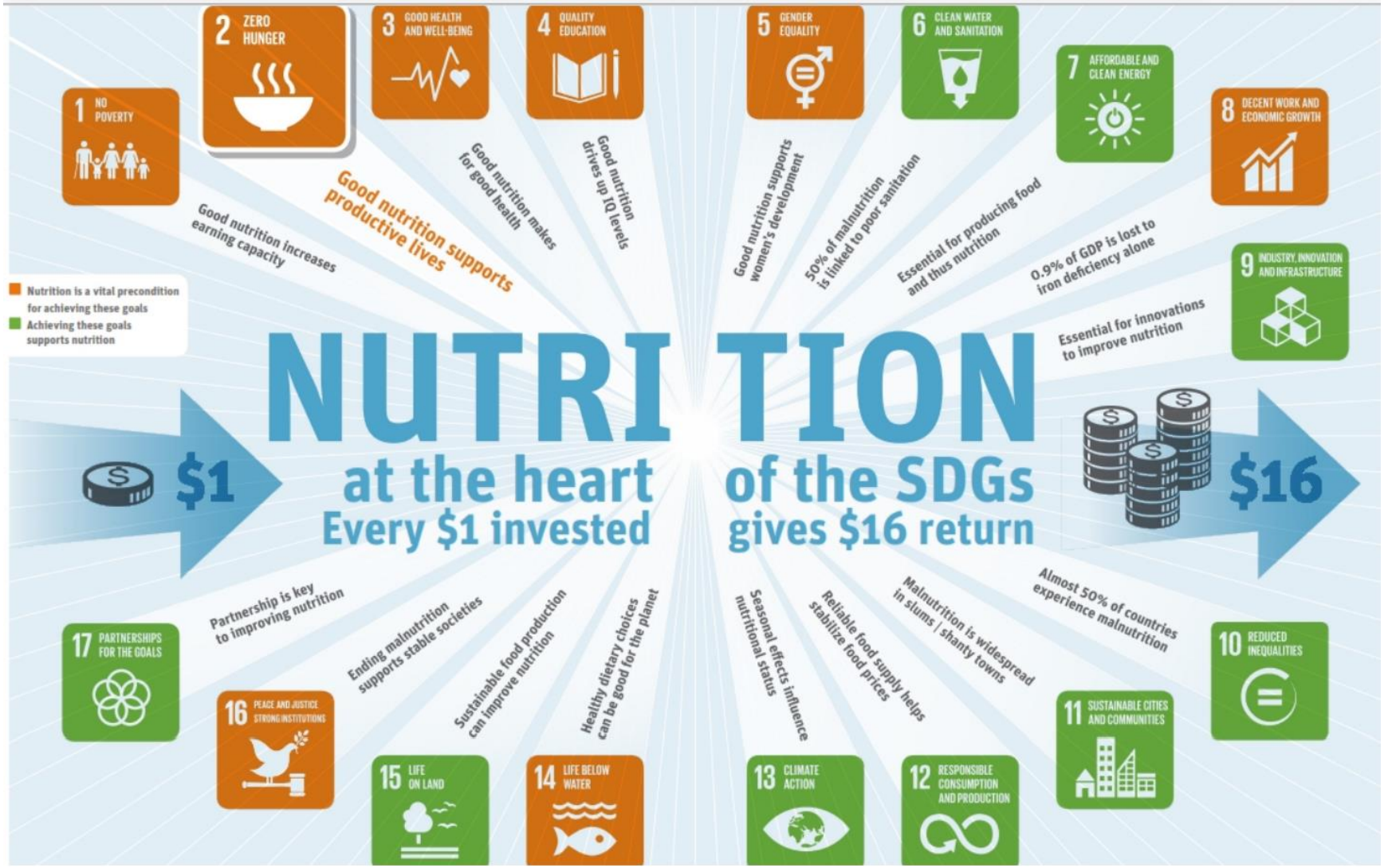
monthly income loss of USD 700 million – 16.5 billion, and in private sector annual sales losses of USD 135.4 billion across 95 LMICs, which was equivalent to 0.01% to 1.2% of national Gross Domestic Product (GDP) across countries (45). The global economic burden of childhood obesity was estimated to be USD13.62 billion and USD 49.02 billion by 2050 (46). The cost of overweight and obesity across all age groups in 161 countries was estimated to be 2.19% of global GDP in 2019, which ranged from USD 6 per capita in low-income countries to USD 1,110 in high-income countries(47). Overall, malnutrition was estimated to cause global Gross National Product (GNP) losses of 8% in the 20th century and 6% in the 21st century (48). Nutrition-related illness can lead to substantial government health expenditures, for example, the annual health care costs in 11 Asian countries was estimated to be as high as USD 30.1 billion (49), and in the United States (US) it was over USD 15.5 billion (50). Such direct and indirect costs were estimated to have an impact on the global economy of USD 3.5 trillion annually or 5% of global income (51).

The returns of investment in malnutrition reduction are high. An analysis of nutrition interventions in 40 countries estimated that every USD1 spent on scaling-up nutrition interventions would yield USD16 in return (52). In addition, it was estimated that every USD1 invested in childhood stunting reduction, in low-and-middle-income countries, would yield USD 2 to 81 annually (45).

Nutrition and sustainable development

Nutrition is linked, directly or indirectly, to all Sustainable Development Goals (SDGs) as either a cause or a consequence (28). The relationships between nutrition and most SDGs were summarised in the 2017 Global Nutrition Report (3). Nutrition is part of the Sustainable

Development Goal 2 (SDG2) “End hunger, achieve food security and improve nutrition, and promote sustainable agriculture”. Nutrition contributes to and is influenced by SDGs 1 (No poverty), 3(Good health and well-being), 4 (Quality education), 5 (Gender equality), 8 (Decent work and economic growth), 14 (Life below water), and 16 (Peace and justice and strong institutions). It is supported by SDGs 6 (Clean water and sanitation),7 (Affordable and clean energy), 9 (Industry innovation and infrastructure), 10 (Reduce inequality), 11 (Sustainable cities and communities, 12 (Responsible consumption and production), 13 (Climate action), 15 (Life on land), and 17 (Partnership for the goals) as shown in Figure 1. Clearly, addressing malnutrition is both of national and global significances.



Source of data: Global Nutrition Report 2017 (3). **Source of infographic:** https://sightandlife.org/infographics/nutrition-at-the-heart-of-the-sdgs/

Figure 1 Interlinkage between nutrition and SDGs

1.3.2 Global and regional trends in the double burden of malnutrition in children

Malnutrition-related risk factors are estimated to contribute to 75.5% of DALYs among children aged 0-9 years old (1). The global health statistics (6, 8) divides children into two groups i.e., children under five years of age and children aged 5 to 19 years old. They present statistics on all forms of malnutrition for children under five years of age, but they do not present statistics on the prevalence of stunting for older children. The statistics for children under 5-years of age show the double burden of malnutrition is a global nutrition target (7). Detailed information is shown below.

Children under five years of age

Globally, there have been downward trends of low birth weight, stunting and wasting over the past two decades, but not overweight and obesity (6, 53). Globally the prevalence of stunting prevalence has improved to the greatest extent, declining from 33.1% in 2000 to 22.0% in 2020 (6). The prevalence of wasting has decreased slightly from 7.9% in 2012 to 6.7% in 2020, while the prevalence of overweight has been almost constant at 5.6% in 2010 and 5.7% in 2020 (53). Examining the trends over the last decade by region, shows the double burden of malnutrition among children under 5-years of age exists in all regions but the proportions of each form of malnutrition differ by region (6). Stunting and wasting is prevalent in South-East Asia and Africa, while overweight is the major form of malnutrition among young children in the Americas and Europe (6).

Children 5-19 years old

From 2010 to 2019, the global double burden of malnutrition among children aged 5-19 years old increased to a greater than among younger children (5). In this time frame, the global prevalence of overweight and obesity among boys aged 5-9 years old increased from 17.0% to 24.5% and the prevalence of wasting decreased slightly from 12.8% to 10.9%. Similar trends were found in boys aged 10-19 years old, as the global prevalence of overweight and obesity increased from 14.4% to 20.2% and there was a slight decrease in the prevalence of wasting (13.4% to 12.3%). Among girls aged 5-9 years old, the global prevalence of overweight and obesity increased from 15.5% to 21.4%, and the prevalence of wasting remained almost the same (9.6% to 8.9%). For 10–19 year-old girls, the global prevalence of overweight and obesity increased from 13.8% to 18.4%, and like the younger group, wasting did not change significantly (8.1% to 7.9%). Among this age group, between 2000 and 2019, the prevalence of overweight and obesity rapidly increased in all regions of the world, while wasting only remained prevalent in African and Asian countries (8). Thus, compared with children under 5-years of age, the double burden of malnutrition in children aged 5-19 years old is much higher and continues to grow. These trends underscore the need for research on the double burden of malnutrition in school-aged children, which is the central concern of my thesis.

Inequalities in the double burden of malnutrition

An analysis of the data obtained from 123 countries indicated that, from the 1990s to 2010s, the prevalence of the double burden of malnutrition increased in the poorest countries and decreased in other groups (54). Among these countries, the increase in the double burden

of malnutrition was most common in Asian countries, while the decrease was most common in Latin America/Caribbean and Middle East/North Africa (54). The increasing trends of the double burden of malnutrition in Asian countries were mainly due to the increase in overweight and obesity. The increase in overweight and obesity was found across all age groups and all Asian countries regardless of GDP levels (54). At the household level, the coexistence of child stunting and maternal overweight was prevalent in richer households in poorer countries and in poorer households in richer countries (55).

GDP has a positive relationship with BMI in both children (56, 57) and adults (58). However, an analysis of 175 countries' profiles showed that the positive relationship of GDP and BMIs was found only when GDP was below USD 3000 per capita (58). Socio-economic status is a key determinant of the malnutrition because poverty leads to poor-quality diets (59), nevertheless, GDP is not the only factor that influence BMI. Other factors, including unhealthy food environments, sedentary lifestyle, urbanisation, industrialisation, income inequalities, poor market system regulations, were found to be associated with increased BMI (54, 60).

1.3.3 Why address malnutrition in school-aged children?

A life course approach has been recommended by the World Health Organization (WHO) to address malnutrition because malnutrition can affect, both short- and long-term health throughout the life-course (61). In this approach, special attention should be paid on child nutrition because child nutrition lays foundation for health and human capital development. Across the life-cycle, children are also at high risk for malnutrition given their high nutrient needs for rapid growth and development (62, 63). Initially, the primary focus of

child malnutrition was on the first 1,000 days concept (63). More recently, the focus has expanded to the first 8,000 days to ensure optimal physical and psycho-emotional development of children (62). The 8,000 days are categorised into four phases aligning with different stages of child development, which include the first 1,000 days, middle childhood growth and consolidation (5-9 years old), adolescent growth spurt (10-14 years old), and adolescent growth and consolidation (15-19 years old)(62).

The school-age period is a second opportunity (after the first 1,000 days) for reducing the long-term consequences of malnutrition. This is a critical stage in life for nutrition interventions for four reasons. Firstly, improving the nutritional status of school-aged children can mitigate the effects of early childhood malnutrition in terms of short stature in adulthood and deficits in cognitive performance (64). Secondly, pre-adulthood is a critical phase for rapid growth and pubertal development (65), therefore interventions at this stage can contribute to breaking the intergenerational cycles of malnutrition. Thirdly, long-term protective effects can be expected from an intervention at this stage since some forms of malnutrition and eating behaviours established in the school-age years can continue into adulthood (66, 67). Fourthly, the rising global trend of malnutrition among children aged 5-19 years old is alarming, particularly the trend for increasing rates of overweight and obesity (5).

Despite the worrying trend of rising rates of malnutrition in school-aged children (see section 1.3.2), it is often overlooked because it is not captured in global nutrition-related targets (5, 68). This lack of attention, in the global agenda, on malnutrition in school-aged

children could lead to inadequate responses to the problem, which are needed to prevent a devastating global increase in nutrition-related chronic diseases in the future.

1.3.4 Addressing malnutrition among school-aged children with school-based nutrition interventions: Global models

Schools provide an opportunity for nutrition interventions to reach children on a massive scale across a country, even in underserved rural areas (69). This institutional environment also makes it is easier to control the quality and quantity of food or other services provided to students than in the home environment by individual caretakers (69).

Thus, for decades, School Feeding Programmes have been implemented worldwide in primary schools to address hunger among school-aged children and its consequences (11). These programmes generally aim to provide school meals or snacks to primary school children; however, the programmes have been tailored to suit the local needs and capacities at the local level. Apart from food provision, some complementary components, such as health and nutrition education, foodborne diseases prevention, and home or community farms and gardens, have been implemented in some schools. COVID-19 significantly impacted School Feeding Programmes in many countries. To re-establish and strengthen their programmes, a global School Meals Coalition was launched in 2021, garnering support from 83 stakeholders, including major UN agencies (70). The Coalition forms partnership with member states and empowers them to overcome challenges, especially financial constraints in providing free school meals in low-income countries. By 2022, 76 countries had joined the Coalition and 41% of the world's school-aged children received free school meals (70).

Focusing Resources on Effective School Health (FRESH) is another framework to enhance nutrition, health, and the quality and equity of education, which was developed by United Nations Educational, Scientific and Cultural Organization (UNESCO), United Nations International Children's Emergency Fund (UNICEF), WHO, and the World Bank in 2000 (71). This framework recommends four core components for schools to adopt, which include *health-related school policies* (to promote overall health, hygeine, and nutrition), *provision of safe water and sanition*, *skills based health education* (in the areas such as HIV/AIDS, reproductive health, early pregnancy, violence, tobacco and substance abuse), and *access to health and nutrition services* (such as provision of snacks and deworming). These components should be complemented by three supporting stragies including effective partnerships between the health and education sectors, effective community partnerships, and pupil awareness and participation.

In 2019, UNESCO reconvened an inter-agency group on school health and nutrition, leading to the establishment of an essential package supported by the United Nations World Food Programme (WFP) and UNICEF in 2020 (72). This package, developed based on the FRESH framework, aims to enhance the promotion of health, nutrition, and education in primary schools across 40 countries. It recommends 12 components, including basic education, food for education, promotion of girls' education, access to potable water and sanitary latrines, education in health, nutrition, and hygiene, systematic deworming, micronutrient supplementation, HIV and AIDS education, psychosocial support, malaria prevention, school gardens, and improved stoves.

To enhance the quality of school nutrition programmes, the United Nations System Standing Committee on Nutrition (UNSCN) provides recommendations based on relevant global lessons which consider schools as a system for addressing malnutrition (69). These recommendations state that this system should create healthy school food environments (e.g., healthy school lunches, snacks, and drinking water) and enabling school environments for physical activity promotion, and it should provide comprehensive nutrition and physical education and supportive health services (e.g., health and nutrition monitoring and school sanitation). To create this system, multiple stakeholders both in schools and outside schools (such as families, communities, farmers or local food producers, health centres) should be engaged. The system also can be multipurpose, including nutrition promotion, community development, social protection, economic empowerment, and effective agricultural production.

Another global guideline for school-based nutrition interventions is the WHO health promoting school (HPS) model (73, 74). This model includes health promotion and educational attainment in general, and it also addresses child malnutrition. Health promoting schools are perceived as "a school that is constantly strengthening its capacity as a healthy setting for living, learning and working"(73). Key elements of the model include engagement of all key stakeholders (e.g., health and educational officials, school staff, students, parents, and community leaders), and the inclusion of multiple components (e.g., healthy school environments, health education, school health services, nutrition and food safety programmes, physical education and recreation, counselling, and social and mental health support). There are eight global standards for health promoting schools outlined in these guidelines as follows: 1) government policies and resources, 2) school policies and resources, 3) school governance

and leadership, 4) school and community partnerships, 5) school curriculum (to encourage a healthy lifestyle), 6) school social-emotional environment, 7) school physical environment (healthy safe, secure, inclusive), and 8) school health services. At the national level, the government should commit to facilitating and supporting the HPS. At the school level, to enable the HPS implementation, the school needs appropriate policies, governance and leadership, adequate resources, and school-community partnerships. Schools should provide health education to encourage a healthy lifestyle, a healthy environment to encourage healthy behaviours, a secure and inclusive social environment, and inclusive health services. Currently, the HPS is implemented locally in some countries (75).

1.3.5 Dekthai Kamsai school nutrition programme: A case study in Thailand

Thailand is an upper middle-income country located in Southeast Asia. Thailand has experienced rapid economic growth over the last five decades, which has led to a nutrition transition from undernutrition to the double burden of malnutrition (76). The growth has been accompanied by urbanization and industrialization, which has spread obesogenic environments (60, 77). A recent health burden report for Thailand indicated that imbalanced diet and overweight and obesity were the 5th and 6th leading health risk factors contributing to DALYs among the Thai population (78).

Why was the Dekthai Kamsai school nutrition programme implemented?

In Thailand, the free school lunch scheme, which was originally set-up to address undernutrition in primary school aged children, has been implemented since 1999 in all public primary schools (23). However, the double burden of malnutrition remains a major health

problem among school-aged children with an increase in the prevalence of overweight and obesity from 5.8% to 18.1% between 1995 and 2014, together with persistent undernutrition (wasting: 15.0% to 14.4% and stunting: 6.6% to 2.9%) (21). Therefore, an effective school nutrition intervention is needed to address the double burden of malnutrition in school-aged children in Thailand.

Overview of the Dekthai Kamsai programme

The Dekthai Kamsai programme is a complex school nutrition intervention. It was designed to improve overall child development, which include school-aged children's health (nutrition), head (cognitive ability), hands (domestic skills), and heart (social skills and morality). It was intended to empower schools to become key agents in addressing malnutrition in primary schools. This programme offered eight components of participatory activities i.e. healthy food provision, health and personal hygiene, school sanitation, school garden and farm, school cooperatives and vocational training, basic health service, health and nutritional status monitoring, and education in agriculture, nutrition, and health (farm to fork) (24). Figure 2 shows the programme's logic model and more details of the components are as follows.

The healthy food provision component was aimed to promote healthy school lunches and cultivate healthy eating habits among children by establishing a healthy school food environment. Participating schools were required to use the Thai School Lunch programme (TSL) (79) to plan lunch menus. TSL is a computer programme developed by the Institute of Nutrition and the National Electronics and Computer Technology Center for Thai schools to grade the nutritional quality of lunch menus. The programme also shows recommended amounts of each food ingredient suitable for a given number of students and the cost of the

selected menu. The school menu plans made by school staff are automatically recorded into the TSL database. School lunches could be prepared either by school staff or vendors following the menu plans. In terms of snack and drinks management, participating schools were required to ban sugary drinks and savoury/fried snacks. By implementing these practices, students were expected to consume the recommended portions of vegetables 5 times/week, fruit 3 times/week, and desserts ≤1 time/week at school. Training sessions were conducted for school staff to enable them to use TSL and provide healthy school food. Onsite visits were conducted following the training to monitor food provision and to provide advice.

The school farm and garden were aimed to develop farming and gardening skills and a sense of ownership among students, and also to supply safe food ingredients for school lunches. Technical and financial support was provided to participating schools to initiate farm and gardens in schools or surrounding areas provided by communities. All students were engaged in the activities in accordance with their interests and capacities.

The aim of the health and nutritional status monitoring was early detection of student health and nutrition problems so that school staff could respond to such problems at an early stage. Training courses were provided to school staff on measuring the students' weights and heights twice a term, analysing the data, and working with parents to improve the nutritional status of students experiencing malnutrition. Diet and physical activity guidelines for under- and overweight children were provided to schools and parents.

The health and personal hygiene promotion aimed to promote physical activity and personal hygiene. The schools were encouraged to engage students in active leisure activities to

ensure 30 minutes of moderate to vigorous physical activity 5 days/week. For personal hygiene promotion, schools were required to launch campaigns and communicate with students regularly.

The component of agriculture, nutrition, and health education aimed to integrate agriculture, nutrition, and health knowledge into school curriculums and activities.

The school cooperatives and vocational training was developed with an intention to equip students with financial management skills and promote the sustainability of school farms and gardens. Training was provided to school staff so they could guide students on how to manage income and budgets for the school farms and gardens.

The school sanitation component aimed to enable schools to achieve the national school sanitation standard. Guidance and financial support were provided as necessary.

The basic health service provision intended to improve health services in schools, where necessary. Financial support was provided for improving infirmaries.

This programme was led by a non-governmental multi-disciplinary working group and financially supported by an autonomous government agency called Thai Health Promotion Foundation (24). To create a supporting system that facilitate the implementation of this programme, five government organisations were engaged and asked to sign a Memorandum of Understanding (MOU), which included the Ministry of Education, Ministry of Public Health, Ministry of Interior, and Ministry of Agriculture and Cooperatives, and National Electronics and Computer Technology Center (NECTEC).

This programme was a voluntary-based school nutrition programme developed based on the lessons learnt from a school programme developed for disadvantaged children living in remote areas in Thailand (80). In 2014, 544 schools received full support and the number decreased to 50 schools in 2019 due to limited funding. This programme was implemented on a yearly basis. Prior to the beginning of each school year, all primary schools were invited to participate in the programme. Schools interested in participating in the programme then proposed a school's implementation action plan according to the programme's guideline and resources that were required for the programme implementation in the upcoming school year. The programme provides financial support (the amounts depend on the programme's annual budget), social connections, guidelines, tools, materials, multiple training courses for school staff, and school and community monitoring visits. The tools and materials include a lunch planning software called Thai School Lunch (TSL), a nutritional monitoring and information system, active learning guidebooks, pamphlets on healthy eating, self-evaluation forms for schools, and websites to provide information and share experiences on school lunch management among schools.

When this PhD research project was conceptualised, it was not known whether the Dekthai Kamsai programme would effectively address the double burden of malnutrition among school-aged children in Thailand and what the influential factors were for programme success. Such information is critical for informing both programmatic and national policy decisions on school-based nutrition intervention programmes design and key factors needed for its successful implementation at scale.

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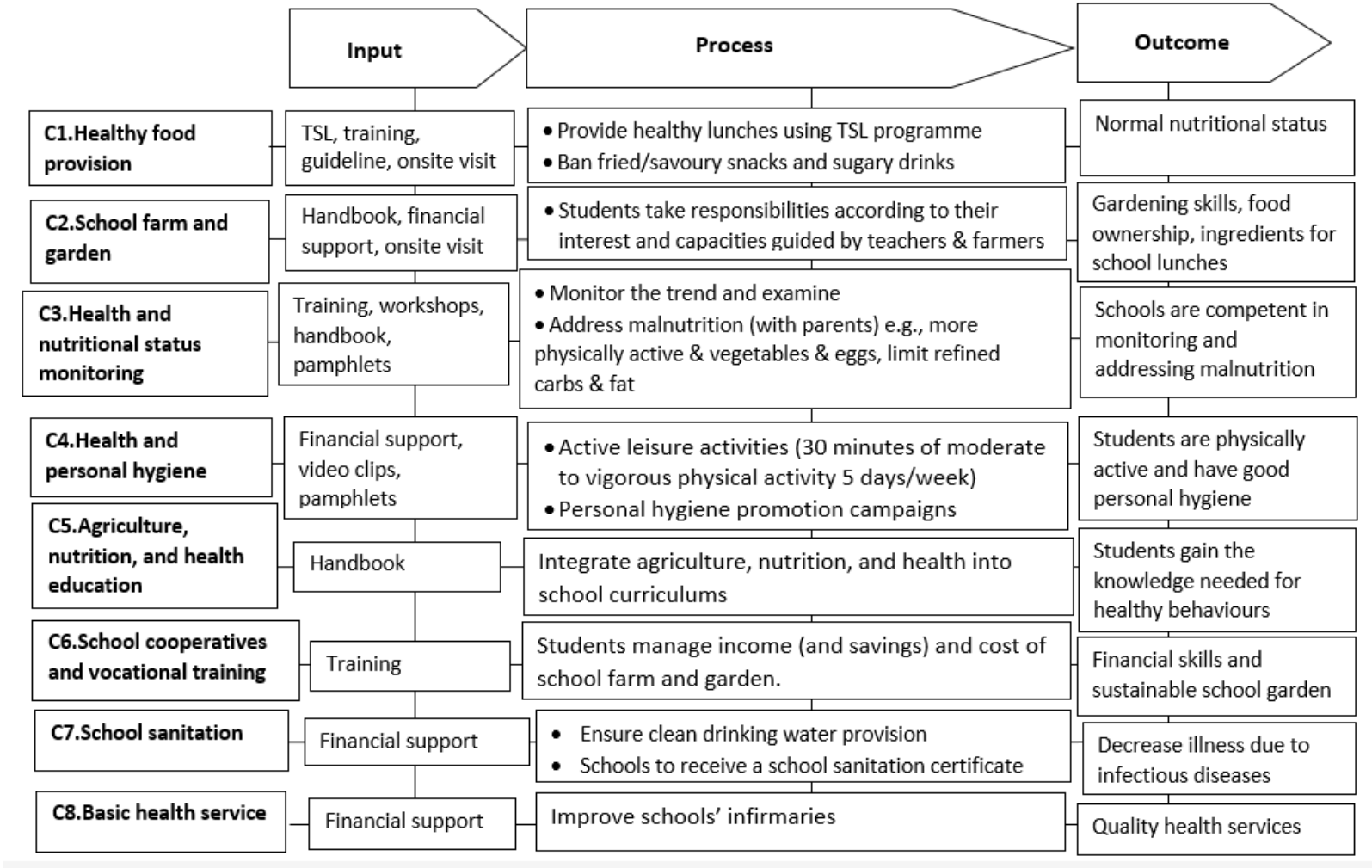

Figure 2 The Dekthai Kamsai programme's logic model

1.3.6 Evidence on the effectiveness of school-based interventions aiming to improve children's nutritional status prior to my studies

Impacts of school nutrition interventions on children's nutritional status from a global perspective

There have been 11 systematic reviews published between 2000 and 2021 that have examined the effectiveness of school-based interventions for tackling overweight and obesity (9-20) and one systematic review that has examined the effectiveness of school-based nutrition programme for addressing both over- and undernutrition (20).

The majority of these reviews (n=9) conclude that school-based interventions can reduce Body Mass Index (BMI) or Body Mass Index for-age z-score (BAZ) to a small extent (9-17), while the results of other two systematic reviews were inconclusive (18, 19). The one study examining the effectiveness of school-based nutrition programmes, in addressing undernutrition, showed no significant effect among African students (20). The geographic locations, study designs and results of these reviews are summarised in Table 1.

Summarising the results by geographical region, reviews indicates that school nutrition interventions in western countries and China reduce mean BMI or BAZ, while those for middle-income and African countries were inconclusive. Most of the studies reviewed were carried out in western countries and China, which limits the conclusions that can be drawn for other parts of the world. Evidence from low- and middle-income countries, including Asian countries, is

limited, indicating a need for further research to inform school nutrition policy in these countries.

In terms of intervention components, the reviews indicate that multi-component interventions have a greater impact on over-nutrition than single component interventions. Among single-component interventions, physical activity was the most promising intervention for reducing mean BMI. In contrast, there is insufficient evidence to confirm that a diet intervention reduces over-nutrition, even though diet is a key factor determining nutritional status (81).

In summary up to 2021, the majority of studies evaluating school-based interventions, for improving the anthropometric status of school children, focused on reducing overweight and obesity and were done in high income countries or China. There is clearly a need for further research on the effectiveness of school-based interventions, for reducing both over- and under-nutrition in low- and middle-income countries, including Asia, to inform programmatic decisions and policy.

Table 1 Findings of systematic reviews examining the effectiveness of school-based nutrition programmes from 2000 to 2022

Year of publication	Country	Study design	Outcome
2008 (13)	USA (5 studies), Israel (1 study), Greece (1 study), and Chile (1 study)	RCTs	- Nutrition education and physical activity reduced mean body weight by -0.29 kg (95%CI: -0.45, -0.14). - Nutrition education, physical activity, and parental involvement reduced mean body weight by -0.20 kg (95%CI: -0.41, 0.00).
2012 (14)	USA (19 studies), European countries (18 studies), Asian countries (5 studies), and South American country (1 study)	RCTs and cluster RCTs	- Physical activity, health education, and other complementary components (65% of the included studies), physical activity promotion alone (23% of the included studies) and health education alone (12% of the included studies) reduced mean BMI in children having mixed nutritional status by -0.16 kg/m^2 (95%CI: -0.25, - 0.06), and reduced mean BMI in overweight/obese children by -0.35 kg/m^2 (95%CI: -0.58, -0.12). - Physical activity reduced mean BMI by -0.13 kg/m^2 (95%CI: -0.22, -0.04).
2013 (15)	USA (8 studies), European countries (18 studies), Turkey (2 studies), Australia (2 studies), Brazil (1 study), and China (1 study)	RCTs	- Nutrition training, physical activity, and parental involvement reduced mean BMI by -0.076 kg/m^2 (95%CI: -0.123, -0.028). - Interventions longer than 1 year provided the greatest effect.
2017 (16)	China	Non-RCTs	- Physical activity and health education reduced mean BMI in children having mixed nutritional status and overweight/obese children by -0.19 kg/m^2 (95%CI: -0.27, -0.11) and -1.80 kg/m^2 (95%CI: -2.15, -1.44), respectively.

Year of publication	Country	Study design	Outcome
			- Physical activity reduced mean BMI in overweight/obese children by -0.91 kg/m^2 (95%CI: -1.15, -0.67).
2019 (9)	High-income western countries (40 studies), Asian countries (7 studies), and South America countries (3 studies)	Cluster RCTs and RCTs	- Multi-component interventions (e.g., diet and physical activity interventions) reduced mean BMI-for-age z-score (BAZ) by − 0.07 (95%CI: − 0.14, − 0.001). - Single-component interventions (e.g., physical activity intervention or health education) reduced mean BAZ by − 0.05 (95%CI: − 0.10, − 0.01).
2021 (17)	Western countries (7 studies) and Asian countries (5 studies)	Cluster RCTs	- The pool effects of nutrition education and physical activity, counselling, counselling and physical activity, and nutrition education reduced mean BMI in overweight/obese children by -0.52 kg/m^2 (95%CI: -0.81, -0.22). - Comparisons between subgroups' effect sizes (expressed as Hedge): low and middle-income countries provided a greater effect than high-income countries, and interventions shorter than six months provided a greater effect than longer interventions
2021 (11)	Western countries (34 studies), Asian countries (7 studies), Oceania (4 studies), and South American countries (3 studies)	Cluster RCTs and RCTs	- Physical activity, school environment, nutrition education, and counselling reduced mean BMI by -0.39 kg/m^2 (95%CI: -0.47, -0.30) and mean BAZ by -0.05 (95%CI: -0.08, -0.02). (11) - Interventions lasted four to six months provided a greater effect on BMI reduction than their counterparts, but the opposite trend was found for BAZ reduction.
2021 (12)	High-income countries	Cluster RCTs and RCTs and quasi-experiments	- Nutrition education, school environment, and parental involvement reduced mean BAZ by -0.06 (95%CI: -0.10, -0.03).

Year of publication	Country	Study design	Outcome
2021 (10)	Western countries	RCTs and quasi-experiments	- School food environment improvement reduced mean BAZ by -0.12 (95%CI: -0.15, -0.10). - RCTs reduced mean BAZ by -0.10 (95%CI: -0.13, -0.07). - Quasi-experiments reduced mean BAZ by - 0.20 (95%CI: -0.26, -0.14).
2012 (18)	Low and middle-income countries	Cluster RCTs and non-RCTs	- 11 multi-component interventions (nutrition education and physical activity interventions) and 14 single-component interventions (nutrition education or physical activity) provided mixed results.
2020 (19)	African countries	RCTs and quasi-experiments	- 7 multi-component interventions (nutrition education and physical activity interventions) and 3 single-component interventions (physical activity) provided mixed results.
2020 (20)	Sub-Saharan Africa	RCTs and pre- & post- tests	- 8 multiple-component interventions (nutrition education and physical activity) and 6 single-component interventions did not significantly increase BAZ.

USA – United States of America; RCT – Randomised control trial

Impacts of the Dekthai Kamsai Programme on overweight and obesity

There was a recent paper published in February 2023, which assessed the impact of the Dekthai Kamsai programme on childhood overweight and obesity (82). This study was published after I had completed the impact evaluation of the programme (see Chapter 4) and had written it up for publication. This recently published study used three sets of cross-sectional anthropometric data from students in all grades, which were measured in the second school term of the 2014 (after five months of intervention exposure), 2016 and 2019 school years and available from the Ministry of Education of Thailand. The first set of data were collected from 311 intervention schools that had participated in the programme from 2014 to 2016, and 1504 comparison schools (Group1). The second set of data were collected from 75 intervention schools that had participated in the programmes since 2019 and 216 control schools (Group 2).

Propensity score matching with difference-in-difference regression analyses were used to compare changes in overweight and obesity between intervention and control schools over time. Between 2014 and 2016, there were 0.6 and 1.1 percentage point reductions, in the probability of overweight in the intervention schools in Group 1 and Group 2, respectively. Between 2014 and 2019, there was 1.7 percentage point reduction in the probability of being overweight and a 0.9 percentage point reduction in the probability of being obese in the intervention schools that joined the programme until 2019. This evaluation showed that the Dekthai Kamsai programme reduced overweight and obesity in schoolchildren. However, there were several limitations of this study. First, it was based on cross-sectional data rather than

panel data which limits causal inferences. Second, it did not use baseline data because the 2014 data were collected after the students had been exposed to the interventions for five executive months. Third, it did not examine programme effectiveness by sex to determine if sex differences exist. Finally, it did not examine factors perceived to influence programme success which is important for scaling-up the programme in Thailand. Thus, further research on this complex school nutrition programme is needed.

1.4 Aim and objectives

As stated, the double burden of malnutrition is increasing among school-aged children living in low- and middle-income countries, including Asia. In Thailand, the prevalence of over-weight and obesity among school aged children is increasing and the prevalence of wasting is relatively high (22).

Growing evidence indicates that multi-component school nutrition interventions are more effective than single component interventions in reducing over-weight and obesity, which underpins global recommendations from the UNSCN and WHO to enhance the quality of school nutrition programmes through the adoption of a systems approach involving multiple components and active stakeholder engagement. Yet, there is limited evidence on whether school-based nutrition interventions can effectively reduce this double burden of nutrition, in Asia, especially undernutrition. In Thailand, more research is needed to determine whether the complex school nutrition intervention (the Dekthai Kamsai programme) is effective in reducing the double burden of malnutrition in primary school-aged children, and the key implementation factors influencing its success. Thus, to influence national policy decisions, further evidence is required, especially in Asia and for national level programmes, on the impact of school-based

nutrition interventions on the double burden of malnutrition and factors influencing its effectiveness. Therefore, to provide such evidence, the aims and objectives of this thesis are as follows:

Aim

To assess the impact and factors influencing the impact of school-based nutrition programmes on over- and undernutrition in school-aged children in Asia.

Objectives

The three objectives of this PhD research are:

1. To review the characteristics and impact of school-based nutrition programmes on over- and undernutrition among school-aged children in Asia.
2. To assess the impact of the Dekthai Kamsai school nutrition programme on over- and undernutrition among Thai school-aged children.
3. To explore underlying reasons which potentially explain why the Dekthai Kamsai is effective or ineffective in addressing over- and undernutrition in Thai school-aged children.

To achieve this aim and these objectives, a systematic literature review of primary school nutrition programmes in Asia initially was conducted to assess the impact of school nutrition programmes on nutrition outcomes and factors that may have contributed to the impact. Afterwards, a mixed-methods study was carried out to evaluate a complex school nutrition intervention in Thailand. The findings from this research will provide evidence that strengthens school nutrition programmes in Asia, especially Thailand.

1.5 Collaborating institution, role of the candidate, and funding

Overall, I was responsible for the conceptual design of the thesis, developing its overall aim and objectives, the study protocols and tools, the data collection and analysis, and writing the manuscripts and the thesis. I also wrote the research proposal to secure funding for the research undertaken in this thesis and wrote the research reports for the funders. My supervisors provided feedback on the entire process. My advisory committee provided feedback on my thesis and the manuscripts.

As described above, the thesis has three objectives. My role in achieving these objectives are as follows. For the first objective, which was systematic literature review and meta-analysis to describe the characteristics and impact of school-based nutrition programmes on the double burden of malnutrition among school children in Asia, I designed the study, conducted the review and data analysis, and drafted the manuscript. I received external support from an independent researcher who did the double screening of papers selected for review and provided a second opinion for the critical appraisal of them.

For the second objective, which was an impact evaluation of the Dekthai Kamsai programme, I obtained the data from IHPF. I was a staff member of IHPF when the evaluation was done in collaboration with the Dekthai Kamsai programme. I contributed to the research design, research proposal development, data collection, data management and analysis, and a research report of the evaluation project. I designed and conducted the data analysis for objective two in my thesis. I drafted a manuscript of this study and shared the draft with my supervisors and all co-authors for their feedback.

For objective three, which was a process evaluation of the Dekthai Kamsai programme, I designed, managed, conducted, and analysed the data for the study. I developed a research proposal and successfully obtained the research funding for this study. I collected the data with staff I trained from the International Health Policy Programme Foundation (IHPF) to assist me with the data collection. These staff members also provided logistical support for the data collection and a second opinion when coding the qualitative data for the process evaluation I analysed the data and wrote a research report for the process evaluation, which was submitted to the funder. I drafted a manuscript of the process evaluation, which was shared with my supervisors and all co-authors for their feedback.

The research projects, undertaken for this thesis, were funded by Thai Health Promotion Foundation. My tuition fees and living costs were funded by Health Policy and System Research Fellowship and IHPF.

Chapter 2

Methods

2.1 Proposed evaluation framework for this PhD research project

The majority of school nutrition programs implemented globally are complex interventions (9, 18), which are defined as interventions containing multiple interacting components that need multiple and difficult actions from actors and recipients as well as multiple stakeholders, provide multiple outcomes, and are adaptable to suit the local context and needs (83).

Randomised controlled trials (RCTs) are considered the gold standard in assessing the effectiveness of an intervention and to establish causality between treatment and outcomes (84). This evaluation design accounts for possible biases by randomly allocating participants into intervention and control arms, and balancing counterfactuals across the groups. However, RCTs alone are unlikely to capture the complexity of complex interventions and are considered impractical for most complex interventions, especially large scale interventions, interventions with small effects, or intervention with long-term effects (83, 85).

To capture the complexity of complex interventions, process evaluation frameworks, including the realist evaluation (25), RE-AIM framework (26), and UK Medical Research Council (MRC) process evaluation (27), were developed to supplement standard evaluation methods. These frameworks enable evaluations to account for the complexity and explain mechanisms of impacts of complex interventions. The realist framework is a theoretical framework, while the others provide practical guidelines. These three frameworks formed the basis of framework developed to guide the design and analyses of my PhD research studies, as described below.

The realist evaluation approach was introduced in 1997 (25). This approach attempts to understand the Context-Mechanism-Outcome pattern Configurations (CMOCs) of complex interventions. Context refers to the conditions that interventions are introduced into. Mechanisms can be referred to as the process that explains how programmes contribute to given outcomes. Outcome patterns encompass multiple intended and unintended consequences as a result of the variations described above. CMOC describes the relationship between a context, mechanism, and outcomes in a particular intervention.

The RE-AIM framework was proposed in 1999 to assess five dimensions of health interventions including reach (participation at the individual level), efficacy or effectiveness (outcomes or impacts of the programme), adoption (participation at the organisational level), implementation (programme delivery e.g., cost and quality of actual implementation), and maintenance (sustainability) (26).

Introduced in 2015, the UK Medical Research Council's (MRC) process evaluation framework investigates three elements contributing to the program's outcomes, which include implementation, mechanism of impact, and context (27). Implementation describes how interventions are implemented in the field. It consists of actual practices and dose, resources, fidelity, adaptations, and reach. Mechanism of impact identifies causal relationships of interventions. It includes responses from and interactions among participants, mediators, unexpected pathways, and consequences. Context refers to contextual factors contributing to the impacts of interventions.

These frameworks share some core components as shown in Table 2. For examples, both the RE-AIM and MRC frameworks have implementation and outcome components, while the realist approach encourages the exploration of all components and their relationships. They also contain different components that have the potential to complement each other and constitute a more complete process evaluation framework. The RE-AIM framework introduces the components of 'adoption' (i.e., why an intervention was adopted/not adopted and how it was adopted in the settings and by stakeholders) and 'maintenance' (how an intervention continued or was integrated into routine practices? did the outcomes remain the same over time?). The MRC and Realist frameworks contain the 'context' components (what are the background conditions of an intervention and interplays between the intervention and condition?), which complement the RE-AIM framework.

Table 2 Components and subcomponents of the RE-AIM, MRC process evaluation and Realist frameworks

Intervention components	Realist	RE-AIM	MRC
Adoption	Not applicable	Organisation and staff participation	Not applicable
Implementation	Context-Mechanism-Outcome pattern Configurations	- Consistency - Adaptation - Cost/resources/time - Reach	- Fidelity (intervention implemented as planned) - Actual practices and dose

Intervention components	Realist	RE-AIM	MRC
	(CMOCs), which explains 'mechanisms' that cause 'outcomes (intentional and unintentional)' in 'certain population groups and conditions (context)'		- Resources - Adaptations - Reach
Mechanism		Not applicable	- Responses from and interactions among participants - Mediators - Unexpected pathways
Outcome		Outcomes/impacts	- Intentional and unintentional consequences
Context		Not applicable	Conditions that interventions are introduced into
Maintenance	- Not applicable	- Continuity of implementation - Long term effects	Not applicable

Therefore, for my PhD thesis, I developed a framework adapted from the current frameworks, which contains the following components:

1) Adoption— how and why the intervention is adopted in the settings and by stakeholders?
2) Implementation —How (across settings and individuals) the intervention is implemented? Were there any changes made along the way? To whom is it delivered and how are their participation?
3) Outcomes — what are the intentional and unintentional consequences?
4) Context — what are the conditions the intervention is introduced into and what is the interplay between this condition and the intervention?
5) Maintenance — Is the intervention institutionalized or integrated into routine practices?

This evaluation framework was expected to enable evaluations that comprehensively informs policy decisions regarding interventions' implementation and scalability. It was developed to not only facilitate investigations on the effectiveness of school nutrition programmes but also to identify internal and external factors influencing the effectiveness. In addition, it was developed to identify lessons learnt on how interventions were adapted to suit the local contexts and vice versa.

I used this evaluation framework to guide my PhD research studies, which included 1) a systematic review and meta-analysis of school nutrition interventions implemented in Asia, 2) a quantitative analysis assessing the impacts of a school nutrition intervention in Thailand, and 3)

a qualitative process evaluation of this school nutrition intervention in Thailand. The systematic review and meta-analysis was done to answer the following research questions: 'how have school nutrition programmes been implemented to address the double burden of malnutrition among school-aged children in Asia?', 'how have these programmes been evaluated?', and 'what are the findings?'. Through this systematic review, I identified methods commonly used for evaluating school nutrition interventions in Asia and gaps in the evidence. This review also informed my second and third studies.

The second study was a quantitative data analysis done to assess the impact of the Dekthai Kamsai school nutrition programme on the double burden of malnutrition in Thai primary school-aged children. It was complemented by my third study, which was a qualitative study designed to provide insights into the underlying reasons explaining the programme's impacts. The findings from these three studies were then synthesised, in the discussion, to provide evidence on 'what works or does not work?', 'in what respects?' 'for whom?' and 'in what circumstances?'. Figure 3 shows the framework of my PhD research.

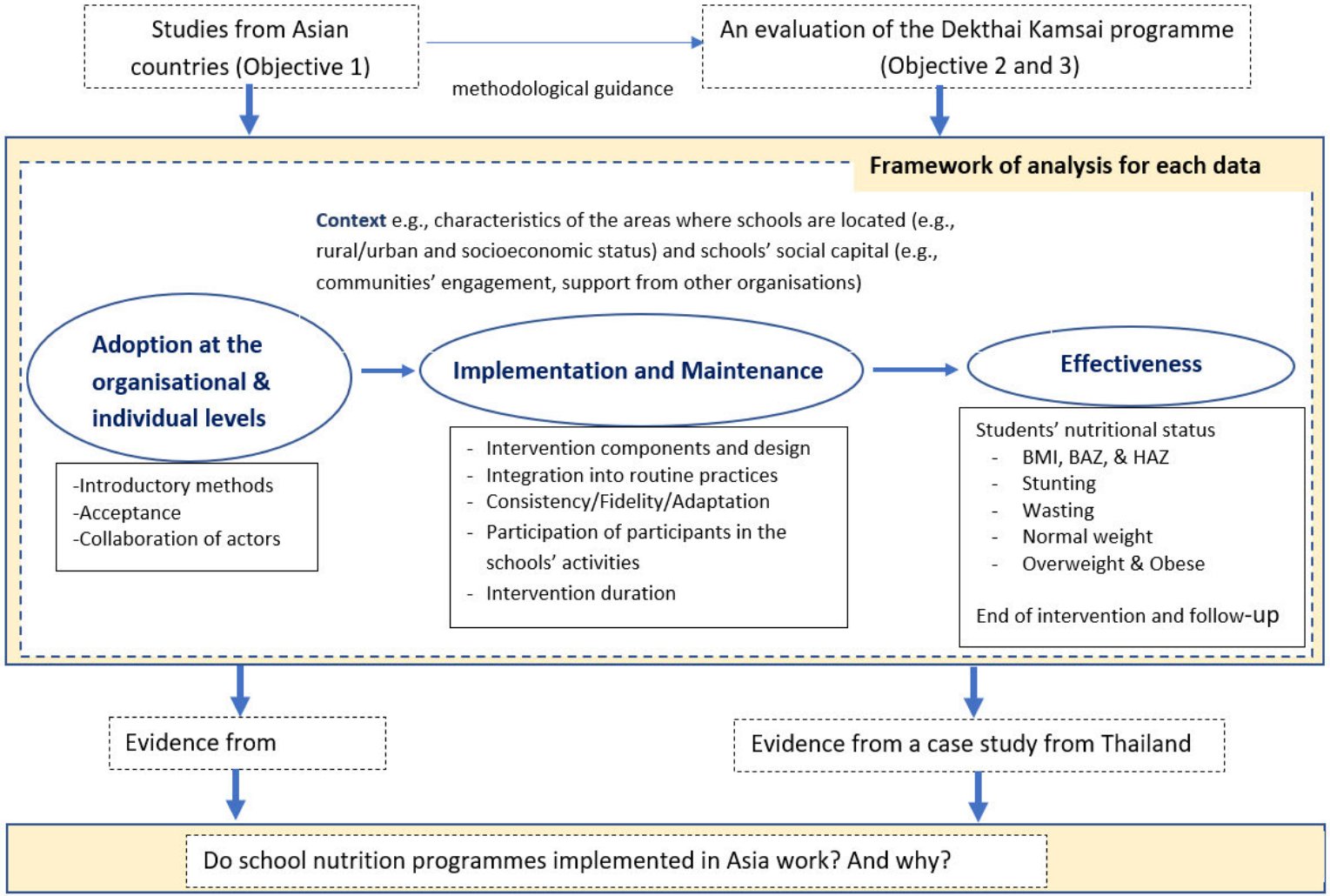

Figure 3 Framework of my PhD research

2.2 Methods for objective 1 (Study 1)

Objective 1 To review the characteristics and impact of school nutrition programmes on over- and undernutrition among school-aged children in Asia.

2.2.1 Research questions:

1. Do primary school nutrition programmes implemented in Asian countries improve the nutritional status of school-aged children?

2. Why are they effective or ineffective in reducing over and undernutrition?

2.2.2 Methods:

I conducted a systematic review and meta-analysis to describe the characteristics and features of school nutrition interventions implemented in Asia and estimated their pooled effects in order to answer the research questions mentioned above. A systematic review was done because it enables comprehensive search together with a critical appraisal and syntheses of relevant empirical studies to provide a comprehensiveness summary of findings in view of possible biases and errors (86). Also, meta-analyses provide estimates of pooled effects from the interventions reviewed (87). These methods are widely used in diverse areas (e.g., medical or health sciences, social sciences, public policy, international development) to provide a comprehensive overview of existing evidence that can inform policy decisions and future research (88).

My review was guided by the Preferred Reporting Items for Systematic reviews and Meta-analyses Protocols (PRISMA-P) (89) and reregistered in PROSPERO with registration no. CRD42021226176.

2.2.1 Search strategies

I searched articles published in peer-review journals in the Web of Science, Embase, Ovid MEDLINE, Global Health, Econlit, APA PsycInfo, and Social Policy and Practice using the following search terms: (student* or kid* or child* or pupil* or youth* or school?age*) AND (BMI or body mass index or wast* or stunt* or overweight* or obes* or nutrition?status) AND (school?based nutrition intervention* or school nutrition intervention*). English articles published from January 2000 to January 2021 were included.

2.2.2 Eligibility and quality assessment

Double screening was conducted independently by two reviewers using the inclusion and exclusion criteria as follows:

Inclusion criteria: Population (school-aged children), intervention (school-based nutrition interventions to improve nutritional status implemented in primary schools in Asia), outcome (BMI, BMI z score, overweight, obesity, stunting, wasting), and study design (complete pre-posttest with control study: including randomised control trials or cluster randomised control trials or quasi-experiments).

Exclusion criteria: Population (school-aged children enrolled in secondary schools or multiple school levels), study design (study protocol with no outcomes).

The quality of randomised and clustered randomised controlled trials was appraised using the Cochrane risk-of-bias tools for randomized trials and cluster randomized trials (90). The randomised and cluster randomised controlled trials were categorised into low risk of bias, some concerns, and high risk of bias. Quasi-experiments were assessed for their quality using the ROBINS-I tool (91). The quasi-experiments were classified into four tiers, namely low, moderate, serious, and critical risk of bias.

2.2.3 Data extraction and data analysis

The following data were extracted from the selected articles: basic bibliographic information, sample size, participant characteristics, the study's objective, study design, intervention characteristics, and outcomes. The effects of the interventions on BMI and BAZ were calculated from differences in mean changes from pre-intervention to post-intervention between intervention and control groups.

Heterogeneity was measured using I^2 statistics. The levels of heterogeneity were rated as low (I^2 = 25%), moderate (I^2 = 50%) or high (I^2 = 75%). Funnel plots and the Egger's test (92) were performed to assess publication bias using STATA version 16.

Random-effects models with inverse variance methods were used to pool the effect estimates. RevMan5.4 was used to estimate the pooled effects, heterogeneity, and sensitivity (93). Differences with a $p<0.05$ were considered as significant. Sensitivity analysis was carried out by excluding experimental studies having a high risk of bias and quasi-experimental studies.

Subgroup analyses were performed according to the following characteristics that were pre-specified in the review protocol: components of interventions (single component versus

multi-component, nutrition education versus extra exercise sessions versus multi-component intervention, and having a healthy food provision [improved school food environment or food boxes by increasing fruits and vegetables or wholegrains, decreasing fat/oil and sugar, and restricting fast food availability in and around schools] versus not having a healthy food provision), duration of intervention (< 1 year versus ≥1 year), sample size (< 1,000 students versus ≥ 1,000 students), and engagement of parents (involved parents versus did not involve parents).

2.3 Methods for objective 2 (Study 2)

Objective 2 To assess the impact of the Dekthai Kamsai school nutrition programme on over and undernutrition among Thai school-aged children.

3.1 Research question: Is the Dekthai Kamsai programme effective in reducing malnutrition among school-aged children?

3.2 Method:

I used statistical methods to analyse secondary data obtained from a Dekthai Kamsai evaluation project conducted by International Health Policy Programme Foundation (IHPF) in collaboration with the Dekthai Kamsai programme. The evaluation employed a quasi-experimental design to measure the impacts of the Dekthai Kamsai programme on the development of school-aged children. The programme was a complex, multi-component programme, including time use, socio-emotional skills, health behaviours, health and nutrition, and well-being (described in Chapter 1). I obtained permission from the research team to use the data required for my PhD research project. The Dekthai Kamsai evaluation project received

ethical approval from the Institute for the Development of Human Research Protections, Ministry of Public Health of Thailand (certificate of approval number IHRP 021-2563) and my analyses received ethical approval from London School of Hygiene and Tropical Medicine (LSHTM Ref. No.26555) (see Appendix 2).

3.2.1 Sampling and sample size

In total, 25 intervention schools and 25 control schools from 12 cities in different regions were invited to participate in the quasi-experiment. Thirty-five schools accepted the invitation, consisting of 16 intervention schools and 19 control schools. All students enrolled in grades 1 to 3 in the selected schools were invited. Written informed consent was received from 2675 students and their parents, consisting of 896 students from intervention schools and 1779 students from control schools. This sample size had 97% power to detect a difference in the rates of overweight and obesity of 20% in intervention and 30% in control groups respectively, using a two-tailed significance level of 0.05 and adjusted for clustering (94). These expected overweight and obesity rates were based on the prevalence of overweight among Thai school-aged children in 2014 after adjusting for an expected increase given the trend for an increase in the prevalence of overweight among Thai children) (21) and the effectiveness of school-based obesity tackling programmes implemented globally in 2014 (95). With no prior information of intra-cluster correlation coefficient (ICC), 0.05 was assumed for both intervention and control arms.

3.2.2 Data collection

The students' weights and heights collected from 2018 to 2019, twice a term (at the beginning and the end of each term), by class teachers who were trained by local health

personnel. In Thailand, there are two terms a year, and each term lasts approximately five months with a three-week and six-week breaks between the two. Therefore, the data were collected eight times in total and the first and eighth measurements were conducted at baseline and the end of the programme.

I assessed the accuracy of the teachers' height and weight measurements to provide insights into the quality of the data analysed by examining the agreement between the measurements obtained by a trained researcher and teachers who carried out the student anthropometric measurements in 2018 and 2019. The data were collected in 2020 from 364 students enrolled in 4 intervention schools (25% of all intervention schools) and 4 control schools (21% of all control schools). The measurement methods and data analysis described previously (96) was adapted. In each school, the researcher and teacher (one teacher/school) were at their station and independently measured the weight and height of each student twice. The teachers used the schools' measurement equipment (stadiometers to the nearest 0.1 cm and digital weighing scales to the nearest 0.1 kg). The researcher used the measurement equipment provided by the evaluation project (a digital scale to the nearest 0.1 kg (Tanita, HD382, Tokyo, Japan) and a portable stadiometer to the nearest 0.1 (Institute of Nutrition, Mahidol University, Thailand)). The results showed that the agreement of the measurements was excellent because the Intraclass Correlation Coefficients (ICCs) of height, weight, BMI, and BAZ were more than 0.9 as shown in Table 3.

Table 3 Agreement between the student anthropometric measurements conducted by researcher and teachers

Variable	Researcher	Teacher	Agreement (ICC)
All samples (N=364)			
Height (Mean, SD)	143.6, 8.9	143.7, 8.9	0.998
Weight (Mean, SD)	38.4, 12.4	38.5, 12.4	0.998
BMI (Mean, SD)	18.29, 4.22	18.29, 4.19	0.999
BAZ (Mean, SD)	0.08, 1.49	0.09, 1.48	0.998
Samples in Dekthai Kamsai schools (N=198)			
Height (Mean, SD)	143.5, 8.9	143.4, 8.9	0.998
Weight (Mean, SD)	38.6, 12.2	38.6, 12.3	0.999
BMI (Mean, SD)	18.41, 4.17	18.46, 4.16	0.998
BAZ (Mean, SD)	0.13, 1.52	0.11, 1.52	0.998
Samples in control schools (N=166)			
Height (Mean, SD)	143.8, 8.8	144.0, 9.0	0.997
Weight (Mean, SD)	38.3, 12.6	38.1, 12.6	0.999
BMI (Mean, SD)	18.10, 4.3	18.16, 4.2	0.999
BAZ (Mean, SD)	0.02, 1.47	0.06, 1.43	0.997

ICC = Intraclass correlations coefficient, SD = Standard Deviation

3.2.3 Data analysis for the impact evaluation

Variables

Predictors: Intervention (Intervention and control schools).

Confounders/effect modifiers: age, sex, urbanicity, parental occupation, and person who usually cooked for the student.

Outcomes: BMI-for-age z-score (BAZ) and height-for-age z-score (HAZ), overweight/obesity, wasting, and stunting.

I determined the children's height-for-age and BMI z-scores using the egen functions Zanthro in STATA that was developed based on the WHO Reference 2007 (97). I classified the children's nutritional status using the WHO growth reference (98) as normal weight (BMI-for-age z-score -2 to 1), stunted (height-for-age z-score <-2), wasted (BMI-for-age z-score <-2), overweight (BMI-for-age z-score >1 to <=2), and obese (BMI-for-age z-score >2). I used the WHO growth reference because it is recommended for international use in low- and middle-income countries.

Statistical methods

To describe baseline characteristics of the participants, I used the mean and standard deviation for BMI, BAZ and HAZ and an independent t-test to test the difference between the intervention and control groups. For categorical variables (wasting, overweight/obesity, and stunting), I calculated the percentage of children classified into each category and used the chi-square test to test for differences between the intervention and control groups.

To determine the effects of the programme, the difference-in-difference methods with linear regression and Poisson analyses for panel data were used for continuous variables (BMI,

BAZ, and HAZ) and categorical variables (wasting, overweight/obesity, and stunting), respectively (99, 100). Difference-in-difference methods are commonly used to estimate effects of public health interventions by examining the differences between intervention and control groups in terms of changes in outcomes over time (99, 100). Although this approach is used to assess causal relationship for policy evaluations, it does not guarantee unbiased effects when there is a possibility of selection bias in a non-randomised study, such as the analyses done for my study (100). Therefore, I applied propensity score matching (PSM) with nearest neighbor matching technique to balance the probabilities of receiving the intervention between treated and untreated participants (100, 101). PSM mimics randomisation by creating a propensity score for each participant based on observed covariates and matching the propensity scores of treated and untreated participants. Unmatched participants were automatically excluded from the identifications of treatment effects in the difference-in-difference models (102). To estimate propensity scores and match the participants, I used the STATA code "psmatch2" to perform logistic regression with the following potential confounding covariates related to context and demographic: "*urban", "sex*", "*age", "parental occupation", and "person who usually cooked for the students"*. Treated participants were matched with seven nearest neighbour controls within a 0.2 caliper.

Although my continuous outcomes had non-normal distributions, I used parametric statistics such as t-test and linear regression without transforming the data to better fit the normal distribution. The justification for using parametric statistics is evidence that they are valid for skewed data in large studies (103-105) and the sample size of my analysis is sufficiently large (2675 participants). These studies showed the t-test provided robust results in a study

with a sample size of 200 (105) and performed better than a nonparametric test (Wilcoxon-Mann-Whitney rank sum test) in highly skewed data of 1000 samples (103). Linear regression models are also valid for non-normally distributed data when the sample size is large (>10 observations/variable) (104). Also, data transformation for normality distribution is unnecessary for large studies, may provide invalid results, and make result interpretation more sophisticated (104).

2.4 Methods for objective 3 (Study 3)

Objective 3 To explore underlying reasons which potentially explain why the Dekthai Kamsai is effective or ineffective in addressing over- and undernutrition in Thai school-aged children.

4.1 Research questions: Why and how the programme was adopted, implemented, delivered, and effective/ineffective?

4.2 Methods:

4.2.1 Process evaluation design

This process evaluation qualitatively assessed the following components.

1. Adoption

   Aim: To assess factors affecting the programme adoption and to assess the practices used to integrate the programme into schools' routine practices.

   Evaluation topic guide:

   - Why the intervention was adopted or not adopted?

- Whether the intervention was institutionalized or integrated into routine practices and how?

2. Implementation

   Aim: To assess the programme's fidelity and variation in delivery across intervention schools and to compare between the implementation of intervention and control schools.

   Evaluation topic guide:

   - How the intervention was implemented and adapted?
   - Whether the implementation align with the programme's guidelines and requirements (fidelity assessment)?

     Fidelity was classified into three levels:

     1) Good if all programme's components were implemented and requirements for the components were achieved.

     2) Moderate if all programme's components were implemented, but requirements for the components were not achieved.

     3) Poor if some programme's components were implemented and requirements for the components were not achieved.
   - Who delivered the programme? to whom it was delivered and how was their participation?
   - What were the control schools' routine practices to promote students' health, nutrition, and well-being?

3. Observable outcomes

Aim: To assess both intentional and unintentional outcomes.

Evaluation topic guide:

- What were the consequences of the programme (both intentional and unintentional)?

4. Influence of school context

Aim: To assess contextual factors that might influence the adoption, implementation, and outcomes of the programme.

Evaluation topic guide:

- What were the conditions the intervention was introduced into?
- What was the interplay between this condition and the intervention?

This process evaluation was conducted using a qualitative approach, which consisted of focus group interviews (FGIs) and a document analysis. There was no quantitative information for retrospective analysis to describe integrity or fidelity of the programme's implementation. This process evaluation received ethical approvals from the Institute for the Development of Human Research Protections (IHRP 021-2563) and London School of Hygiene and Tropical Medicine (LSHTM Ref. No.26555) (see Appendix 2).

4.2.1.1 Focus Group Interviews

Fourteen FGIs were conducted with 69 school staff (4-6 school staff/school) from 14 participating schools (1 FGI/school), including both intervention schools (n=10) and control schools (n=4). The participating schools consisted of group 1: five intervention schools that had the highest increase in the percentage of students becoming normal weight (BMI-for-age z

score -2 to 1) over the intervention period, group 2: five intervention schools that had the lowest percentage of students becoming normal weight over the intervention period (three schools had a high increase in the overweight rate, one school had a high increase in the wasting rate, and one school had a high increase in both rates), and group 3: four control schools as shown in Table 4.

For the intervention schools, the respondents for each FGI included school principal and staff who were involved in the implementation of the Dekthai Kamsai programme in 2018 and 2019. For control schools, the respondents for each FGI were school principal and staff who were responsible for school lunches and students' health in general. These focus group interviews were conducted via video conferences from January to February 2022, since face-to-face FGIs were considered unsafe during the COVID-19 pandemic. Each session took around one hour ($\pm$15 minutes) at a time convenient for the respondents (see the topic guide for the FGIs in Appendix 4). With permission from the respondents, the FGIs were tape recorded, transcribed verbatim and saved in a code-protected personal computer.

Table *4* Participating schools' programmatic outcomes: changes in the rates of wasting, normal BMI, and overweight and obesity between 2018 and 2019

School	Wasting (%)	Normal BMI (%)	Overweight and obesity (%)
Group1: Intervention schools with maximum impacts			
School#1	-7.4	9.0	-1.7
School#2	-2.5	6.6	-4.1
School#3	-8.7	5.3	3.4
School#4	-4.4	5.5	-1.1
School#5	-1.2	1.2	0.0
Group2: Intervention schools with minimum impact			
School#6	-1.6	-0.7	2.3
School#7	2.1	-2.6	0.5
School#8	-0.7	-5.6	6.3
School#9	6.9	-11.1	4.2
School#10	-0.5	-15.5	16.0
Group3: Control schools			
School#11	-4.8	3.0	1.8
School#12	-3.4	0.4	3.0
School#13	-2.5	-4.7	7.2
School#14	0.2	-4.7	4.5

4.2.1.2 Document analysis

The following documents were analysed including all materials provided to participating schools by the Dekthai Kamsai programme (including, school food standard and management guidelines and handbooks and the pamphlets used to guide implementation of the programme), transcripts of semi-structured interviews conducted in 2019 by me assessing school practices for all intervention components in 2018 and 2019 with 45 school staff in 10 intervention schools, the schools' progress reports, the Dekthai Kamsai programme's progress reports in 2018 and 2019, and the Dekthai Kamsai lessons learned reports published in 2018 and 2019.

4.2.2 Data analysis

Findings from the different methods and sources were analysed using the framework analysis technique developed for applied policy research (106), which allows the use of predetermined codes based on my evaluation framework mentioned earlier, while remaining open to emergent new themes (106). This technique was chosen because 1) it is suitable for my research questions that aim to describe contexts, potential factors contributing to its effectiveness and areas for policy improvements., and 2) it allows the combination of inductive and deductive approaches needed to analyse the data according to my process evaluation framework while simultaneously remaining open to new analytical themes or issues raised by the informants. The analysis process followed six steps, namely familiarisation with the data, identifying a thematic framework, indexing the data, charting the data into the framework matrix, and interpretation.

The data from the two methods and different sources were triangulated to cross-check response agreement and reduce potential biases using a protocol adapted from Farmer et. al.'s method (107). Two researchers independently conducted coding using Excel spreadsheets and assessed the convergence and completeness of the data from different sources. Discrepancies were discussed between them to reach agreement. The Standards for Reporting Qualitative Research (SRQR) checklist (108) was used to guide the reporting of results.

Chapter 3

Impacts of school nutrition interventions on the nutritional status of school-aged children in Asia: A systematic review and meta-analysis

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SECTION A – Student Details

Student ID Number	1801282	**Title**	Miss
First Name(s)	Suladda		
Surname/Family Name	Pongutta		
Thesis Title	The impact of complex school nutrition programmes on the nutritional status of school-aged children: A review of Asian countries' experiences and lessons from a case study in Thailand		
Primary Supervisor	Leesa Lin		

If the Research Paper has previously been published please complete Section B, if not please move to Section C.

SECTION B – Paper already published

Where was the work published?	Nutrients		
When was the work published?	28 January 2022		
If the work was published prior to registration for your research degree, give a brief rationale for its inclusion			
Have you retained the copyright for the work?*	**Yes**	Was the work subject to academic peer review?	**Yes**

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Stage of publication	

SECTION D – Multi-authored work

For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	I designed the review, undertook the literature searches, reviewed the literature, wrote the first draft of the paper, and responsed to reviewers' comments.

SECTION E

Student Signature	[redacted]
Date	4 May 2023

Supervisor Signature	[redacted]
Date	12 May 2023

nutrients

MDPI

Review

Impacts of School Nutrition Interventions on the Nutritional Status of School-Aged Children in Asia: A Systematic Review and Meta-Analysis

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Abstract: This review aims to describe school nutrition interventions implemented in Asia and quantify their effects on school-aged children's nutritional status. We searched Web of Science, Embase, Ovid MEDLINE, Global Health, Econlit, APA PsycInfo, and Social Policy and Practice for English articles published from January 2000 to January 2021. We quantified the pooled effects of the interventions on the changes in body mass index (BMI) and body mass index z score (BAZ), overall and by type of intervention. In total, 28 articles were included for this review, of which 20 articles were multi-component interventions. Twenty-seven articles were childhood obesity studies and were included for meta-analysis. Overall, school nutrition interventions reduced school-aged children's BMI and BAZ. Multi-component interventions reduced the children's BMI and BAZ, whereas physical activity interventions reduced only BMI and nutrition education did not change BMI or BAZ. Overweight/obesity reduction interventions provided a larger effect than prevention interventions. Parental involvement and a healthy food provision did not strengthen school nutrition interventions, which may be due to an inadequate degree of implementation. These results suggested that school nutrition interventions should employ a holistic multi-component approach and ensure adequate stakeholder engagement as well as implementation to maximise the effects.

Keywords: school nutrition interventions; school-aged children; nutritional status; obesity; Asia

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1. Introduction

Malnutrition covers various health conditions, including stunting, wasting, underweight, micronutrient deficiencies, overweight, obesity, or diet-related non-communicable diseases [1]. Malnutrition is a leading risk factor for global disability adjusted life years (DALYs), of which children are most affected [2]. The regional trends in malnutrition among children aged 5–19 years are diverse. A four-decade trend (from 1975 to 2016) showed that overnutrition in high-income countries has been stable, while increasing sharply in Asian countries [3]. In addition, overnutrition is the predominant form of malnutrition in high-income countries and some Oceania countries, while a 'double burden' of malnutrition—both under- and overnutrition—is prevalent in Asia and Africa. Malnutrition prevents children from developing to their full potential [4], which could affect not only health outcomes but also other pillars of sustainable development such as education and income.

School nutrition interventions have been implemented in many countries across the world using various approaches to address malnutrition among children [5,6]. During the last two decades, several systematic reviews assessing the effectiveness of school-based nutrition interventions have been published [7–13]. These systematic reviews indicated

that the effectiveness of the interventions varied by context. Interventions implemented in high-income western countries [7–9] and China [10] were effective, especially multi-component interventions. On the other hand, school nutrition interventions implemented in low- and middle-income countries showed inconclusive results [11–13]. Few systematic reviews focused on Asian countries except for China. Therefore, it is still obscure whether school nutrition interventions implemented in the Asian contexts were effective and to what extent.

The effectiveness of school nutrition interventions may also vary by school levels (e.g., pre-, primary, and secondary schools) due to different conditions of children's growth and development, and different food environments in primary and secondary schools [8,14–16]. Primary schools are the intermediate level that provide a great opportunity to improve child nutrition because primary schools reach the majority of the young population [17] and impairments resulting from early child malnutrition could be reduced in primary school children [18]. To make the most of this great opportunity, effective primary school interventions should be implemented. To ensure the effectiveness of school nutrition interventions, the guiding evidence on "what works" and "how" is critical [19]. Unfortunately, the current literature does not focus specifically on assessing the effectiveness of school nutrition interventions implemented in primary schools [7–13].

To date, the effectiveness of primary school nutrition interventions implemented in Asia is still unknown. This missing piece of evidence is crucial for nutrition policy decisions in Asia. This review, therefore, aims to determine the effectiveness of primary school nutrition programmes on reducing any forms of malnutrition among school-aged children in Asian countries.

2. Methods

2.1. Search Strategies

This systematic review was conducted following the Preferred Reporting Items for Systematic reviews and Meta-analyses Protocols (PRISMA-P) guidelines [20]. It was reregistered in PROSPERO with registration no. CRD42021226176.

The search was carried out in Web of Science, Embase, Ovid MEDLINE, Global Health, Econlit, APA PsycInfo, and Social Policy and Practice using these following search terms: population (student* or kid* or child* or pupil* or youth* or school?age*), outcome (BMI or body mass index or wast* or stunt* or overweight* or obes* or nutrition?status), and intervention (school?based intervention* or school intervention*). English articles published from January 2000 to January 2021 were included.

2.2. Eligibility and Quality Assessment

Double screening was conducted independently by two reviewers using the inclusion and exclusion criteria as follows:

- Inclusion criteria: Population (school-aged children), intervention (school-based nutrition interventions for any types of nutritional status implemented in primary schools in Asia), outcome (BMI, BMI z score, overweight, obesity, stunting, wasting), and study design (complete pre-posttest with control study: randomised control trial or cluster randomised control trial or quasi-experiment)
- Exclusion criteria: Population (school-aged children enrolled in secondary schools or multiple school levels), study design (study protocol of pre-posttest with control study.

The quality of randomised and clustered randomised controlled trials was appraised using the Cochrane risk-of-bias tools for randomised trials and cluster randomised trials [21], respectively. The randomised and cluster randomised controlled trials were categorised into low risk of bias, some concerns, and high risk of bias. Quasi-experiments were assessed for their quality using the ROBINS-I tool [22]. The quasi-experiments were classified into four tiers, namely low, moderate, serious, and critical risk of bias.

2.3. Data Extraction and Data Analysis

The following data were extracted from the selected articles: basic bibliographic information, sample size, participant characteristics, study's objective, study design, intervention characteristics, and outcomes. The effects of the interventions on body mass index (BMI) and body mass index z score (BAZ) were calculated from differences in mean changes from pre-intervention to post-intervention between intervention and control groups.

Heterogeneity was measured using I^2 statistics. The levels of heterogeneity were rated as low (I^2 = 25%), moderate (I^2 = 50%) or high (I^2 = 75%). Funnel plots and the Egger's test [23] were performed to assess publication bias using STATA version 16.

Random-effects models with inverse variance methods were used to pool the effect estimates. RevMan5.4 [24] was used to estimate the pooled effects, heterogeneity, and sensitivity. Differences with a $p < 0.05$ were considered as significant. Sensitivity analysis was carried out by excluding experimental studies having a high risk of bias and quasi-experimental studies.

Subgroup analysis was performed according to the following characteristics that were pre-specified in the review protocol: components of interventions (single-component versus multi-component, nutrition education versus extra exercise sessions versus multi-component intervention, and having a healthy food provision (i.e., improved school food environment or food boxes by increasing fruits and vegetables or whole grains, decreasing fat/oil and sugar, and restricting fast food availability in and around schools) versus not having a healthy food provision), duration of intervention (<1 year versus ≥1 year), sample size (<1000 students versus ≥1000 students), and engagement of parents (involved parents versus uninvolved parents).

3. Results

3.1. Results of Screening Process

The PRISMA diagram of this review is shown in Figure 1. The search yielded 8738 publications. After excluding the duplicates, the titles and abstracts of 8334 publications were screened and 81 articles were retrieved for full-text screening. In total, 28 articles were included for data extraction. The reasons for exclusion were mainly related to study designs (not complete RCTs/quasi-experiments pre-posttest with control) and target populations (not in Asian countries).

3.2. Characteristics and Quality of Included Studies

The selected papers were published between 2004 and 2020. These studies included 15 cluster randomized control trials (CRCTs), 10 quasi-experiments, and 3 randomized controlled trials (RCTs), which accounted for 53.6%, 35.7%, and 10.7%, respectively. They were conducted in nine countries and two territories from different regions of Asia, namely mainland China [25–36], Hong Kong–China [37,38], Taiwan–China [39], Korea [40], Turkey [41–43], Lebanon [44,45], Israel [46,47], Iran [48], India [49], Malaysia [50], and Thailand [51]. The majority of the studies (75%) took place in upper-middle income countries [25–36,41–46,49,51,52], followed by high-income countries (21.4%) [37–40,46,47] and low-middle income countries (3.6%) [49]. Most of these studies (85.7%) were carried out in urban areas or large cities [25–29,31–38,40–45,47–51]. The rest (14.3%) were carried out in rural areas [30,39,45,51]. Characteristics of included studies are summarised in Table 1.

Among CRCTs and RCTs, nine studies were categorised as high risk of bias mostly due to the lack of information on controlling possible bias for either the outcome measurement or from non-adherence, and selective reporting of findings [25,27,30–32,41–45,52]. The rest were studies with some concerns [28,34,37,39,48] or low risk of bias [29,33,36]. For the quasi-experiments, seven out of nine studies were rated as serious risk of bias [35,40,46–48,50,51] that was mostly due to insufficient control of possible bias from either possible confounders or dropouts, and/or selective reporting of findings. Other studies were rated as moderate risk of bias [38] or low risk of bias [26].

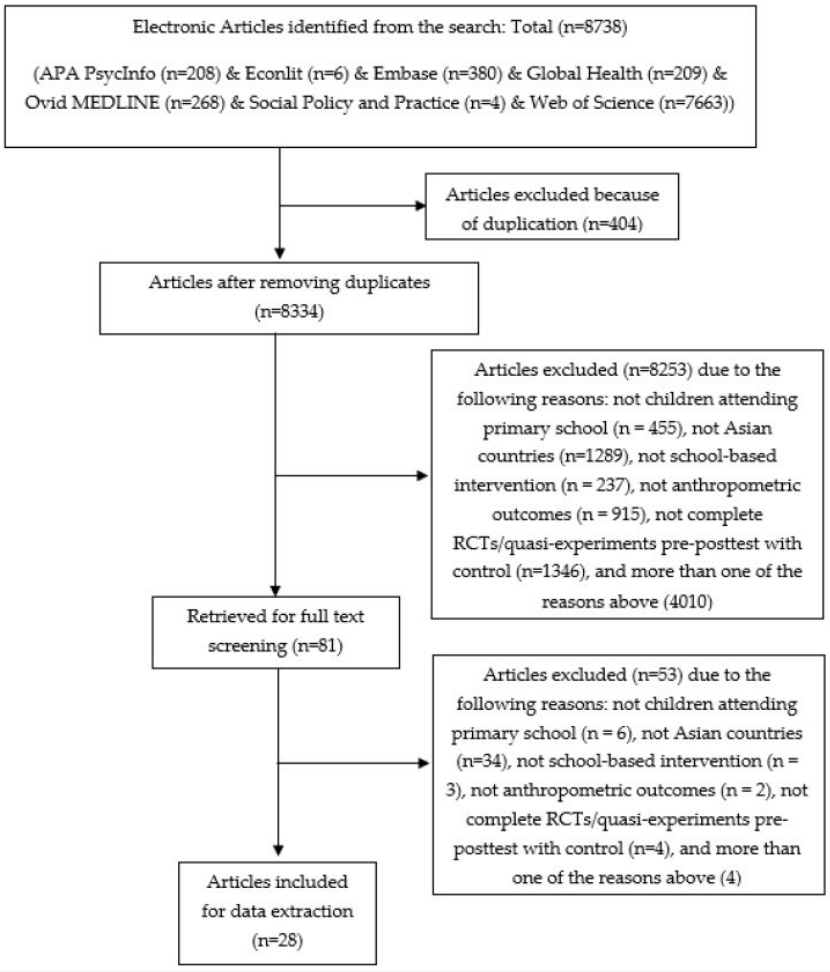

Figure 1. PRISMA diagram of the review process.

Table 1. Summary of the studies included in this review.

Category	Number (%)
Study design	
RCTs	3 (10.7)
Cluster RCTs	15 (53.6)
Quasi-experiments	10 (35.7)
Intervention component	
Nutrition education	5 (17.9)
Extra exercise	3 (10.7)
Multi-component *	20 (71.4)
Intervention duration	
<1 school year	11 (39.3)
≥1 school year	17 (60.7)

Table 1. *Cont.*

Category	Number (%)
Sample size	
<100 students	6 (21.4)
≥100–1000 students	12 (42.9)
>1000 students	10 (32.7)
Country income	
High-income country	6 (21.4)
Low and middle-income country	22 (78.6)
Urbanity	
Urban	24 (85.7)
Rural	4 (14.3)

* Nutrition education, extra exercise, enabling school environments for food and physical activity, psychological intervention, and individual consultations.

3.3. Characteristics of Interventions

Although the double burden of malnutrition has been the main problem in Asia for decades, almost all interventions (27 out of 28 studies) aimed to address childhood overweight and obesity. Only one study was conducted to tackle undernutrition [45]. Among the childhood overweight and obesity studies, eight studies were overweight/obesity reduction (included only overweight/obese children) [26,30,32,37,40,48,50], while the others were prevention studies (included children with all nutritional status). More information is shown in Table S1.

Six studies were carried out primarily by researchers in the health sector [25,27–29,34,35], while most studies were conducted by academic institutions. Five interventions co-developed relevant curriculums or programmes in collaboration with government agencies such as the Ministry of Education [31,44,47], educational and health authorities [42], and the local council [46] to gain cooperation from schools and other local stakeholders. Six interventions were the health sectors' initiatives [25,27–29,34,35], while the rest did not seek government support to work with the schools. Detailed information is described in Table S2.

To implement the interventions, five studies were conducted entirely by investigators [32,38–40,43] and 23 studies engaged the schools and local actors. For the latter, teachers were engaged to provide nutrition education (NE) [28,29,45], physical activity promotion, such as physical education (PE), exercise prescriptions or/and enabling environment for active lifestyle [30,34,35,47], both NE and physical activity promotion [25,27,31,36,42,44,46,48,49], and to take students' anthropometric measurement [51]. Kitchen or canteen staff were asked to provide healthier food [27,28,31,33,36,42,44,45,48,49]. Parents were trained to encourage a healthy diet and/or active lifestyle in children [25–29,31,37,41,42,44,47–49,51] (see Table S2).

The majority of studies (20 studies, 71.4%) implemented multiple-component interventions [25–33,36,37,40,42,45–51]. Among these studies, eight studies implemented nutrition education and extra exercise sessions [25,26,28–30,37,40,47]. Nine studies implemented nutrition education, extra exercise sessions, and additional components, such as healthier school food or lunch boxes, enabling school environments for an active lifestyle, psychological intervention, and individual consultations [31–33,36,42,44,46,48,49]. Two studies provided nutrition education and healthy meals including whole grains [50] and healthy snacks [45]. One study provided nutrition education and participatory eating events/campaigns [27]. Among the single-component interventions, five studies provided nutrition education [39,41,43,44,52] and three studies implemented extra exercise sessions [33,34,37] (see Table S2).

The sample sizes ranged from 32 to 8853 children. Among these, 21.4% were small studies (<100 students), 42.9% were medium studies (100–1000 students) and 32.7% were large studies (>1000 students). The duration of the interventions ranged from 8 weeks to five

school years. Most interventions conducted 1-school-year programmes [25–28,32–34,36,41,45,46], the others conducted 8-week to 8-month programmes [30,35,37,39,40,42–44,49,51,52], 2-year programmes [31,44,47], 3-year programmes [29,45], and a 5-year programme [48] (see Table 1).

3.4. Impacts of Interventions

Most studies reported either BMI or BAZ. Of the 28 studies, 24 studies were eligible for the meta-analysis. Four studies were excluded because they did not report usable forms of outcomes, e.g., no information of standard deviation (SD), standard error (SE), or 95% confidence interval (CI) [35,41,46] or only addressed undernutrition which did not align with other studies [45]. Therefore, the overall effects described in this study are the effectiveness of the school nutrition interventions in reducing BMI or BAZ.

3.5. BMI

Fifteen studies (27 trials) reported BMI as an outcome. The pooled effect of the interventions was a reduced school-aged children's BMI by -0.36 kg/m^2 (95% CI: -0.46, -0.25).

Subgroup analyses identified variation in effectiveness, depending on the type of intervention. The pooled effect size of multi-component interventions was higher than single-component interventions with BMI reductions of -0.54 (95% CI: -0.85, -0.23) kg/m^2 and -0.12 kg/m^2 (95% CI: -0.21, -0.04) respectively, (Figure 2). The confidence intervals of the two pooled effects do not overlap. Among the single-component interventions, extra exercise sessions significantly changed BMI with pooled effects of -0.23 kg/m^2 (95% CI: -0.40, -0.06), while nutrition education did not show a significant change (-0.33 kg/m^2 (95% CI: -0.74, 0.08), (See Figure 3).

The results of subgroup analyses for treatment and prevention interventions, showed that the pooled effect size of interventions aiming to reduce overweight/obesity was higher than interventions aiming to prevent it with the reductions of -0.94 kg/m^2 (95% CI: -1.41, -0.47) and -0.23 kg/m^2 (95% CI: -0.35, -0.12), respectively (see Figure S1). Five multi-component interventions were found in 12 overweight/obesity treatment interventions (42%), and six were found in 15 overweight/obesity prevention interventions (40%).

There was no significant difference in BMI reduction between interventions with and without parents' participation with BMI reductions of -0.24 kg/m^2 (-0.62, 0.14) and -0.29 kg/m^2 (-0.41, -0.16), respectively (see Figure S2). The subgroup without parents' participation contained a lower percentage of multi-component interventions (5 out of 15 trials, 33%) compared to the group with parents' participation (6 out of 12 trials, 50%). The subgroup without parents' participation and the group with parents' participation contained overweight/obesity treatment equally at 5 out of 15 trials (33%) and 4 out of 12 trials (33%), respectively.

Subgroup analysis for interventions with and without healthy food provision showed that the interventions without healthy food provision group reduced BMI with a reduction of -0.77 kg/m^2 (-1.34, -0.19), while the interventions with healthy food provision group did not show a significant reduction. Multi-component interventions were found more frequently in the interventions with healthy food provision than another group (9 out of 9 (100%) versus 12 out of 18 (67%), respectively). Twelve out of 18 interventions without healthy food provision (67%) were overweight/obesity treatment, while none was found in the subgroup of interventions with healthy food provision.

Subgroup analyses according to other characteristics of interest did not show significant differences between subgroups.

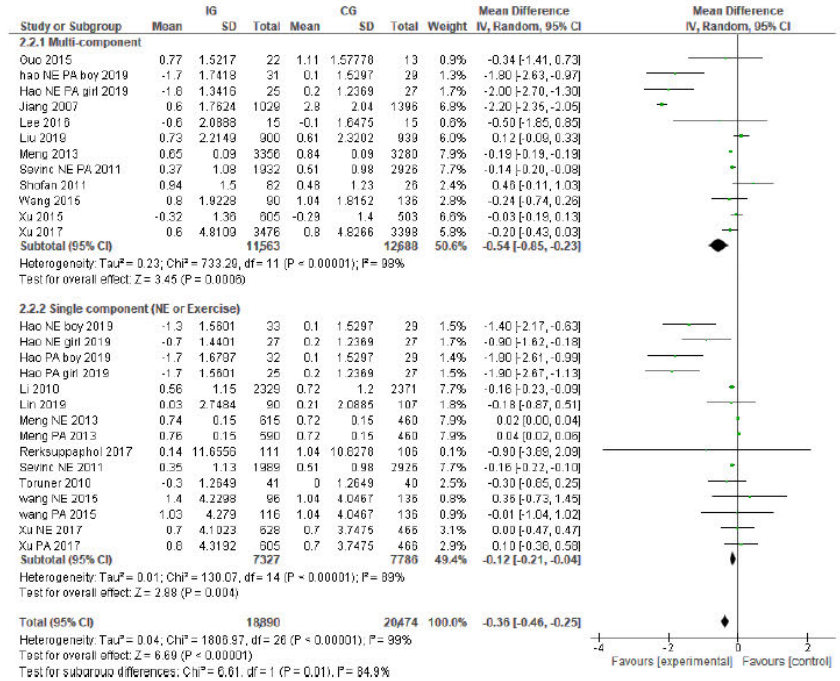

Figure 2. Overall effects on BMI and the difference between multi-component interventions and single-component interventions.

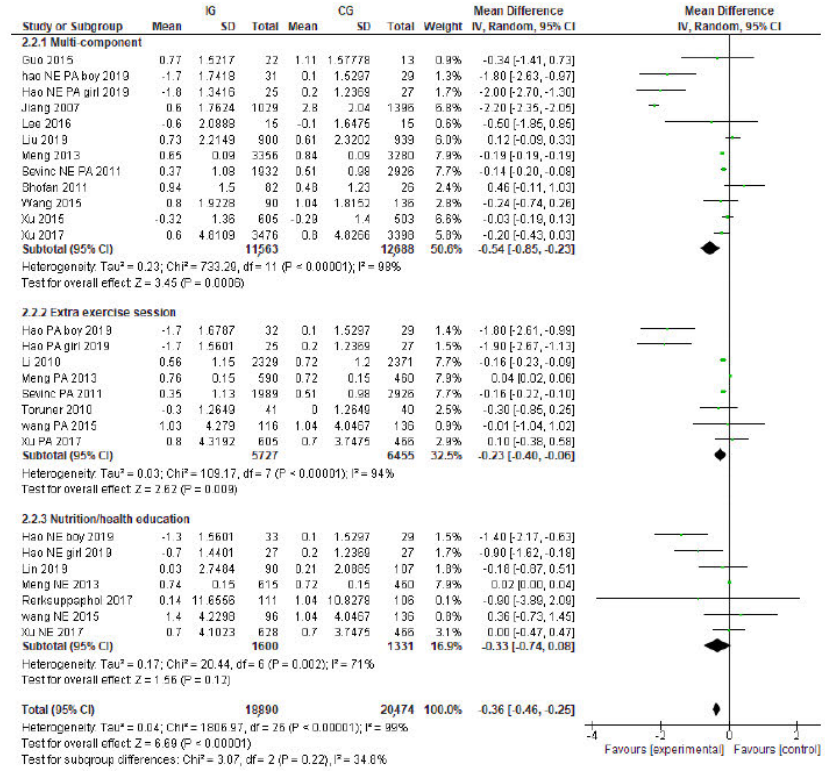

Figure 3. Pooled effects on BMI and the differences between multi-component interventions, nutrition education, and extra exercise prescription.

3.6. BAZ

The pooled effect of 15 studies (20 trials) reporting BAZ was a statistically significant reduction of −0.05 (95% CI: −0.08, −0.03).

Categorised by the interventions' component, the multi-component interventions significantly reduced BAZ by −0.07 (95% CI: −0.08, −0.05), while the pooled effect size of single-component interventions was not statistically significant (See Figure 4). No significant difference was found between nutrition education and extra exercise prescription (See Figure 5).

Similar to the change of BMI, overweight/obesity treatment interventions showed greater effect in reducing BAZ than overweight/obesity prevention interventions with the reductions of −0.15 (95% CI: −0.28, −0.02) and −0.05 (95% CI: −0.07, −0.02), respectively (see Figure S2). All overweight/obesity treatment interventions and six overweight/obesity prevention interventions of 16 studies (40%) were multi-component interventions.

The interventions with parents' participation did not show an outstanding impact. These interventions provided a BAZ reduction of −0.05 (−0.09, −0.01), while the interventions without parents' participation had a BAZ reduction of −0.06 (−0.10, −0.02) (see Figures S2 and S4). Also, there was no difference between the percentage of multi-component interventions among the with and without parents' participation groups (6 out of 11 trials, 55% versus 5 out of 9 trials, 56%, respectively). Three out of 11 interventions without parents' participation (21%) were overweight/obesity treatments, while only 1 out of 9 interventions with parents' participation (11%) was an overweight/obesity treatment.

Subgroup analysis for interventions with and without healthy food provision showed slightly different BAZ reductions between the subgroups. The interventions without healthy food provision provided a BAZ reduction of −0.09 (−0.16, −0.03), while the interventions with healthy food provided a BAZ reduction of −0.04 (−0.07, −0.01). Nine out of 10 interventions with healthy food provision (90%) were multi-component interventions, while only 2 out of 10 interventions without healthy food provision (20%) were multi-component interventions. Overweight/obesity interventions equally belonged to interventions with and without healthy food provision subgroups.

Subgroup analyses according to other characteristics of interest did not show significant differences between subgroups.

3.7. Sensitivity Analysis and Publication Bias

The results of the sensitivity analysis indicated that there were no major changes of pooled effects after excluding studies with a high risk of bias or a quasi-experimental design, as shown in Figures S7 and S8. The BMI pooled effects sizes were −0.34 kg/m^2 (95% CI: −0.49, −0.19, I^2 = 99%) and −0.39 kg/m^2 (95% CI: −0.50, −0.28, I^2 = 99%), respectively, compared with the original −0.36 kg/m^2 (95% CI: −0.46, −0.25, I^2 = 99%).

Publication bias also was not detected. Even though the funnel plot of the studies' effects on BMI was not perfectly symmetric (see Figure 6), the Egger's regression test did not reject the null hypothesis (p = 0.2234).

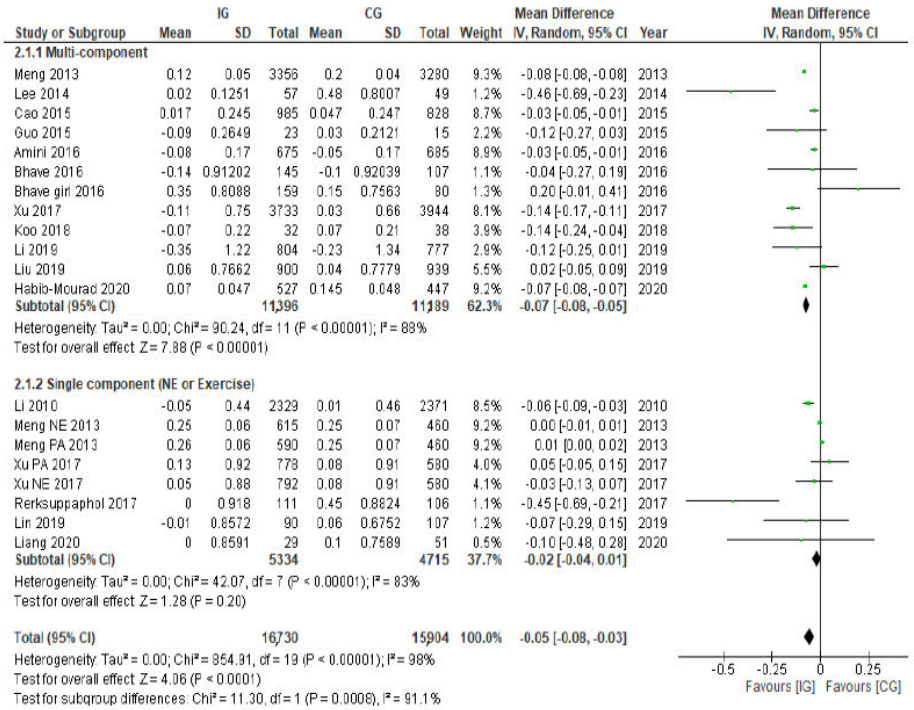

Figure 4. Pooled effects on BAZ and the difference between multi-component interventions and single component interventions.

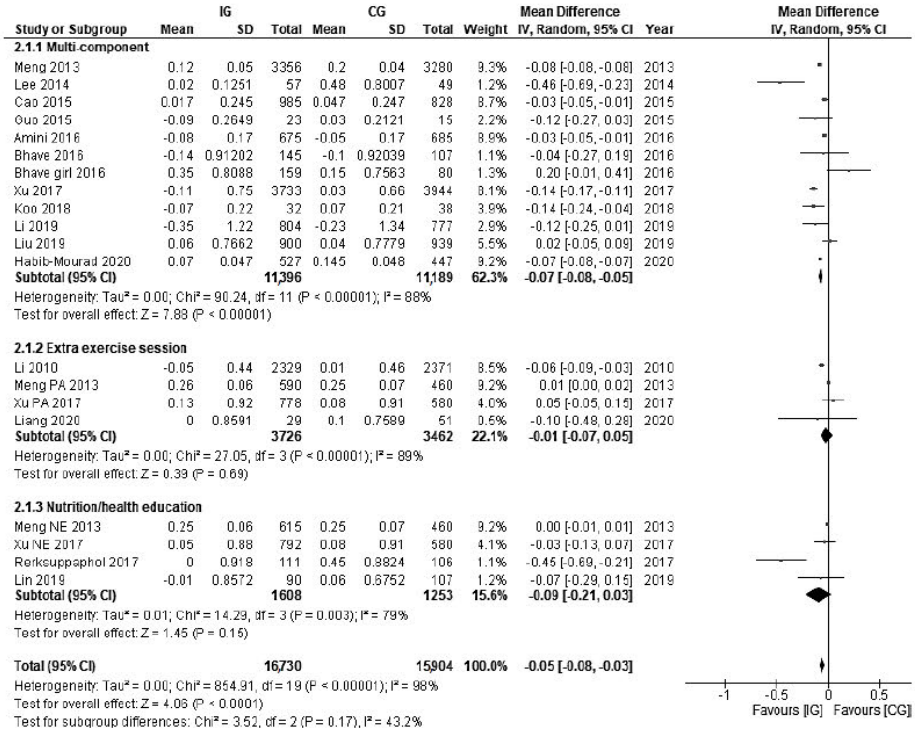

Figure 5. Pooled effects on BAZ and the differences between multi-component interventions, nutrition education and extra exercise prescription.

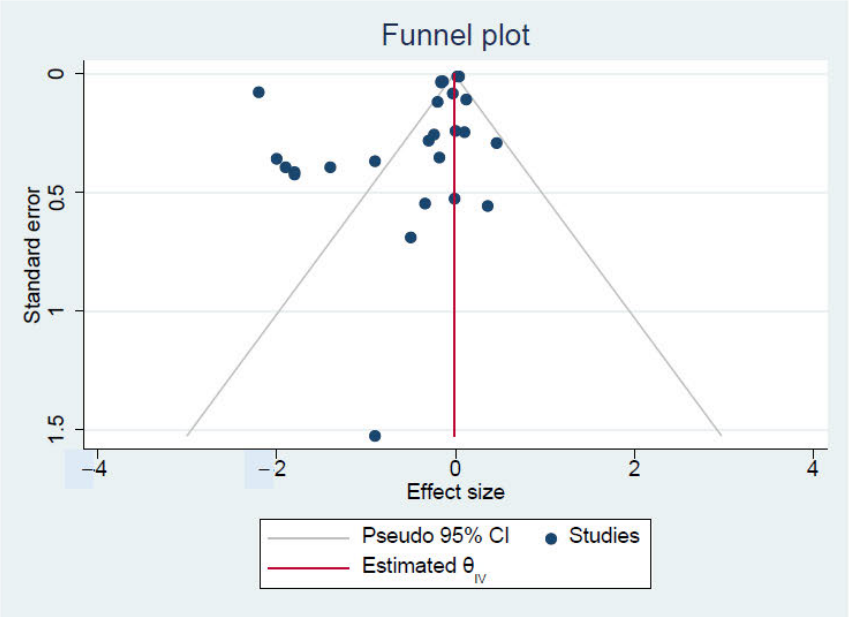

Figure 6. Funnel plot of effects.

4. Discussion

Our findings suggest that, in general, primary school nutrition interventions implemented in different Asian countries significantly reduced BMI and BAZ among school-aged children. However, the effectiveness varies with certain characteristics of the interventions. In terms of intervention components, multi-component interventions showed significant reductions for both BMI and BAZ, while single-component interventions showed a significant reduction only for BMI. In addition, multi-component interventions had a stronger effect than single-component interventions in reducing BMI. Among the single-component interventions, extra exercise sessions significantly reduced the BMI of the children, while nutrition education did not. In terms of intervention aim, overweight/obesity treatment provided stronger effects in reducing BMI and BAZ than overweight/obesity prevention interventions. Involving parents in the interventions did not significantly strengthen the effectiveness of the interventions. Interventions with school food improvement showed a smaller effect size than interventions without the component.

School nutrition interventions were effective in reducing BMI and BAZ among children of all ages in western/high-income countries and China [7–10]. This review adds to the current body of evidence that the interventions were effective in school-aged children in Asian countries as well. This accumulated evidence suggests that school nutrition interventions are promising measures in addressing childhood overweight/obesity across diverse contexts.

The results also suggested that multi-component interventions are more effective than single-component interventions, which are in line with the findings of meta-analyses from other contexts [8–10]. These findings emphasise the importance of a holistic approach in addressing childhood obesity. Among the single-component interventions, this review found that a significant reduction of BMI yielded from physical activity interventions but not nutrition education. A meta-analysis from China [10] also found a significant reduction of BMI from physical activity interventions, while the impacts of nutrition education were not reported. In terms of the educational strategies used in the trials, there was no major difference between nutrition education interventions and multi-component interventions. Most of the interventions were a classroom-based approach, and all interventions emphasised the importance of having a healthy diet, active lifestyle, and normal body weight,

as well as provided guidance on body weight management through a variety of teaching materials. Thus, the different effects found from multi-component and nutrition education interventions may be due to the synergistic power of multiple components. The numbers of trials included in the physical activity and nutrition education subgroup analyses were not different (eight and seven trials, respectively), so the different effects between the interventions may not be due to the size of the analyses. Among the nutrition education interventions, only two trials showed significant BMI reductions. They were conducted in overweight/obese children who had never received nutrition education before [30], while most of the nutrition education interventions were conducted in general children who had received nutrition education. Therefore, the results indicated that additional nutrition education did not reduce mean BMI among children with mixed-nutritional statuses.

The stronger effect found on treatment than prevention of obesity and being overweight is in accordance with the findings from other meta-analyses in children of all ages [10,52]. This review indicated that the greater effects of overweight/obesity treatment were unlikely to be determined by the comprehensiveness of the interventions. This is because the numbers of multi-component interventions in treatment and prevention subgroups were found almost equally when analysing their impacts on BMI. Also, there were no clear distinctions between the treatment and prevention interventions in terms of the components included in those interventions. The information on the interventions' implementation (e.g., fidelity, intensity, and adherence) was not clearly described in most studies, so it is challenging to examine the role of intervention implementation on the different effects. Given the lack of information, we are unable to identify the factors contributing to the different effect sizes between overweight/obesity treatment and prevention interventions.

This review also found that parent involvement did not significantly increase the effectiveness of school nutrition interventions, which is not in line with the findings from other meta-analyses [7,8]. A review of European childhood weight control interventions reported that medium- and high-intensity parental involvement (parents are directly involved in multiple activities and behaviour change methods in multiple sessions) were frequently found in effective interventions, while low-intensity parental involvement (parents are directly involved in one session and indirectly approached in three months period) was frequently found in less effective interventions [53]. The parental involvement of the school nutrition interventions included in this review can be categorised as low according to the criteria described above [54], since parents were invited to parental meetings once or twice with or without learning materials and only one study provided individual consultation for parents who had overweight/obese children. Therefore, whether or not parents are involved may not be the only answer, and the intensity of parental involvement may also play an important role in determining the effectiveness of the interventions.

This review found that interventions with healthy food provision significantly decreased BMI and BAZ of the children. It was also reported elsewhere that a healthy school food environment was effective in reducing students' BAZ [55]. In addition to that, surprising findings were found by our subgroup analysis that interventions with healthy food provision included in this review provided weaker effects compared to interventions without the component. Theoretically, a healthy school food environment has the potential to play an important role in addressing childhood obesity since it could influence students' diet [56,57] and diet is a key factor determining obesity [58]. There may be more factors influencing the unexpected results of this review. Considering the implementation of healthy food provision included in this review, there were variations in terms of the criteria for healthy food, ranging from whole grains to reduction of high caloric food and provision of fruit and vegetables. Also, most studies asked school kitchen staff to provide healthier choices, but there is no information whether food available in the schools met the criteria or not and to what extent the food affected the energy intake of the children. The United Nations also recognised that the results of school food on childhood obesity were not consistent, which may be due to the variation in school food provision, especially nutritional quality of school food, across different contexts [59]. Therefore, the level of

food healthiness and adherence to the healthy food criteria could be the mediators. In addition, most interventions without healthy food provision included in this review were overweight/obesity treatment or multi-component interventions, of which generally provided stronger effects than prevention or single-component interventions. The opposites were found for interventions with healthy food provision. The different prevalence of treatment or multi-component interventions among the subgroups could be another influencer contributing to the different effects.

4.1. Policy Implications

Across all types of intervention, multi-component school nutrition interventions are the best option that provide consistent and strongest impacts in addressing childhood overnutrition. Among single-component interventions, extra exercise sessions have the potential to be mildly effective as a standalone component, while nutrition education should be a supplementary component.

Although parental involvement has been widely recognised as a promising strategy, insufficient involvement may compromise the effectiveness. To gain benefit from implementing a healthy food environment, the criteria for healthy food should comply with school nutrition standards and practice guidelines.

4.2. Future Research

The way primary studies reported the outcomes is important. Incomplete or unclear information restricts the ability to use the evidence. A significant proportion of studies selectively reported only certain forms of outcomes that are not comparable to the majority of literature, causing those studies to be excluded from secondary analyses. Also, not many studies provided clear information on intervention implementation (e.g., fidelity, intensity, and compliance), especially components related to food and physical activity environment and parental support. The lack of information compromised the usefulness of these included studies. Therefore, future evaluative studies on school nutrition interventions should provide complete information on both intervention implementation and outcomes. Existing tools such as the Template for Intervention Description and Replication (TIDieR) checklist [60] could be used to guide in the intervention reports. In addition, standard tools for food classification, such as nutrient profiling or school food standards, may help improve the intervention assessment regarding the nutritional quality of food provided to children.

4.3. Limitations

An interpretation of the findings of this review may require careful consideration due to the following limitations. Firstly, this review is restricted to English articles published in peer-reviewed journals, so some evidence published only in Asian languages might have been excluded. Secondly, a high degree of heterogeneity was detected in the pooled effect analysis. Sensitivity tests showed that there are no concerns related to study quality and study design. The school nutrition interventions are complex with variations of actors, intervention intensity, and surrounding environments. The complexity of interventions may be related to the considerable degree of heterogeneity. Thirdly, identifying factors contributing to the effects are not feasible. This is because the number of primary studies was not large enough, and the interventions' contents were not clearly described for all studies.

5. Conclusions

Primary school nutrition interventions implemented in Asia are effective in reducing BMI and BAZ among school-aged children. Multi-component interventions provided promising outcomes in reducing the children's BMI and BAZ. Among single-component interventions, extra exercise has the potential to reduce BMI, but nutrition education did not lead to significant changes. Overweight/obesity reduction interventions are more effective

than overweight/obesity prevention interventions potentially due to different levels of intensity. Parental involvement and a healthy food provision do not always boost the effectiveness of school nutrition interventions, especially when the implementation is not sufficient. Comprehensiveness and intensity are key factors that must be considered seriously when designing school nutrition interventions to maximise the interventions' effects. Studies assessing the impacts of school nutrition interventions should report complete information related to the interventions and outcomes to ensure their maximum benefit.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/nu14030589/s1, Figure S1: Pooled effects on BMI, and the difference between overweight/obesity reduction and overweight/obesity prevention interventions, Figure S2: Pooled effects on BMI, and the difference between interventions with parents' involvement and without parents' involvement, Figure S3: Pooled effects on BMI, and the difference between interventions with healthy food provision and without, Figure S4: Pooled effects on BAZ, and the difference between overweight/obesity reduction and overweight/obesity prevention interventions, Figure S5: Pooled effects on BAZ, and the difference between interventions with parents' involvement and without parents' involvement, Figure S6: Pooled effects on BAZ, and the difference between interventions with healthy food provision and without, Figure S7: Sensitivity analysis: removing high risk of bias studies, Figure S8: Sensitivity analysis: removing quasi-experimental studies, Table S1: Characteristics of studies included in this review, Table S2: Intervention characteristics.

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Supplementary

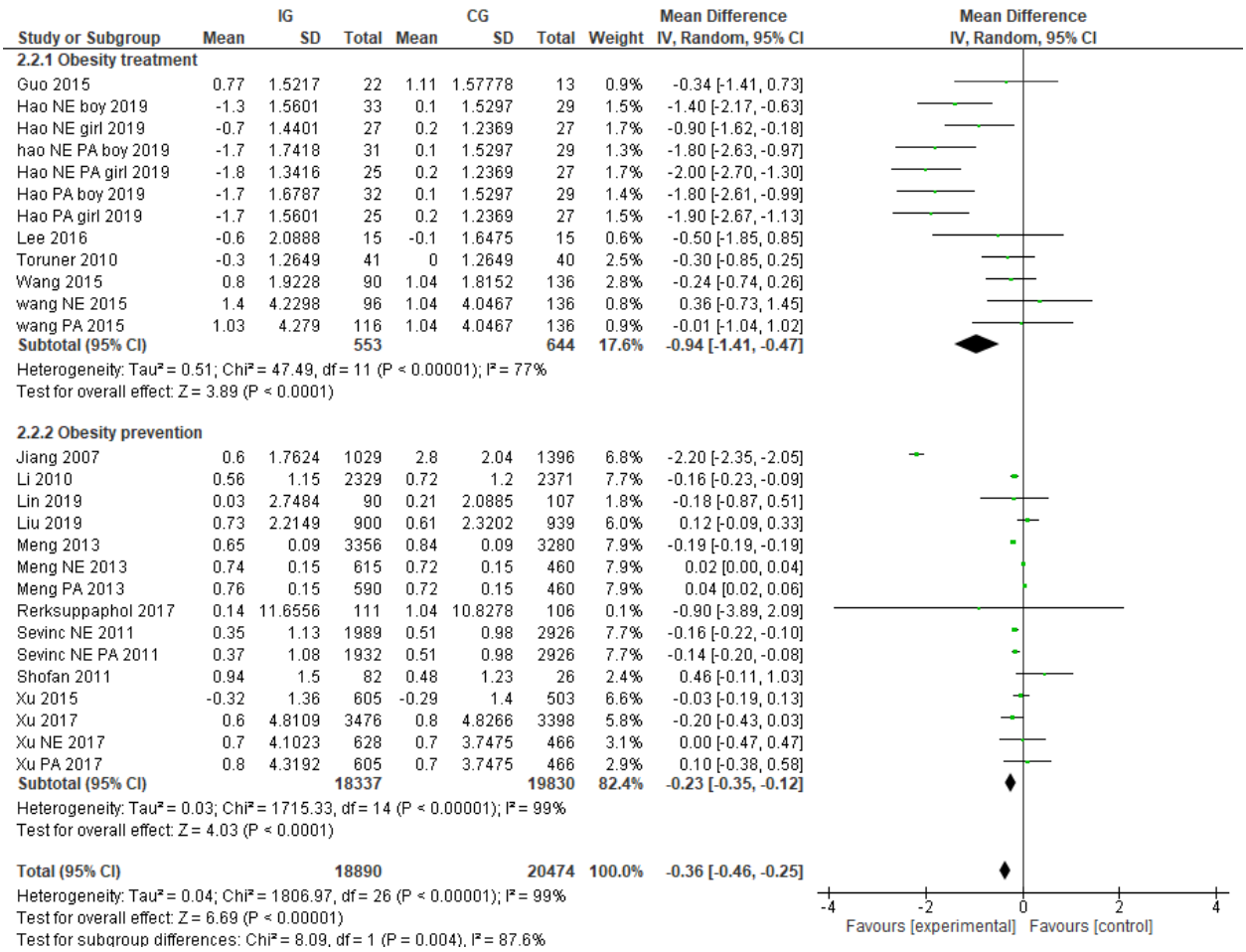

Fig. S1 Pooled effects on BMI, and the difference between overweight/obesity reduction and overweight/obesity prevention interventions

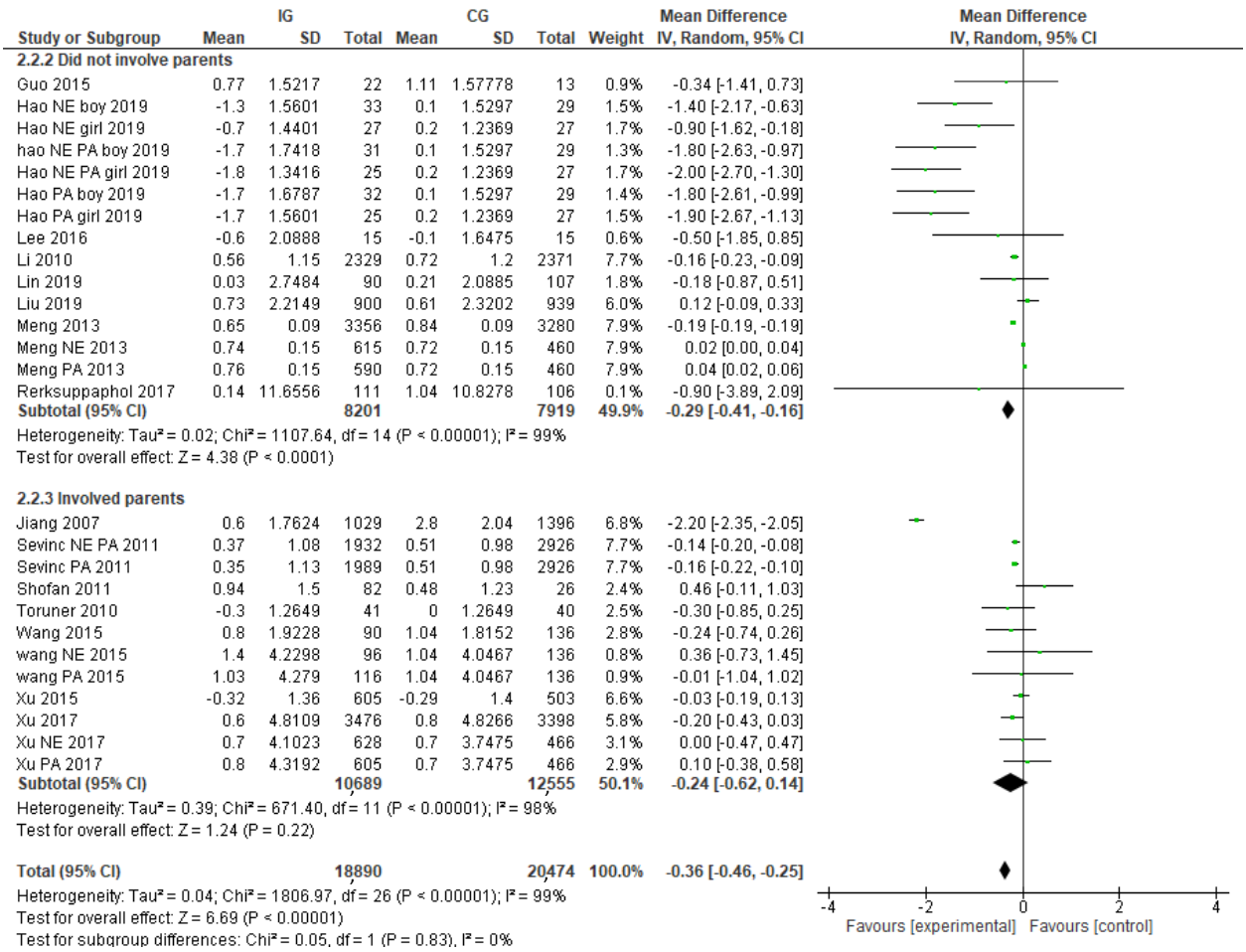

Fig. S2 Pooled effects on BMI, and the difference between interventions with parents' involvement and without parents' involvement

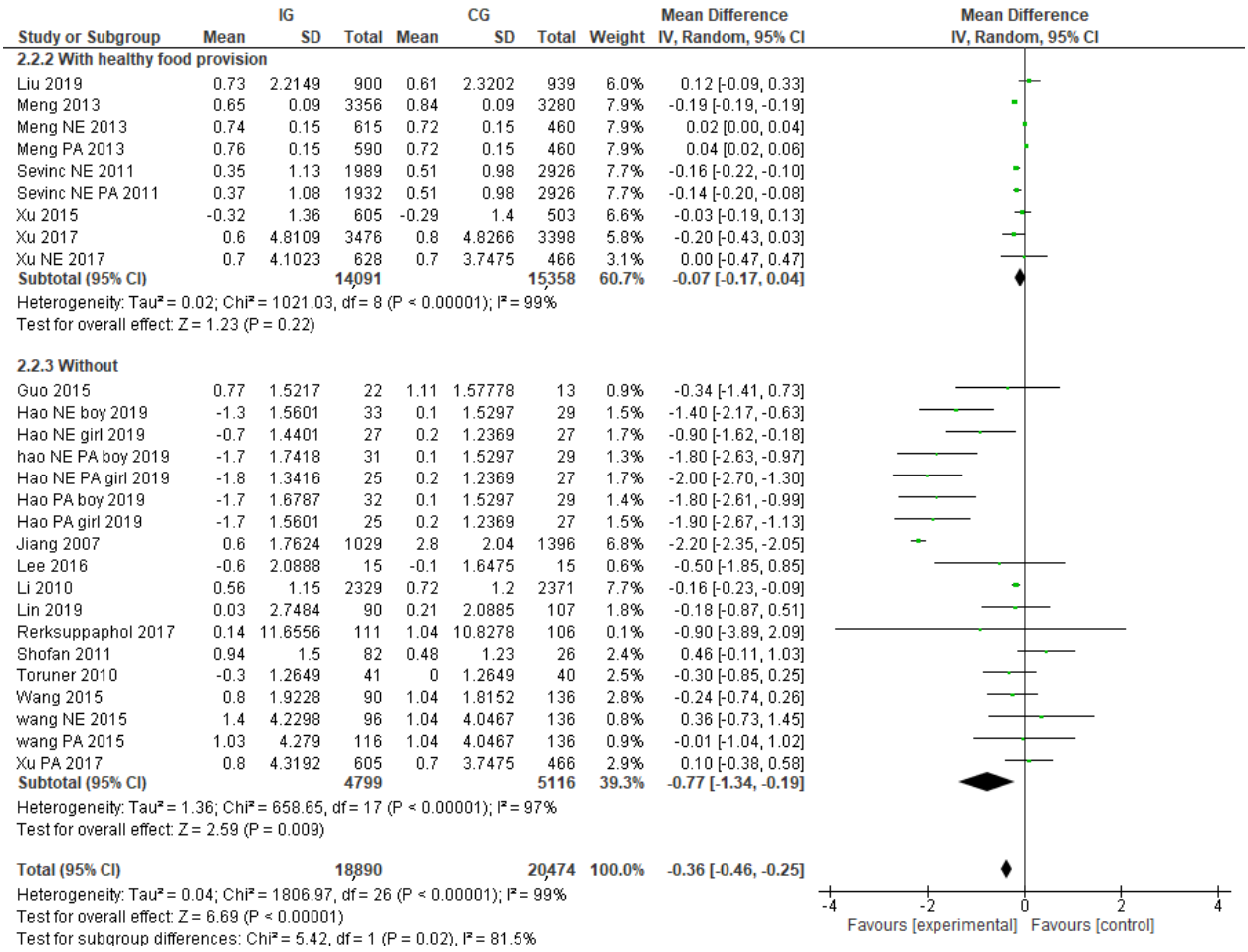

Fig.S3 Pooled effects on BMI, and the difference between interventions with healthy food provision and without

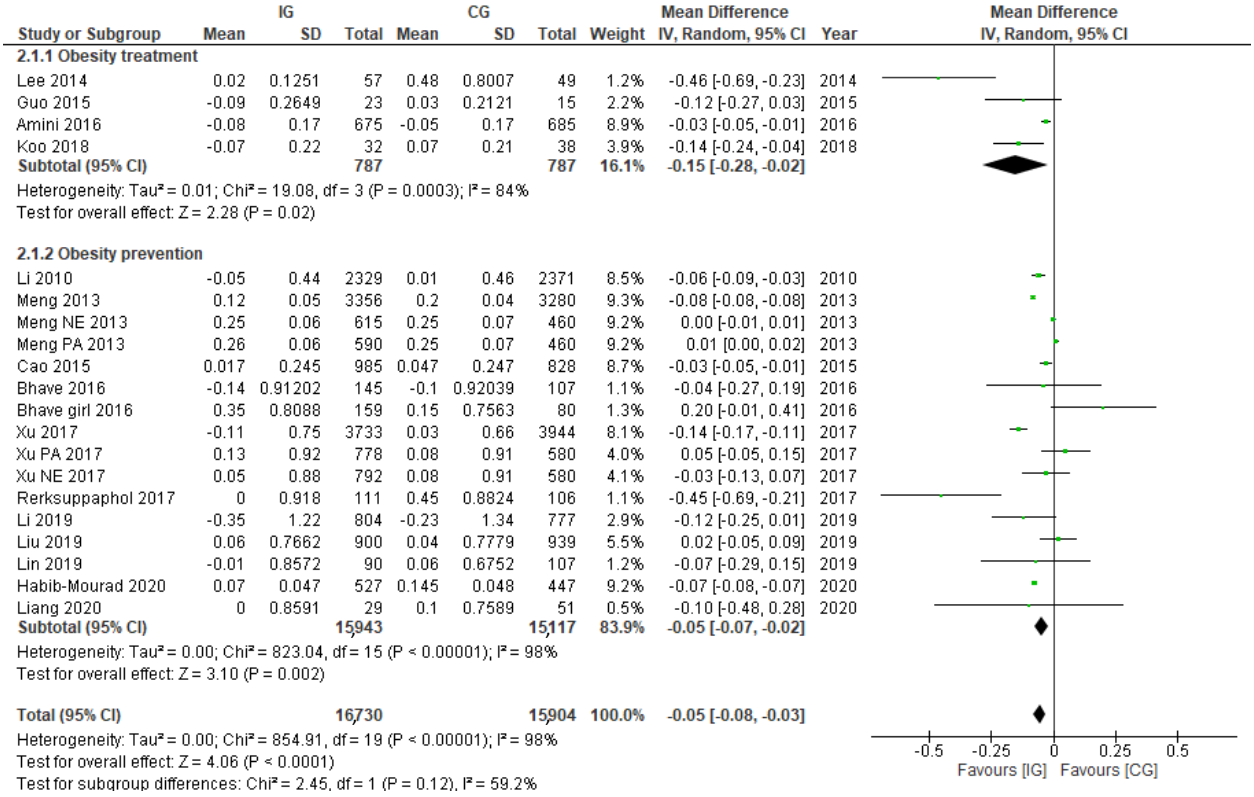

Fig.S4 Pooled effects on BAZ, and the difference between overweight/obesity reduction and overweight/obesity prevention interventions

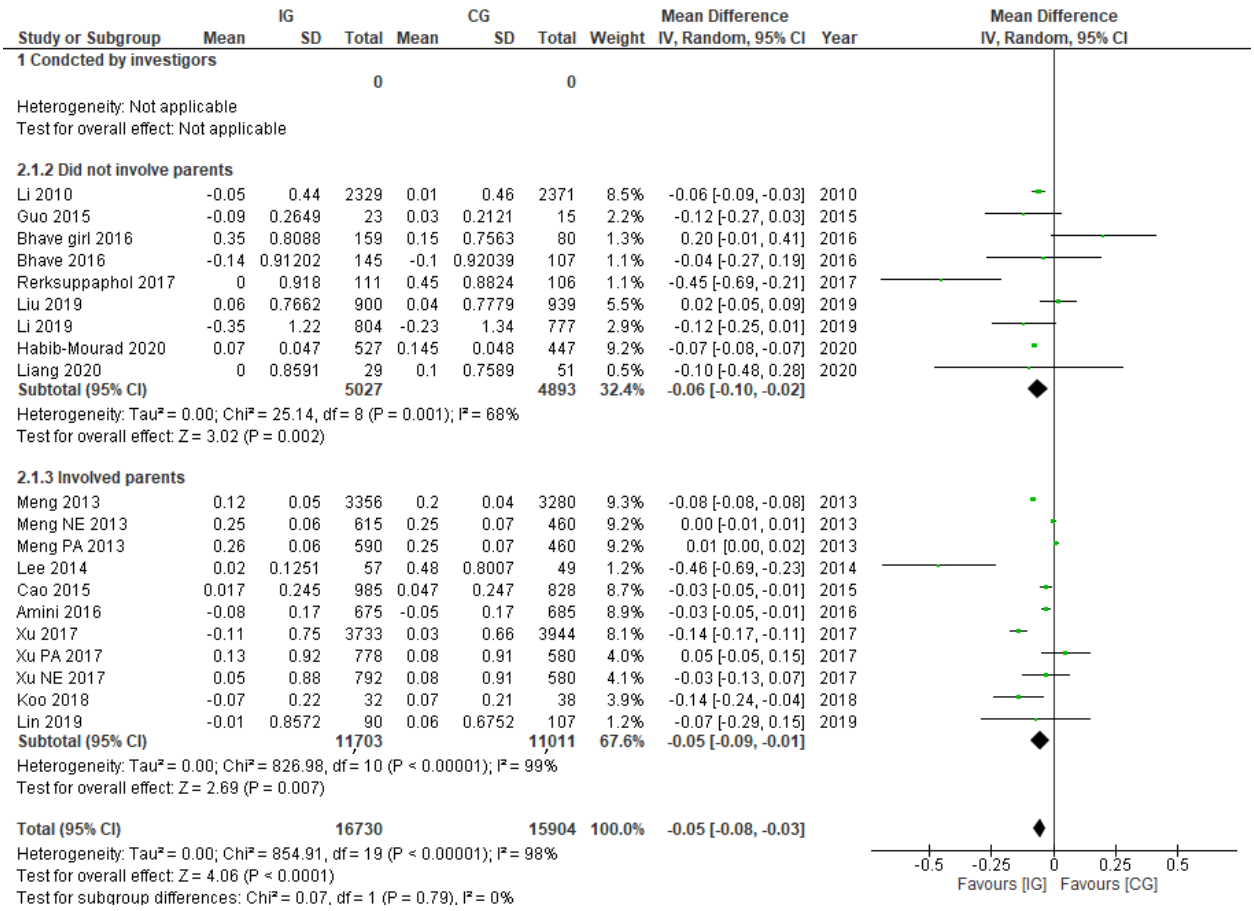

Fig.S5 Pooled effects on BAZ, and the difference between interventions with parents' involvement and without parents' involvement

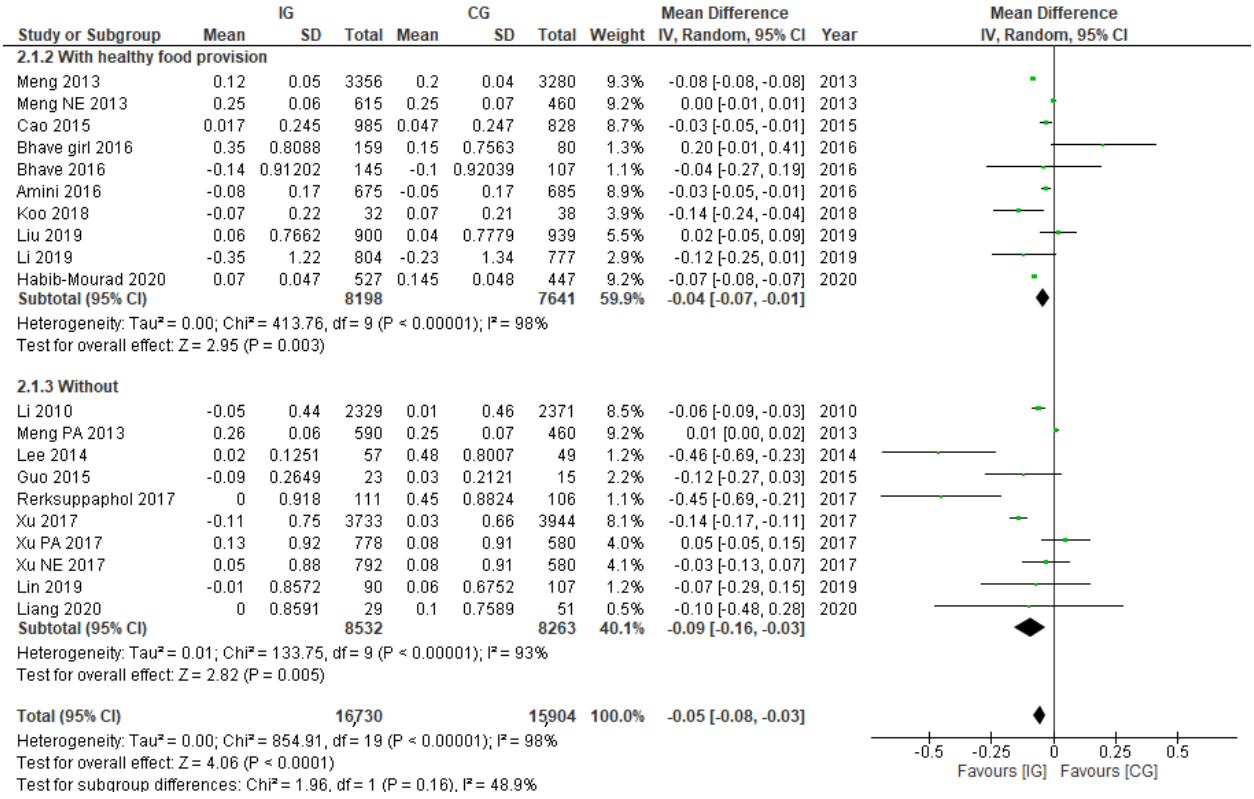

Fig.S6 Pooled effects on BAZ, and the difference between interventions with healthy food provision and without

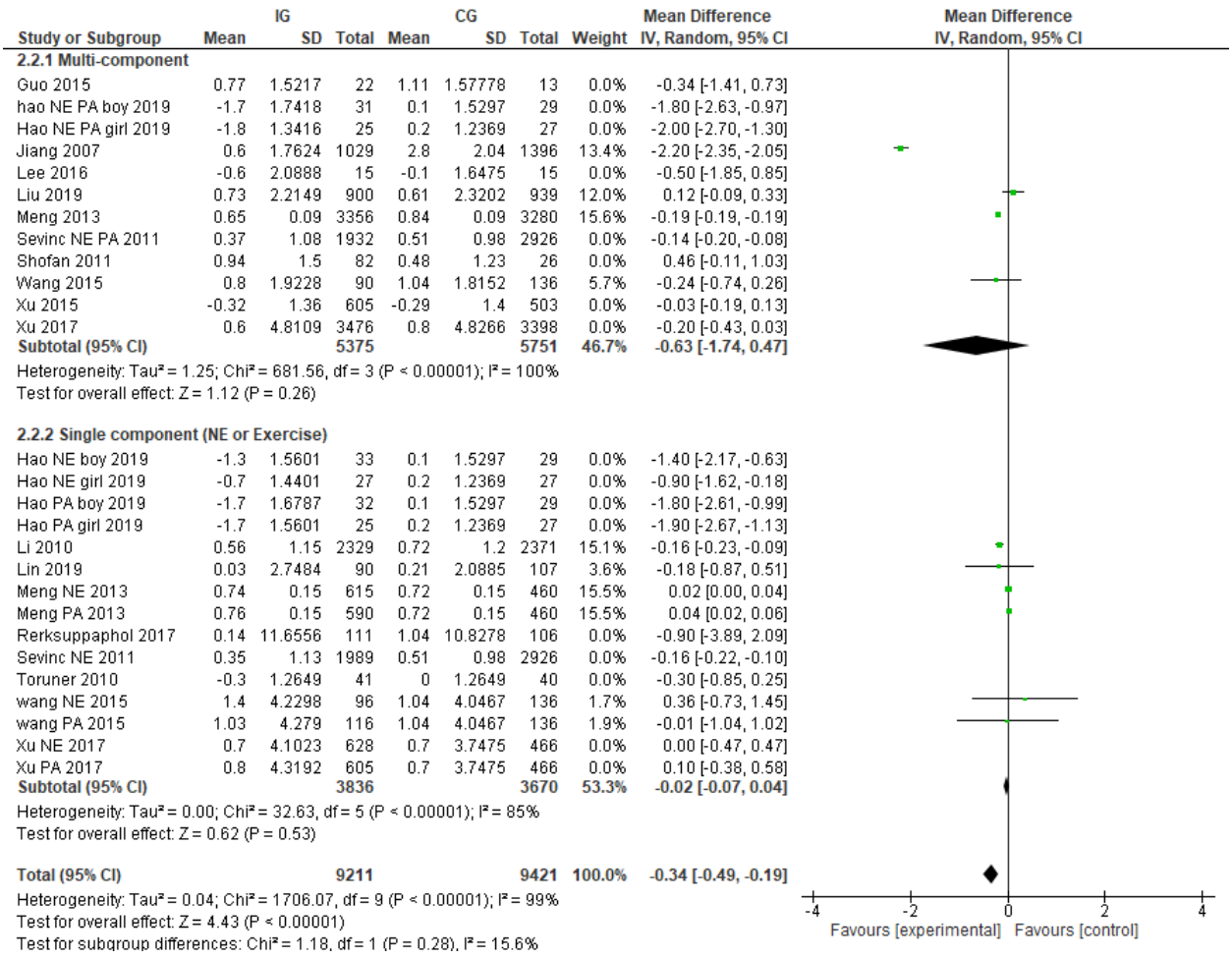

Fig.S7 Sensitivity analysis: removing high risk of bias studies

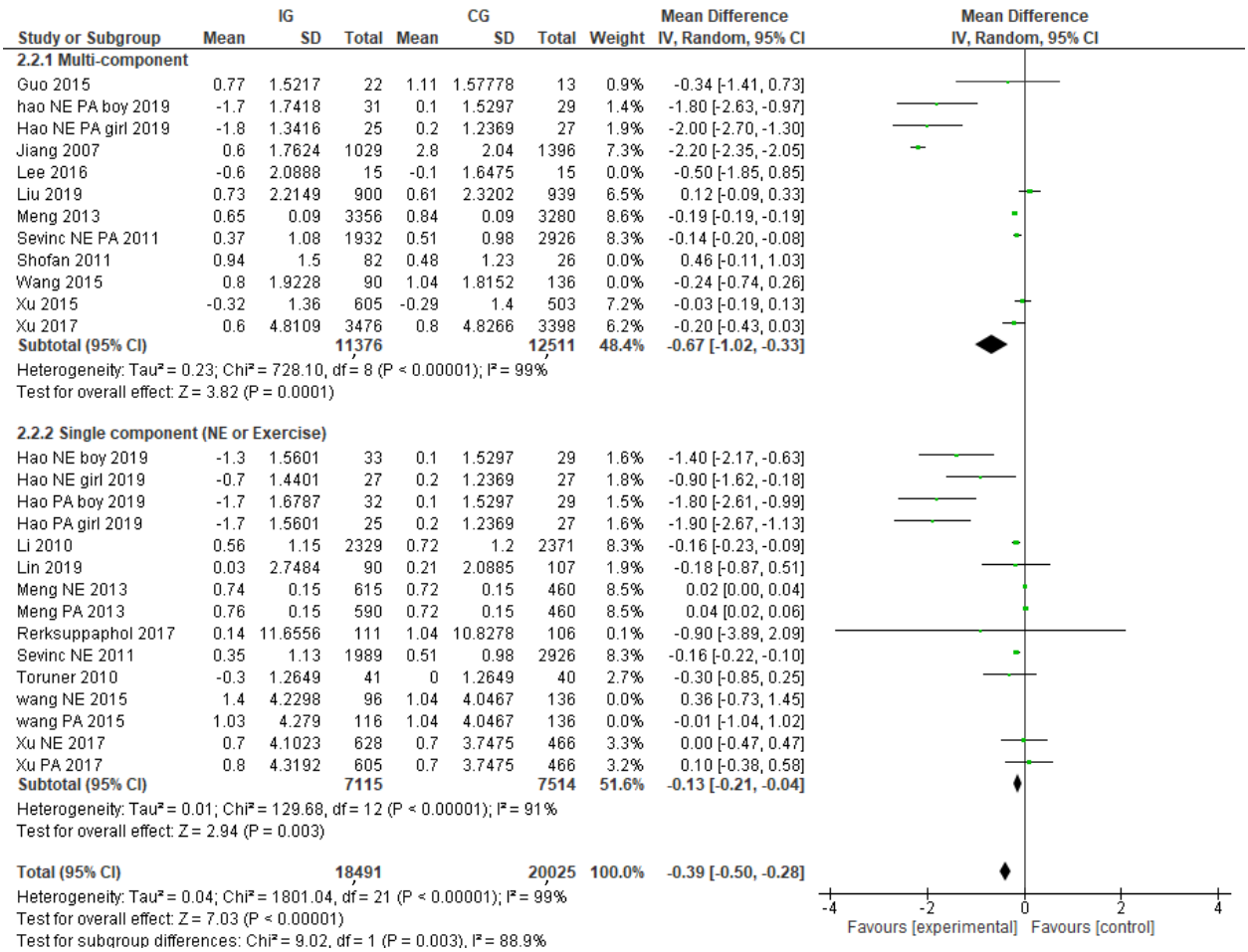

Fig.S8 Sensitivity analysis: removing quasi-experimental studies

Table S1 Characteristics of studies included in this review

Reference	Title	Objective	Study design	Sample
Akdemir M, et al, 2017	The Effect of Nutritional and Physical Activity Interventions on Nutritional Status and Obesity in Primary School Children: A Cluster Randomized Controlled Study	To measure the effect of intervention on preventing and reducing obesity by teaching healthy nutritional behaviour and physical activity among primary school children	Cluster RCT	**Intervention:** 1 primary school, grade 1-8, 675 students **Control:** 1 school, grade 1-8, 685 students
Amini M, et al, 2016	A School-Based Intervention to Reduce Excess Weight in Overweight and Obese Primary School Students	Evaluated the effect of an intervention for reducing excess weight gain in primary school-age children in Tehran	Cluster RCT	**Intervention:** 6 schools, grade 4-6, 167 overweight students **Control:** 6 schools, grade 4-6, 167 overweight students
Aperman-Itzhak, T, et al, 2004	School-Based Intervention to Promote a Healthy Lifestyle and Obesity Prevention Among Fifth- and Sixth-Grade Children	To evaluate the effectiveness of a healthy lifestyle intervention on health knowledge, behavior, and anthropometric measurements	Quasi experiments	**Intervention:** 2 religious and 2 secular schools (not BW selective), grade 5-6, 200 students **Control:** 2 religious and 2 secular schools (no weight selective), grade 5-6, 196 students (matched by sociodemographic characteristics and religious status)
Bhave S, et al, 2016	Effectiveness of a 5-year school-based intervention programme to reduce adiposity and improve fitness and lifestyle in	To report the effectiveness of a non-randomised intervention carried out in one school in the city of Pune in western India.	Quasi experiments	**Intervention:** Symbiosis Pune school, grade 3-4 students, 375 students **Control:** Symbiosis Nasik

Reference	Title	Objective	Study design	Sample
	Indian children; the SYM-KEM study			school (200 km away), 1. grade 3-4 students from: 209 students, 2. grade 8-9 students from the same school as IG group (compare their 2005-2006 data to the IG's 2010 -2011 data): 374 students
El Harake MD, et al, 2018	Impact of a pilot school-based nutrition intervention on dietary knowledge, attitudes, behaviour and nutritional status of Syrian refugee children in the Bekaa, Lebanon.	To evaluate the impact of a 6-month school nutrition intervention on changes in dietary knowledge, attitude, behaviour (KAB) and nutritional status of Syrian refugee children	Quasi experiments	**Intervention:** 2 informal schools, Syrian refugee children grade 4 - 6, 195 students **Control:** 1 informal school, Syrian refugee grade 4-6, 101 students
Habib-Mourad C, et al, 2020	Impact of a three-year obesity prevention study on healthy behaviours and BMI among Lebanese schoolchildren: Findings from Ajyal Salima Program	To investigate (1) the long-term effects of a school-based intervention program when implemented over two years on body mass index (BMI), healthy dietary behaviours, and physical activity (PA); and (2) whether the effects are sustained after one-year washout.	Cluster RCT	**Intervention:** public & private schools (different SES), grade 4-5, 698 students **Control:** public & private schools (different SES), grade 4-5, 541 students
Hao M, et al, 2019	Short-Term and Long-Term Effects of a Combined Intervention of Rope Skipping and Nutrition Education for Overweight Children in Northeast China	To evaluate whether an exercise intervention, nutrition education, or the combination of both were effective in weight reduction and maintenance	Quasi experiments	**Intervention:** grade 4-6 overweight students, PA group 57 students, nutrition education 60, PA & Nutrition

Reference	Title	Objective	Study design	Sample
		for rural school children		education 56 students **Control:** grade 4-6 overweight students, 56 students
Jiang J, et al, 2007	The effects of a 3-year obesity intervention in schoolchildren in Beijing	To measure the effects of a primary school-based intervention programme on the prevalence of obesity in Beijing	Clustered RCT	**Intervention:** 2 primary schools, 1029 students **Control:** 3 primary schools, (matched by school size, physical education and socio-economic status), 1396 students
Koo HC, et al 2018	The GReat-Child Trial: A Quasi-Experimental Intervention on Whole Grains with Healthy Balanced Diet to Manage Childhood Obesity in Kuala Lumpur, Malaysia	To test the hypothesis that a whole grains intervention for the treatment of childhood obesity would have a greater effect on anthropometric measurements	Quasi experiments	**Intervention:** 40 overweight students **Control:** 43 overweight students
Lee A, et al, 2014	Childhood obesity management shifting from health care system to school system: intervention study of school-based weight management programme	Evaluation of the effectiveness of a multi-component school-based weight management programme for overweight and obese primary school children via a home-school joint venture	RCT	**Intervention:** 57 overweight students **Control:** 49 overweight students
Lin YC, et al, 2019	NASA Mission X Program for Healthy Eating and Active Living among Taiwanese Elementary School Students	Assessed the effects of an intervention program adapted from the NASA Mission X (MX) program on children's Healthy Eating Active Living	Cluster RCT	**Intervention:** 4 schools, grade 3-4,92 students **Control:** 4 schools, grade 3-4, 109 students

Reference	Title	Objective	Study design	Sample
		(HEAL) knowledge and behaviours and anthropometry		
Meng LP, et al, 2013	The Costs and Cost-Effectiveness of a School-Based Comprehensive Intervention Study on Childhood Obesity in China	To evaluate the cost and the cost-effectiveness of a comprehensive intervention program for childhood obesity.	Multi-center RCT	**Intervention:** non-boarding school with >=10% overweight & >50% have lunch at school, grade 1-5, Beijing: Nutrition education 615, PA 590, Other 5 cities: Nutrition education & PA 3356 **Control:** Beijing: 460. Other 5 cities: 3280
Rerksuppaphol L & Rerksuppaphol S, 2017	Internet Based Obesity Prevention Program for Thai School Children-A Randomized Control Trial	To assess the efficacy of internet-based obesity prevention program in Thai school children	RCT	**Intervention:** 1 school, grade 1-6, 111 students with BMI >=-1 SD, no NCD, can stand straight **Control:** 1 school, grade 1-6, 107 students
Sevinc O, et al, 2011	Evaluation of the effectiveness of an intervention program on preventing childhood obesity in Denizli, Turkey	To determine the efficiency of 2 different intervention programs (healthy nutrition education and/or physical activity programs) for preventing the obesity of primary school students	Cluster RCT	**Intervention:** Grade 1-7, PA & Nutrition education: 1932 students, Nutrition education: 1989 students **Control:** Grade 1-7, 2926 students
Toruner EK, et al, 2015	Efficacy of a School-Based Healthy Life Program in Turkey	To evaluate the effectiveness of a school-based healthy life program	Cluster RCT	**Intervention:** from 2 schools, grade 3-7,497 students

Reference	Title	Objective	Study design	Sample
				School: 2 schools, grade 3-7, 470 students
Wang JJ, et al, 2015	Evaluation of a comprehensive intervention with a behavioural modification strategy for childhood obesity prevention: a nonrandomized cluster-controlled trial	Describes the development and implementation of a comprehensive, social cognitive behaviour modification intervention using accelerometery and a dietary diary to tackle child overweight and obesity	Quasi experiments	**Intervention:** overweight children aged 7-12 yr old: G1 .PA+diet (school a) 90 students, G2.PA (school B C D) 116 students, G3 diet (school E F G) 96 students **Control:** School (H I J) 136 students
Xu HQ, 2017	Comprehensive school-based intervention to control overweight and obesity in China: a cluster randomized controlled trial	To evaluate the effect of comprehensive school-based intervention on childhood obesity	Multi-center cluster RCT	**Intervention:** 6-13 years, 15 schools, 4827 students **Control:** 6-13 years, 17 schools, 4026 students
Cao ZJ, et al, 2015	A Randomized Trial of Multiple Interventions for Childhood Obesity in China	To evaluate the effectiveness of a family-individual-school–based comprehensive intervention model.	cluster RCT	**Intervention:** 8 schools, 1287 first graders **Control:** 9 schools, 1159 first graders
Guo T, et al, 2015	Intervention of childhood and adolescent obesity in Shantou city	To evaluate the effects of multicomponent school-based intervention constituted of diet modification, regular exercise and psychosocial consultation on body status in overweight and obese children and adolescents. And to come up with an appropriate intervention protocol	cluster RCT	**Intervention:** 3-5 graders, 26 overweight/obese **Control:** 3-5 graders,15 overweight/obese

Reference	Title	Objective	Study design	Sample
		for controlling children and adolescents' obesity in Shantou city		
Shofan Y, et al, 2011	A school-based program of physical activity may prevent obesity	To evaluate the effects of a 2-year intervention program in elementary school on the prevention of obesity	quasi-experiment	**Intervention:** 82 children aged 9-11 yrs **Control:** 27 children aged 9-11 yrs
Lee GY, et al, 2016	Effects of an obesity management mentoring program for Korean children	To develop and test a mentored obesity management program guiding physical exercise, improving eating habits, and promoting self-esteem among elementary school learners.	quasi-experiment	**Intervention:** Overweight/obese 9-12 yrs old, 17 students **Control:** Overweight/obese 9-12 yrs old, 15 students
Li B, et al,	The CHIRPY DRAGON intervention in preventing obesity in Chinese primary-school--aged children: A cluster-randomised controlled trial	To evaluate clinical- and cost- effectiveness of the Chinese Primary School Children Physical Activity and Dietary Behaviour Changes Intervention (CHIRPY DRAGON) developed using the UK MRC complex intervention framework to prevent obesity in Chinese primary-school–aged children	Cluster RCT	**Intervention:** 20 schools, 832 students aged 6 years **Control:** 20 schools, 809 students aged 6 years
Li YP, et al, 2010	Report on childhood obesity in China (8): Effects and sustainability of physical activity intervention on body composition of Chinese youth	To determine whether a large-scale physical activity intervention could affect body composition in primary school students in Beijing, China	Cluster RCT	**Intervention:** 10 schools, 2371 students (grades 3-4) **Control:** 10 schools, 2329 students (grades 3-4)
Liu A, et al, 2008	Evaluation of a classroom-based	To evaluate the effect of the Happy 10 programme on the	quasi-experiment	**Intervention:** 1 school, grades 1-5, 328 students

Reference	Title	Objective	Study design	Sample
	physical activity promoting programme	promotion of physical activity, physical growth and development of primary school students, and on obesity control and prevention		**Control:** 2 school, grades 1-5, 425 students
Liu Z, et al, 2019	A School-Based Comprehensive Intervention for Childhood Obesity in China: A Cluster Randomized Controlled Trial	To evaluate a theory-based comprehensive intervention implemented within primary schools for childhood obesity in China	cluster RCT	**Intervention:** 6 schools, 930 students aged 7-11 yrs old **Control:** 7 schools, 959 students aged 7-11 yrs old
Toruner EK & Savaser S, 2010	A Controlled Evaluation of a School-Based Obesity Prevention in Turkish School Children	To assess the effect of a weight management program in Turkish school children with overweight and obesity	RCT	**Intervention:** 1 school, grade 4, 41 overweight/obese students **Control:** 1 school, grade 4, 40 overweight/obese students
Xu F, et al, 2015	Effectiveness of a Randomized Controlled Lifestyle Intervention to Prevent Obesity among Chinese Primary School Students: CLICK-Obesity Study	To assess the effectiveness of a school-based multi-component lifestyle childhood obesity prevention program (the CLICK Obesity study) in Mainland China.	Cluster RCT	**Intervention:** 4 schools, grade 4, 638 students **Control:** 4 schools, grade 4, 544 students

Table S2 Intervention characteristics

Reference	Adoption	Component & delivery method	Duration	Context	Outcome	Maintenance
Akdemir M et al, 2017.	• Introduction of the intervention Investigators provided nutrition education to parents to encourage a healthy diet and active lifestyle in children. • Adoption of stakeholders No information on the extent of adoption from the schools or parents.	1. Extra nutrition education (ENE) for students by an investigator 5 sessions of a 40-minute class about "healthy diet & active lifestyle" and "obesity prevention" (3 times before and 2 after school breaks). 2. Nutrition education for parents by an investigator. 2 sessions of a 1-hour workshop and 1 brochure.	1 school year	A city with higher SES and better health outcomes than the average of Turkey (an upper-middle income & central Asia country)	1.04-fold increase of the prevalence of normal weight students in the intervention group compared to the control group n (RR = 1.04; 95% CI = 1.01 - 1.06; p = 0.0025)	NA
Amini M, et al, 2016.	• Introduction of the intervention 1. Face-to-face training and a guidebook for school health instructors to provide nutrition education to students	1. ENE for students 12 weekly sessions of 15-45 minutes classes (food groups & body weight management) by school health instructors. 2. Lifestyle education for parents	18 weeks	Low- and middle-class districts of urban capital city of Iran (an upper middle-income, west Asia country)	• Mean differences of BMI z score in the intervention group vs the control group were (-0.08) ± 0.17 vs (-0.05) ± 0.17, p<0.05.	NA

Reference	Adoption	Component & delivery method	Duration	Context	Outcome	Maintenance
	2. Investigators provided lifestyle education for parents • Adoption of stakeholders Teachers' collaborations varied across schools. Parents attended the meetings for 40%.	4 monthly sessions of 20-minute healthy lifestyle sessions by investigators. 3. Extra PA education for students (2 hrs/week). 4. Schools' canteens improvement asked staff to stop selling high-calorie food, reduce oil use, and increase whole grains and vegetables (monitored the change).				
Aperman-Itzhak T, et al, 2004.	• Introduction of the intervention 1. Collaborated with the local council to gain full support from the local stakeholders. 2. Launched opening ceremony-"healthy year" with a city march. 3. The intervention was delivered by teachers. • Adoption of stakeholders	1. Nutrition education for students Teachers integrated healthy eating and physical activity contents in different subjects according to the MOE guidance. 2. PA promotion in schools Teacher led active breaks & schools provided attractive playgrounds.	1 school year	A city with different religions and mixed cultures in Israel (a high-income and central Asia country).	In the intervention group, overweight and obesity decreased from 25% to 17.9%, $p<0.05$). In the control group, no significant change was found (from 20.5% to 17.6%, $p = 0.12$).	NA

Reference	Adoption	Component & delivery method	Duration	Context	Outcome	Maintenance
	No information on the extent of adoption from the stakeholders.	3. teacher encouraged healthy snacks eating. 4. City campaign "A happy year" 5. Nutrition education for parents Label reading & healthy eating plan 6. PA promotion in community Leisure activity places discounted fares				
El Harake MD, et al, 2018.	• Introduction of the intervention Two 2-day workshops (prior and refreshing) for teachers. One workshop for kitchen staff. • Adoption of stakeholders Good adherence to the intervention components.	1. ENE for students Teachers provided interactive classes for 45 mins bi-weekly basis in 6 months (hygienic practices, importance of consuming breakfast daily, role of fruits and vegetables in a healthy diet, benefits of consuming water versus sugar-sweetened beverages, healthy snacking behaviors, and	2 school years	Informal schools for refugees in underserved rural Bekaa region of Lebanon (an upper middle-income and central Asia country)	Improved undernutrition • Mean difference of BMI for-age-z score in the intervention group = 0.10 ± 0.06, while in the control group = (-0.10 ± 0.08, p=0.039) • Increased BMI for-age-z score in the intervention	NA

Reference	Adoption	Component & delivery method	Duration	Context	Outcome	Maintenance
		importance of physical activity) using hands-on activities and games, visually appealing and culturally sensitive posters and printed material technique. 2. Provision of locally prepared healthy snacks (357 kcal per day, 11 g protein, 58 g carbohydrates, and 9 g of fat).			group (β = 0.25, 95% CI = 0.10, 0.41).	
Hao M, et al, 2019.	• Introduction of the intervention A local nutritionist provided nutrition education. Teachers provided exercise intervention (skipping rope). • Adoption of stakeholders No information on the extent of adoption from the teachers.	Group1. PA 30 minutes of rope skipping/day & two 45-minute physical education classes/week by teachers. Group2. ENE 45 min class 2 times/week for 2 months (growth of children, nutritional requirement for children, daily diet plan, healthy eating habits, PA, health) by a local nutritionist. Group3. PA & ENE	2 months	Rural elementary schools with the largest number of students in Benxi City, Liaoning Province, in Northeast China (an upper middle-income and east Asia country)	Mean BMI in all the interventions (PA, ENE, PA&ENE), significantly decreased at the end of intervention compared to baseline, while mean BMI of the control group did not decreased. Among the interventions, PA&ENE provided	Mean BMI in all the intervention groups (PA, ENE, PA&ENE), significantly decreased at 1-year follow-up compared to baseline, while mean BMI of the control group did not decreased. Among the interventions,

Reference	Adoption	Component & delivery method	Duration	Context	Outcome	Maintenance
					the strongest effect, followed by PA.	PA&ENE provided the strongest effect, followed by ENE.
Jiang J, et al, 2007.	• Introduction of the intervention Investigators trained teachers to teach nutrition class and a textbook was provided. • Adoption of stakeholders No information on the extent of adoption from the teachers.	1. ENE for students by investigators 2. Nutrition education for parents 1 session/term by investigators about obesity, food pyramid, Chinese food composition tables, and a healthy lifestyle (vegetables and fruit consumption, 'traffic light' food item system, overeating, eating out in restaurants, fast food consumption, television viewing, computer games, and PA). 3. An extra meeting for parents with overweight and obese children	3 years	Beijing urban area in China	The overweight & prevalence in the intervention schools vs control schools: 9.8% vs. 14.4%, P < 0.01. The obesity prevalence in the intervention schools vs control schools: 7.9% vs. 13.3%, P < 0.01. The prevalence of overweight and obesity decreased by 26.3% and 32.5% in intervention schools, respectively. The	NA

Reference	Adoption	Component & delivery method	Duration	Context	Outcome	Maintenance
		4. PA for overweight and obese children and students who failed PE tests 20-min run X 4 days/week,			prevalence of overweight and obesity increased in control schools.	
Koo HC, et al, 2018.	• Introduction of the intervention Investigators provided nutrition class to students and an individual consultation to parents. • Adoption of stakeholders No information on the extent of adoption from the parents.	1. ENE for students 30-min nutrition education classes X 6 times, which employed Food Guide Pyramid, visual plate model, whole grain food recommendation, and balanced diet 2. school delivery of whole-grain foods food delivery to schools consisting of whole-grain bread, whole-grain biscuits, and whole-grain ready-to-eat cereal, on a daily basis of for 12 weeks. 3. Nutrition education for parents 1-hour individual meeting with parents to encourage the students to consume wholegrain food and to	3 months	Keramat zone in Kuala Lumpur, Malaysia (an upper middle-income and southeast Asia country)	The intervention group had lower BMI for age z score compared to the control group at 9-month follow-up: −0.12; 95% CI: −0.21, −0.03; p = 0.009. There was no significant change of BMI for age z score among the intervention group (mean difference: −0.07 (−0.15, 0.01) p=0.092), while there was a significant increase among the control group (mean difference: 0.07 (0.01, 0.14), p=0.032)	There was no significant change of BMI for age z score among the intervention group (mean difference: −0.06 (−0.25, 0.13), p=0.544), while there was a significant increase among the control group (mean difference: 0.18 (0.10, 0.26), p<0.001) at nine month later. There was no significant change of waist

Reference	Adoption	Component & delivery method	Duration	Context	Outcome	Maintenance
		practice a balanced diet at home.			at the end of the intervention. Waist circumference of the intervention group decreased (mean difference: −2.1 (−3.7, −0.5), p=0.014, while there was no change among the control group (mean difference: 0.7 (−0.3, 1.7), p=0.165)	circumference of the intervention group (mean difference: −1.9 (−4.1, 0.3), p=0.091), while there was an increase among the control group (mean difference: 2.5 (0.9, 4.1), p=0.002)
Lee A, et al, 2014.	• <u>Introduction of the intervention</u> 1. The project team (a dietician, a nutritionist and physiotherapist) guided the schools' teachers to implement the intervention in the schools 2. The project team worked with parents	Health Promoting School (HPS) approach 1. <u>ENE, PA and self-image sessions for students</u> 75-minute afterschool sessions and 3-hour weekend sessions 2. <u>Nutrition education for parents</u> - An introductory seminar on the basic principles on	4 months	Urban areas in Hong Kong-China (a high-income special administrative region of China)	The intervention group had lower BMI for age z score and body fat compared to the control group at the end of the intervention (BMI for age z-score: −0.21, 95% CI −0.34 to −0.07, P = 0.003), body fat: −2.67%,	The intervention group had lower BMI for age z score compared to the control group at 4-month follow-up (− −0.06, 95% CI −0.11, −0.007, P = 0.028)

Reference	Adoption	Component & delivery method	Duration	Context	Outcome	Maintenance
	to encourage a healthy lifestyle in students • Adoption of stakeholders No information on the extent of adoption from the stakeholders.	weight management -A 1-hour follow-up training on healthy eating and exercise strategies to assist weight control in children. 3. Label education training for parents and children. 4. Progress monitoring and solutions finding with parents Discussed with parents about the progress, obstacles, and solutions.			95% CI −5.12 to −0.22, P = 0.033).	
Rerksuppapholl & Rerksuppapholl S, 2017.	• Introduction of the intervention Investigators introduce a computer programme to students for self-learning. Teachers were asked to measure students'	Provision of a self-learning and self-monitoring computer programme for students - Nutrition knowledge (nutritional status, recommendation of daily amounts of portion and	4 months	A rural town in Thailand (an upper middle-income and southeast Asia country)	Prevalence of overweight and obesity in the intervention group vs the control group: 39.6% vs 56.6%, p =0.009. Net BMI gains in the	NA

Reference	Adoption	Component & delivery method	Duration	Context	Outcome	Maintenance
	weights and heights and enter the data into the computer programme monthly. • Adoption of stakeholders No information on the extent of adoption from the stakeholders.	serving sizes of each food groups, nutritional status) - Physical activity recommendations based on students' nutritional status			intervention group vs the control group: 0.40kg/m2 vs 1.24kg/m2, p =0.027). The intervention group had no changes in BMI for age z-score (-0.001, 95%CI -0.19 to 0.18, p =0.988), while the control group had increased BMI for age z-score at the end of study (0.45, 95%CI 0.27 to 0.63, p <0.001)	
Sevinc O, et al, 2011.	• Introduction of the intervention Teachers were asked to add extra physical education classes. Investigators provided workshops for teachers and parents	1. Extra physical education (PE) classes Increased PE sessions from 2 h/wk to 3 h/wk. 2. Nutrition education for students Workshops about healthy	8 months	School having a half-day education system, located in low- and high SES regions in an	BMI changes in the intervention group1 and intervention group2 vs the control group were	NA

Reference	Adoption	Component & delivery method	Duration	Context	Outcome	Maintenance
	to encourage a healthy diet and body weight management in students. • Adoption of stakeholders No information on the extent of adoption from the stakeholders.	diet and obesity prevention by staff of the Health Training Division of the City Health Administration. 3. Nutrition education for parents and teachers Workshops about healthy diet and childhood obesity prevention by staff of the Health Training Division of the City Health Administration. 4. Provision of boxed milks 5. Provision of healthier food in school canteens e.g., water, freshly squeezed fruit juice, buttermilk, milk, and seasonal fruits were sold in school canteen.		industrial city of Turkey	0.37 ± 1.08, 0.35 ± 1.13 vs 0.51 ± 0.98, which was significantly different (p = 0.000). There was no significant difference between the intervention groups (P = 0.847). the BMI change of the students in the control group was associated with the income level of the family (p = 0.005). This relationship was not shown in the intervention groups.	

Reference	Adoption	Component & delivery method	Duration	Context	Outcome	Maintenance
Xu HQ, et al, 2017.	• Introduction of the intervention 1. Schools' classroom tutors and/or health educators attended training sessions on how to integrate the program into the school curriculum and to perform the activities. They received slides and videos about nutrition, childhood obesity, risk factors, health consequences, and prevention prepared by Chinese CDC. 2. Parents attended 2 workshops by nutrition professionals to encourage their children to have a healthy diet. • Adoption of stakeholders The school staff modelled the lessons to ensure that they	Group 1 1. ENE for students. 40-minute lecture X 6 sessions about healthy eating proportions of three meals, how to choose the beverage and snacks, reducing eating out and Western-style fast food. Cartoon pamphlets were provided. 2. Nutrition education for teachers and school staff 40-minute lecture X 4 times 3. Nutrition education for parents 40-minute lecture X 2 times 4. Provision of learning materials including a nutrition handbook, "Dietary Pagoda for Chinese people" posters displayed on classrooms' walls. Cartoon handbooks containing all of this information were distributed to all	1 school year	Schools in the capital city of China	The overweight and obesity prevalence in the control group increased by 1.5% ($p<0.001$), while there was no significant change in the intervention group (0.2%, $p=0.954$). Compared with the control group, the comprehensive intervention effects could be found (BMI mean difference: -0.3 kg/m2 (-0.4, -0.2), $p<0.001$, BMI for age z score mean difference: -0.14 (-0.18, -0.11), $p<0.001$	NA

Reference	Adoption	Component & delivery method	Duration	Context	Outcome	Maintenance
	understood the recommended techniques and strategies for implementation. No information on the extent of adoption from the stakeholders.	participants in the nutrition education group to help clarify the concepts presented in the lectures. 5. <u>Regular monitoring of the nutritional quality of school lunch menu and suggestions for improvement</u> Group 2 <u>Extra PA</u> 10-minute of preferable PA (25-35.1 kcal) X 2 times/day for 5 days/week or the "happy 10" <u>Group 3</u> Group 1 and 2 were combined.				
Cao ZJ, Wang SM, Chen Y, 2013.	• Education Bureau and Institute of Education involvement established an administrative system (e.g.,	<u>1. Health education</u> - Nutrition classes (6 hrs) /term (obesity risk factors, health consequences, and obesity prevention)	33 months	Shanghai, China. Urban city. Highest prevalence of obesity among school-aged children. The	The overall prevalence of overweight/obesity declined from 28.92% in 2011 to 24.77% in	NA

Reference	Adoption	Component & delivery method	Duration	Context	Outcome	Maintenance
	relevant rules and regulations), supervised school canteen staff, and provided funding for the project • Research team organised trainings for school staff to integrate the intervention program into the school curriculum (teachers as agents at school) Research team invited experts to conduct lectures for students and their parents (parents as agents at home)	- Obesity related information dissemination through school communication platform e.g., morning meetings, blackboard newspaper, brochures, seminars etc. - Parent-school meeting every term and brochures <u>2. Dietary intervention</u> - Reduce fat content in school food and increase availability of fruit and vegetables - Provide information about balanced diet principles and methods and instructions for parents to help children to have a healthy diet <u>3. Exercise intervention</u> - At least 1 hr PA/day: 20-meter music shuttle run 2–3 times/wk and fun sports e.g. football, rope skipping		increasing trend of childhood obesity gained great attention from all sectors.	2014, with a difference of 4.15% in the intervention group compared with a 0.03% decline (from 30.71% to 30.68%) in the control group. The odds of developing obesity among IG vs CG was 0.583 (0.428, 0.794), $p<0.001$, while of developing obesity & overweight of IG vs CG is 0.625 (0.493, 0.793), $p<0.001$. BMI z-scores of IG vs CG: overweight students $\beta = -0.030$ (–0.049, –0.011), 0.002 and obese students $\beta = -0.046$	

Reference	Adoption	Component & delivery method	Duration	Context	Outcome	Maintenance
		- Rope was provided to students to do rope skipping at home during school breaks (PA plan and form was provided for parents to monitor and record students' PA)			(–0.072, –0.021), p<0.001.	
Guo HT, Zeng XS, Zhuang QY, Zheng YB, Chen SR, 2015.	The intervention was conducted by investigators	1. <u>Nutritional education session</u> 1hr lecture/month & brochures to teach how to eat healthily (less calories & fat & more nutritious) 2. <u>Exercise session</u> 1-hr session to have at least 1hr medium or vigorus PA a day (reaching 70-80% maximum heart rate) 3. <u>Psychological intervention</u> 1-hr psychological education and consultation session/month 4. <u>Fun PA contest</u> 1-2 PA contests during school breaks	1 year	Shantou, a coastal city and special economic zone in China.	BMI (kg/m^2): IG baseline 22.18 ± 2.13, post intervention 22.95 ± 2.53 (p=0.002), CG baseline 22.05 ± 2.57 post intervention 23.16 ± 2.39 (p=0.013). BMI z score: IG baseline 1.56 ± 0.33 post intervention 1.47 ± 0.44 (p=0.036), CG baseline 1.45 ± 0.35 post intervention 1.48 ± 0.31 (p=0.617)	NA

Reference	Adoption	Component & delivery method	Duration	Context	Outcome	Maintenance
		5. Telephone follow-up phone calls every 2 weeks				
Shofan Y, Kedar O, Branski D, Berry E, Wilschanski M, 2011.	The programme was led by the Braun School of Public Health in cooperation with the Ministry of Education. PA guideline for children was disseminated to schools to follow. Health professionals provided nutrition education to children ad encouraged parents to provide healthy diet to children.	1. Nutrition education lessons 2. Extra aerobic component PE 2x (duration) PE (increase aerobic component by 50%. At baseline, the normal physical education classes consisted of two lessons of 45min each of medium intensity training with an estimated aerobic component of 25% 3. Monthly meeting with parents 1hr session/month X 10 months (no detail of activities)	2 years	School with 350 students, Israel	BMI (mean±SD (range)): IG baseline 17.9±3.9 (11.5–33), post intervention 18.7±4.6 (12–38), mean difference 0.94±1.5 (-2.9–5.5). CG baseline 18.9±4.3 (13.4–33), post intervention 19.4±4.6 (13–31), mean difference 0.48±1.23 (-2–3.5).	
Lee GY, Choi YJ, 2016	Nursing students were trained (16hr) to mentor students. They were informed about	1. Mentoring 1 nursing student mentored 2-3 students. Mentors contacted their	10 weeks	Seoul Capital Area. Awareness of childhood obesity is low in	BMI (mean±SD): IG baseline 25.3 (±3.22) post intervention 24.7 (±3.37), CG	NA

Reference	Adoption	Component & delivery method	Duration	Context	Outcome	Maintenance
	their roles, therapeutic relationship, and effective communication.	mentees once a week to check their daily PA and eating habits. The mentors were evaluated and supervised by psychiatric nurses. 2. <u>NE & PE</u> 8 classes to provide knowledge about obesity, self assessment on BMI & calorie intake, healthy eating, healthy exercise, fun sport, self-motivation and aspiration.		Korea. Snacks provided in schools were mostly unhealthy.	baseline 24.6 (±2.70) post intervention 24.5 (±1.86) (p< .0001).	
Li B, Pallan M, Liu WJ, Hemming K, Frew E, Lin R, et al, 2019	Recruited 5 programme teachers to coordinate and deliver the programme. The teachers were trained and linked with school staff and families. Programme's handbooks were provided to	1. <u>NE for children</u> Individuals' behavioural goals setting, self monitoring, and supervision. 2. <u>Interactive nutrition workshop for carers</u> - correcting common misperceptions about child healthy weight and healthy behaviours, - introducing practical parenting tips for encouraging healthy	1 year	State-funded primary schools in Guangzhou, the largest and one of the most socioeconomically advanced cities in South China.	BMI z score was significantly lower in the intervention compared with the control group, MD = −0.13, 95% CI: −0.26 to 0.00, p = 0.048 in the baseline-adjusted model; MD = −0.13, 95% CI: −0.26 to −0.01, p =	NA

Reference	Adoption	Component & delivery method	Duration	Context	Outcome	Maintenance
	intervention schools to guide the schools.	behavioural change in children - Providing leaflets 3. <u>Healthy school food provision</u> Healthy school lunch goal setting among the programme's teachers and school food providers. Constructive evaluation on the food menus. 4. <u>PA promotion outside schools</u> Taster session to teach fun & active family games at home. PA homework assignment. 5. <u>PA promotion at school</u> - Situation analysis - Monthly goals setting - Action plan to meet the goal & regular evaluation & advice. Programme was mainly delivered as planned.			0.041 in the further-adjusted model	
Li YP, Hu XQ, Schouten EG, Liu AL, Du	A half-day training session for teachers	<u>PA promotion</u> Teachers added extra PA activity twice daily using	1 year	Urban Beijing, China.	BMI increased by 0.56 kg/m2 (SD 1.15) in the intervention	After another year of follow up, compared to the

Reference	Adoption	Component & delivery method	Duration	Context	Outcome	Maintenance
SM, Li LZ, et al, 2010	conducted by the staff of the National Institute for Nutrition and Food Safety, China CDC. This is to inform teachers about integrating the programme activities into school curriculum, childhood obesity and prevention.	teaching materials: cards (to select activity), video demonstrations, tracking posters, and stickers (to track the progress). The 10-minute PA session (moderate or vigorous intensity) consisted of move, cooldown, health message provision (caloric expenditure ranged from 60-70 kcal/day).			group and by 0.72 kg/m2 (SD 1.20) in the control group, with a mean difference of -0.15 kg/m2 (95% CI: -0.28 to -0.02), p=0.03. BMI z score decreased by -0.05 (SD 0.44) in the intervention group but increased by 0.01 (SD 0.46) in the control group, with a mean difference of -0.07 (-0.13 to -0.01), p=0.03.	control group, children in the intervention group had significantly lower BMI mean difference between IG and CG (-0.13, -0.25 to -0.01), p=0.04. BMI z score mean difference between IG and CG (-0.05, -0.10 to -0.01), p=0.03.
Liu A, Hu X, Ma G, Cui Z, Pan Y, Chang S, et al, 2008	Happy 10 was initiated by the National Institute for Nutrition and Food Safety, Chinese Center for Disease Control and Prevention. No information available	<u>PA Promotion</u> Teachers added extra 10-minute exercise at least once every school day. Posters and stickers were used to track the progress of each class.	8 months	urban Beijing, China.	BMI in IG: Boys Baseline 18.09, post intervention 18.95, change 0.86 (<0.05) Girls Baseline 18.63, post intervention 18.16 change -0.47 (<0.05).	NA

Reference	Adoption	Component & delivery method	Duration	Context	Outcome	Maintenance
	on how the programme was introduced to the schools.				BMI in CG: Boys baseline 17.96, post intervention 18.68, change 0.72 (<0.05). Girls baseline 16.42, post intervention 17.08, change 0.66 (<0.05). There was a significant difference in the change between the intervention school and control school after intervention among girls.	
Liu Z, Li Q, Maddison R, Mhurchu CN, Jiang YN, Wei DM, et al, 2019.	NA	1. School policies Sugary drinks ban, water drinking campaign, healthy lunch, 60 MVPA/day, 2. Health education (diet and PA) classes, posters, broadcast, website, teaching materials, diet & PA diaries, drawing contest. 3. PA promotion	1 year	Urban Beijing, China. Increasing ''obesogenic'' environment. Among the school-based interventions in China, few have focused specifically on	Mean BMI (kg/m2) and BMI Z-score were 18.57 (SD 3.60) and 0.31 (1.19) in the intervention group and 18.46 (3.76) and 0.28 (1.23) in the control group. The model-adjusted group differences (intervention vs.	NA

Reference	Adoption	Component & delivery method	Duration	Context	Outcome	Maintenance
		>60 MVPA/day, sport equipment, sport club for overweight & obese. 4. <u>Healthier school lunch</u> school lunch improvement The quantity of intervention delivery was 80%–100% for intervention elements among most intervention schools. Variability exists for the quality of intervention delivery, which was highest for the sport club for children with overweight/obese.		environmental strategies.	control) in BMI and its Z-score at 12 months were 0.07 (95% CI: -0.16 to 0.31; p = 0.54) and 0.02 (95%CI: -0.08 to 0.11; p = 0.73). The estimated intraclass correlation coefficients were 0.04 and 0.05, respectively, consistent with the initial assumption. Obesity intervention vs control groups at 6 months (OR: 0.50, 95% CI: 0.26 to 0.96; p < 0.05).	
Habib-Mourad C, et al, 2020.	• <u>Introduction of the intervention</u> 1. Private schools were approached directly. Public schools were recruited by the MOE.	1. <u>NE for students</u> 12 nutrition education interactive classes (10 to 15 min of discussion about the topic of the week followed by 30 min of games and/or food preparation) in the 1st year	2 school years	Beirut, the capital of Lebanon	There were no changes in terms of BMI, BMI for age z score, and overweight and obesity prevalence	After one-year washout, the intervention group had a 52% reduced odds of being overweight/obese

Reference	Adoption	Component & delivery method	Duration	Context	Outcome	Maintenance
	2. Investigators provided training to teachers. 3. Investigators suggested school food chops to provide healthier food.	and 6 complementary activities in the 2nd year by teachers who had received a 'training of trainers (ToT)' workshop on all program components. 2. <u>Parent meetings and health fairs</u> Showed examples of healthy meals, food recipes and provided pamphlets. 3. Provision of healthy food Asked school shops to sell healthier food in school shops and asked parents to prepare healthy lunch boxes			at the end of intervention.	compared to students in control group. The intervention was scaled up and rolled out as Ajyal Salima– Healthy Kids, a mandatory component in the public schools' health curriculum.
Lin YC, et al, 2019	The intervention was conducted by research team to assure the consistency.	<u>NE & PE training course</u> The image of the astronaut to stimulate children to implement a healthy lifestyle. The 40-min class/weeks X 8 consecutive weeks by the research group. Online materials that	8 weeks	Remote rural areas of Northern Taiwan	BMI (kg/m2) (mean (SD): IG baseline 19.51 (4.37), post intervention 19.54 (4.32), CG baseline 18.41 (3.34), post	

Reference	Adoption	Component & delivery method	Duration	Context	Outcome	Maintenance
		can be easily integrated into math, science, and reading classes. Water bottles and "space logs" were distributed to motivate the children to keep training and recording their physical activities and diet at school and at home.			intervention 18.62 (3.26). BMI z score (kg/m2) (mean (SD): IG baseline 0.72 (1.39), post intervention 0.71 (1.31), CG baseline 0.54 (1.09), post intervention 0.60 (1.04). No significant changes.	
Meng LP, et al, 2013.	Investigators provided nutrition & health education to students, teachers, parents, health workers. Teachers were trained to provide PE.	1. <u>Nutrition education for children</u> 6 nutrition and health class 2. <u>Training course for parent</u> 2 times for the parents 3. 4 times for teachers and health workers. 4. The menu for students of school lunch cafeteria was evaluated periodically and specific nutrition improvement was suggested accordingly PA: In each school day, the students were conducted "Happy 10" led by	1 school year	Beijing, Shanghai, Chongqing, Guangzhou, Jinan and Harbin	BMI and BAZ increment was 0.65 kg/m2 (SE 0.09) and 0.01 (SE 0.11) in the combined intervention, respectively, significantly lower than that in its' control group (0.82±0.09 for BMI, 0.10±0.11 for BAZ). No significant differences were found neither in	NA

Reference	Adoption	Component & delivery method	Duration	Context	Outcome	Maintenance
		teachers to do a 10-minute segment moderate intensity, age- and space-appropriate exercises. The form of exercises was game, dance or rhythmic gymnastics. Students were also encouraged to develop more forms of exercises they like. Furthermore, education about physical activity was provided to students, parents, health workers and teachers. Each student attended the "Happy 10" 10 minutes for once, twice a day or 20 minutes for each time, once a day. Nu ed + PA			BMI nor in BAZ change between the PA intervention and its' control, which is the same case in the nutrition intervention	
Bhave S, et al, 2016.	• <u>Introduction of the intervention</u> 1. Meetings were held to inform families and teachers about the study. 2. Investigators trained teachers to deliver the intervention.	<u>1.Extra PA</u> 6 PA sessions/week, making PE a 'scoring' subject that contributed to the children's academic marks, engage the children in daily yoga-based breathing exercises ('pranayam'), and offering	5 years	A symbiosis school in Pune has a strong academic reputation and most students had high socio-economic status.	No significant changes were found.	NA

Reference	Adoption	Component & delivery method	Duration	Context	Outcome	Maintenance
	3. Investigators encouraged kitchen staff to provide healthy food. 4. Parents were trained and asked to prepare healthier lunch boxes. • <u>Adoption of stakeholders</u> No information on the extent of adoption from the stakeholders.	attractive physical activity sessions (e.g., 'Bollywood dancing') during holidays <u>2. Provision of healthy food</u> Nutritionists worked with kitchen staff to provide healthier lunch with more fruit and vegetables and ban fast-food sellers from outside the school gates. <u>3. NE</u> 1 hr session/week teaching about the importance of diet, healthy eating, active lifestyle and integrate nutrition into science classes.		The school provided paid lunch for students, and two compulsory 40-minute physical education (PE) periods per week. Outdoor activities are constrained by a small playground.		
Liang Y, Lau PWC, Jiang YN, Maddison R, 2020	The investigators conducted the intervention.	<u>PA Promotion</u> After-school extracurricular 1-hr PA session (10–15 minutes warm-up, followed by the active video game (AVG game)) X 8 weeks using two game consoles-	8 weeks	Hong Kong-China. Limited outdoor space in primary schools (2 m^2/student) and constraints of outdoor programs (i.e.,	BMI z score (mean (SD)) in the IG at baseline was 0.4 (1.4), at post intervention 0.4 (1.3). Mean difference (IG mean difference – CG	NA

Reference	Adoption	Component & delivery method	Duration	Context	Outcome	Maintenance
		Xbox 360 Kinect™. Trained researchers led the AVG classes. The game required both upper and lower body movements.		safety concern, air pollution, and inclement weather).	mean difference) was 0 (−0.1, 0.1), p = 0.42.	
Toruner EK, et al, 2015.	The investigators conducted nutrition education.	4 training sessions over 3 months. Each training session lasted 1 class hour (an average of 40 minutes). The sessions included the presentation of information on (a) healthy life, (b) nutrition, (c) sedentary lifestyle, and (d) physical exercise through lectures, discussions, and short messages. Before the 2nd, 3rd, and 4th training sessions, short messages about the previous training session(s) were used to prompt the children. Teaching methods included playing games, videos, and show and tell. group playing	3 months	Turkey	No significant difference was observed in the initial and final BMI of the intervention Group.	NA

Reference	Adoption	Component & delivery method	Duration	Context	Outcome	Maintenance
		was performed with red, yellow, and green traffic lights for healthy and unhealthy foods; and 2 short cartoons (2 to 3 minutes) were presented. Teachers joined the sessions with the students. Brochures were sent to families.				
Wang JJ, et al, 2015.	Medical research postgraduate students implemented the intervention with the help of a physical trainer.	Used social cognitive theory. 1. <u>PA</u> Extra exercise sessions were prescribed. 2. NE Lectures about diet and PA were provided during the parental meeting (Education materials and content were delivered to the parents without attendance by the mail and phone) 3. Diet prescription and monitoring	1 year	China	Positive but non-significant adjusted changes in body mass index and waist circumferences were observed.	NA

Reference	Adoption	Component & delivery method	Duration	Context	Outcome	Maintenance
		Normative feedback & individual feedback were given to students (in person) and parents(telephone)). Gifts were awarded to students who achieved their goals.				
Xu F, Ware RS, Leslie E, Tse LA, Wang ZY, Li JQ, et al, 2015.	The NE and PE were integrated into the current health eductation. Healthy diet and PA promotion messages were delivered to parents through regular parent meetings. All teachers were trained and provided with the same teaching materials to present for students.	1. <u>NE and NE curriculum</u> 30-minute lesson/month X 8 months (delivered by teachers). The content was about healthy diet, active lifestyle, and tips to a healthy lifestyle. The classes were monitored by the research team. 2. <u>School environment support</u> Monthly updated posters made by students presented at classroom, gymnasium, playground, and cafeteria. 3.<u>Family involvement</u> Carers meeting twice a term run by researchers to provide knowledge about childhood	1 year	An urban district of Nanjing. Health education is compulsory for all primary and high schools. The first priority of family and schools is academic performance.	Mean differences of BMI (SD) among IG vs CG: -0.32±1.36 vs. -0.29±1.40, p = 0.09.	NA

Reference	Adoption	Component & delivery method	Duration	Context	Outcome	Maintenance
		obesity, healthy diet, and active lifestyle. Interactive assignment about high-dense energy home food and BMI assessment was offered. 4.Fun programme/events a) presentation competition (tell their stories by drawing). A stage drama of the story wining the prize. b) no unhealthy snack week. c) no TV week. d) No soft drink week.				
Toruner EK, Savaser S, 2010.	NA	1. NE for children 1-2 hr(s) training session x 7 sessions in 2.5 months about self-recognition, self-expression, healthy nutrition, physical exercises, the negative effects of a sedentary life, and goal setting based on Social Cognitive Theory. 2. Training session for parents	13 months	Ankara capital city of Turkey.	No statistically significant difference was detected between the first and second BMI measurements in both the intervention and the control groups. BMI (kg/m2) (mean (SD)): IG at baseline 23.1 (2.0), at post intervention 22.5	

Reference	Adoption	Component & delivery method	Duration	Context	Outcome	Maintenance
		Two sessions to increase awareness of childhood obesity. 3. Consultation for parents 30-50 minutes session. This is to improve eating and PA behaviours at 3 levels: 1. Psychological -to improve intention, perception of one's own capacity, and goal setting, 2.Behavioural- healthy eating and active lifestyle promotion 3. Environmental- parents to encourage healthy eating and PA at home.			(1.8). CG at baseline 23.2 (2.5), at post intervention 23.5 (2.4).	

Chapter 4

The impact of a complex school nutrition intervention on double burden of malnutrition among Thai primary school children: a 2-year quasi-experiment

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SECTION A – Student Details

Student ID Number	1801282	**Title**	Miss
First Name(s)	Suladda		
Surname/Family Name	Pongutta		
Thesis Title	The impact of complex school nutrition programmes on the nutritional status of school-aged children: A review of Asian countries' experiences and lessons from a case study in Thailand		
Primary Supervisor	Leesa Lin		

If the Research Paper has previously been published please complete Section B, if not please move to Section C.

SECTION B – Paper already published

Where was the work published?	Public Health (Elsevier)		
When was the work published?	19 September 2023		
If the work was published prior to registration for your research degree, give a brief rationale for its inclusion			
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Stage of publication	Choose an item.

SECTION D – Multi-authored work

For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	I co-designed the quasi-experiment, designed and undertook the data analysis, wrote the first draft of the paper, and will respond to reviewers' comments.

SECTION E

Student Signature	Suladda Pongutta
Date	8 December 2023

Supervisor Signature	[redacted]
Date	15 December 2023

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Original Research

The impact of a complex school nutrition intervention on double burden of malnutrition among Thai primary school children: a 2-year quasi-experiment

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ABSTRACT

Objective: This study assessed the impacts of the *Dekthai Kamsai* programme on overweight/obesity, underweight and stunting among male and female primary school students.
Study design: A quasi-experiment was conducted in 16 intervention and 19 control schools across Thailand in 2018 and 2019. In total, 896 treated and 1779 control students from grades 1 to 3 were recruited. In intervention schools, a set of multifaceted intervention components were added into school routine practices. Anthropometric outcomes were measured at baseline and at the beginning and end of every school term.
Methods: Propensity score matching with linear and Poisson difference-in-difference analyses were used to adjust for the non-randomisation and to analyse the intervention's effects over time.
Results: Compared with controls, the increases in mean BMI-for-age Z-score (BAZ) and the incidence rate of overweight/obesity were lower in the intervention schools at the 3rd, 4th and 8th measurements and the 3rd measurement, respectively. The decrease in mean height-for-age Z-score (HAZ) was lower at the 4th measurement. The decrease in the incidence rate of wasting was lower at the 5th, 7th and 8th measurements. The favourable impacts on BAZ and HAZ were found in both sexes, while the favourable impact on overweight/obesity and unfavourable impact on wasting were found in girls.
Conclusions: This intervention might be effective in reducing BAZ, overweight/obesity, poor height gain, but not wasting. These findings highlight the benefits of a multifaceted school nutrition intervention and a need to incorporate tailor-made interventions for wasting to comprehensively address the double burden of malnutrition.

Introduction

The double burden of malnutrition in children, which is defined as the coexistence of over- and under-nutrition, is a leading cause of global disability-adjusted life years (DALYs).[1] This threat undermines the global capacity to achieve the United Nations' Sustainable Development Goals (SDGs) not only because nutrition is a

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part of SDG2 (End hunger, achieve food security and improved nutrition and promote sustainable agriculture) but also nutrition contributes to ensuring healthy lives and human well-being (SDG3) and development.[2,3]

Malnutrition is extremely challenging to address due to its complex aetiology.[3] Current progress in addressing it is slow and unlikely to achieve the global nutrition targets for 2025.[4] Children aged 5–19 years are often neglected, as they are not prioritised in global targets. In this age group, there has been a rapid increase in overnutrition (overweight and obesity) as well as the continued presence of undernutrition (wasting and stunting) in low- and middle-income countries.[4,5] There is evidence that school nutrition interventions have the potential to decrease overweight and obesity in school-aged children and adolescents; however, most studies were carried out in high-income countries and China.[6,7] Moreover, the effects of interventions on undernutrition among school-aged children are rarely reported, and there is limited information on whether boys and girls respond differently to school-based interventions. Therefore, more evidence, especially from diverse low- and middle-income countries, is needed to guide the effective implementation of school-based nutrition interventions to address the double burden of malnutrition.

The double burden of malnutrition among school-aged children is increasing in Thailand because of a rise in child obesity (5.8%–18.1% between 1995 and 2014) alongside with a persistence of undernutrition (14.4% wasting, 2.9% stunting in 2014).[8] Although a free school lunch scheme has been implemented in public primary schools in Thailand since 1999,[9] the double burden of malnutrition among Thai school-aged children still continues to rise. This indicates that providing free school lunch alone is insufficient.

Therefore, a school nutrition intervention called the '*Dekthai Kamsai* Programme' was implemented in primary schools to address malnutrition in school-aged children. It is a multipurpose, multicomponent and multiactor school nutrition intervention based on lessons learned from previous school nutrition programmes in Thailand.[10] A recent study, published in February 2023, indicated that this programme might reduce overweight and obesity among school-aged children.[11] However, since the study was cross-sectional with no baseline data and it did not assess the impact of the programme on undernutrition, further research should be conducted to examine whether the programme really had impacts on the double burden of malnutrition among the children and in both sexes. From 2018 to 2019, a 2-year quasi-experiment assessing the impacts of *Dekthai Kamsai* Programme was conducted. Our study analysed the data obtained from this quasi-experiment to assess the impacts of the *Dekthai Kamsai* programme on overweight/obesity, wasting and stunting among different sexes of primary school students.

Methods

Study design and participants

This study analysed data from a 2-year quasi-experiment conducted in 2018 and 2019. A convenience sample of 50 public primary schools were invited to participate in the study. Thirty-five schools accepted the invitation, consisting of 16 intervention schools and 19 control schools from 12 provinces. The intervention schools were schools located in major provinces across different regions in Thailand and willing to implement the programme. Control schools were schools located in the same provinces as the intervention schools and willing to participate as controls in this study. All students from grades 1 to 3 in these schools were eligible for inclusion. In total, 2675 students, consisting of 896 students from intervention schools and 1779 students from control schools, were recruited into this study. This sample size had 97% power to detect a difference in the rates of overweight and obesity of 20% in intervention and 30% in control groups, respectively, using a two-tailed significance level of 0.05 and adjusted for clustering.[12] These overweight and obesity rates were estimated based on the prevalence of overweight among Thai school-aged children in 2014[8] and a pooled effect of school-based obesity tackling programmes implemented globally in 2014.[13] Written informed consent was obtained from both students and their parents/caretakers with assistance from school staff. Ethical approvals were granted by the Institute for the Development of Human Research Protections (IHRP 021-2563) and London School of Hygiene and Tropical Medicine (LSHTM Ref. No.26555). The process of recruitment is shown in Fig. 1.

Intervention design

The *Dekthai Kamsai* programme was developed by a multidisciplinary working group using lessons learned and tools available from previous school initiatives.[10] The programme was intended to build the capacity of primary schools to improve nutrition and child development among children in their schools, while avoiding unacceptable school staff workloads to gain acceptance and ensure sustainability. The programme's components were designed with an aim to integrate nutrition promotion into regular practices of primary schools rather than introducing additional duties. This programme was implemented on an annual basis according to the programme's and schools' annual budgets and action plans.

The programme strengthened the schools' capacity to implement eight synergistic components, as detailed in Table S1. Broadly, they were related to 1) healthy food provision; 2) school farm and garden; 3) health and nutritional status monitoring; 4) school co-operatives and vocational training; 5) personal health and hygiene promotion; 6) school sanitation; 7) basic health service; and 8) agriculture, nutrition and health education. The intervention schools were required to be competent in implementing the 'healthy food provision' and 'health and nutritional status monitoring' components. Other components were complementary components. The implementation strategies of these components were adaptable to suit the schools' contexts, for example, schools are allowed to provide local food menus with equivalent nutritional values to standard school meals and choose traditional dances or active plays over common sports to promote students' physical activity. Each intervention school formed a working group to integrate these components into the school's routine practices and communicate with class teachers who engaged the students in the programme implementation. Training courses, materials and onsite

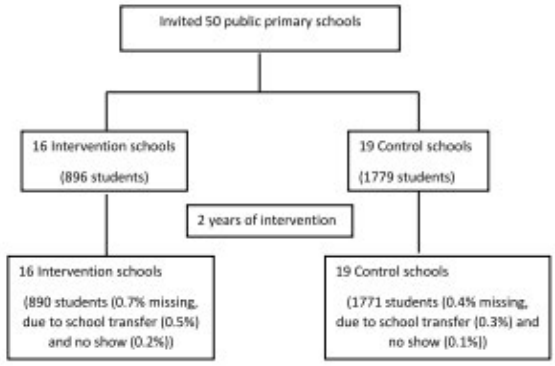

Fig. 1. Participant recruitment and retention.

visits were provided to support the teachers, students and parents. The comparison between the *Dekthai Kamsai* implementation and control schools' routine practices is described in Table S1.

The programme also created a platform for schools to obtain support from authorities at the local level by having five organisations, including the Ministry of Education, Ministry of Public Health, Ministry of Interior, Ministry of Agriculture and Co-operatives, and the National Electronics and Computer Technology Centre, sign a memorandum of understanding to provide support for the schools to implement these components. The programme encouraged schools to work together with communities to ensure a sufficient supply of safe and fresh food ingredients. *Dekthai Kamsai* annual conferences were organised for the intervention schools to share their knowledge and experiences. Intervention schools with excellent practices were promoted as role models, and their experiences were shared on social media and television programmes for facilitating mutual learning. Control schools continued to operate their routine practices.

Outcome measurement and data collection

Anthropometric measurements were conducted by class teachers who were trained by local health personnel. This training is routinely done in all Thai primary schools and did not differ between the intervention and control schools. Students' weights and heights were measured using the schools' calibrated digital scales to the nearest 0.1 kg and portable stadiometers to the nearest 0.1 cm. Consistent measuring instruments and methods were used to measure the children within each school throughout the study period. Data collection was conducted at the beginning and end of each school term, with a total of eight data collection points in the years 2018 and 2019. The first and eighth measurements were conducted at the beginning and end of the programme. The long school break (i.e. 6 weeks) occurred between the 4th and 5th measurements.

Reliability of staff's measurements was assessed by researchers using a method previously described.[14] The weights and heights of 364 students from eight randomly selected schools (i.e. 4 intervention and 4 control schools) were measured independently by school staff using their regular measuring instruments and the research team using a digital scale (Tanita, HD382, Tokyo, Japan) to the nearest 0.1 kg and a portable stadiometer (Institute of Nutrition, Mahidol University, Thailand) to the nearest 0.1 cm. The results showed excellent agreement between the school staff's and research team's measurements (the intraclass correlations coefficient (ICC) were: weight ICC = 0.99, height ICC = 0.99, body mass index (BMI) ICC = 0.99 and BMI *z* score ICC = 0.99).

Statistical analysis

Outcome variables included BMI (kg/m^2), BMI-for-age Z-scores (BAZ), height-for-age Z-scores (HAZ), wasting, stunting, and overweight and obesity. The Z-scores were calculated using the World Health Organization growth reference data.[15] Children were categorised as wasted or stunted if their BAZ or HAZ, respectively, were less than -2SD. They were categorised as overweight and obese if their BAZ were more than 1SD and 2SD, respectively.

Although the distributions of continuous outcomes (i.e. BMI, BAZ and HAZ) were non-normal, the large sample size of this study allows the application of parametric statistical methods without having to transform the data.[16] The independent *t*-test was used to compare the mean BMI, BAZ and HAZ of the intervention and control groups at baseline. For binary variables (wasted, overweight or obesity and stunted), the chi-squared test was used to compare the intervention and control groups at baseline. We used nearest neighbour propensity score matching with the code 'psmatch2' to adjust for the non-randomised design of this study in STATA version 17.[17,18] Logistic regression was performed to estimate propensity score for each observation using the following baseline characteristics: *urbanicity, sex, age, parental occupation* and *person who usually cooked meals for the student*. Treated participants were matched with seven nearest neighbour controls within 0.2 caliper. To determine the effects of the programme, the difference-in-difference approach with linear and Poisson regression models for panel data was used for continuous outcomes (BMI, BAZ and HAZ) and binary outcomes (overweight/obesity, wasting and stunting), respectively. All models were adjusted for the clustering effects of school because the sampling process and treatment assignment were done at the school level and also students in the same school were exposed to the same context.[19,20] Significance tests were set at $\alpha = 0.05$.

Results

Table 1 describes the sociodemographic and anthropometric characteristics of the control and intervention groups at baseline. There were no statistically significant differences between intervention and control groups in terms of gender, average age, parental occupation, the person who usually cooked meals for the student, mean BMI, mean BAZ and percentage of stunted children. However, there were significant intergroup differences in the percentage of students living in urban areas, the participants mean HAZ and the percentages of overweight/obese and wasted participants. Of 1779 controls, 1609 controls were good matches for 896 treated participants and were included in the analyses. The balancing property was satisfied with Rubins' B less than 25% and R between 0.5 and 2 (Table S2).

Mean BMI and BAZ increased over time in both groups (Table S3). The effect of the intervention on the students' BAZ was shown in Table 2. The increase in mean BAZ in the intervention

Table 1
Sociodemographic and anthropometric characteristics of children in intervention and control schools at baseline.

Variable	Intervention group ($N = 896$)	Control group ($N = 1779$)	*P*-value
Male (%)	50.7	54.1	0.090
Age (years) (mean (SD[d]))	7.7 (1.08)	7.8 (1.05)	0.070
Live in urban area (%)	50.5	73.8	<0.0001[e]
Parental occupation (%)			
Daily wage worker	42.3	41.2	0.432
Farmer	10.7	11.7	
Business owner	11.0	11.6	
Private sector employee	15.5	15.5	
Civil servant	4.5	4.1	
Unemployed	3.5	5.1	
Other, e.g. monk, died or lost contact	12.5	10.8	
Person who usually cooked meals for the student (%)			
Mother	51.5	53.0	0.321
Other family member	14.6	14.4	
Oneself	27.5	24.8	
Other, e.g. food vendors	6.4	7.8	
BMI[a] kg/m^2 (mean (SD[d]))	16.64 (3.76)	16.85 (4.28)	0.222
BAZ[b] (mean (SD[d]))	0.15 (1.65)	0.09 (2.17)	0.473
HAZ[c] (mean (SD[d]))	−0.33 (1.16)	0.05 (1.32)	<0.0001[e]
Overweight and obese (%)	26.1	32.6	0.001[e]
Wasted (%)	5.8	12.5	<0.0001[e]
Stunted (%)	5.6	4.8	0.407

[a] BMI – body mass index.
[b] BAZ – body mass index-for-age Z-score.
[c] HAZ – height-for-age Z-score.
[d] SD – Standard deviation.
[e] Significant difference at $P < 0.05$.

group was significantly lower than that of the control group at the 3rd, 4th, 6th, 7th and 8th measurements. This favourable trend was found in both boys (at the 3rd, 4th, 6th and 8th measurements) and girls (at the 3rd, 4th, 7th and 8th measurements).

The increase in mean BMI was significantly lower in the intervention compared with the control group at the 3rd (−0.267, 95% CI −0.476, −0.058, $P = 0.014$) and 4th measurements (−0.333, 95% CI −0.602, −0.065, $P = 0.017$) (Table S4). This favourable trend was found in both boys and girls.

Mean HAZ in the intervention group did not change much, whereas mean HAZ in the control group decreased over time (Table S3). Overall, the decrease in mean HAZ in the intervention group was significantly lower than the control group only at the 4th measurement (Table 3). This trend was found in both boys and girls.

The percentage of overweight or obese students increased over time in intervention and control groups (Fig. S1). The increase in incidence rate of being overweight or obese in the intervention group was significantly lower than in the control group at the 3rd measurement (Table 4). This trend was found in girls, but not in boys.

The percentage of wasted students decreased in both groups in 2018 and continued to decrease in only the control group in 2019 (Fig. S2). Compared with the control group, the decrease in incidence rate of being wasted in the intervention group was significantly lower at the 5th, 7th and 8th measurements (Table 5). The decrease in incidence rate of being wasted in treated girls was significantly lower than untreated girls at the 4th, 5th, 7th and 8th measurements. There was no significant difference between treated and untreated boys.

Table 2
Effects of the intervention on body mass index Z-scores (BAZ) comparing children in intervention and control schools.

Variable	Coefficient	95% CI	*P*-value
Effect on both sexes ($N = 2505$)			
Reference: 1st measurement			
2018 (Baseline)			
2nd measurement	−0.110	−0.238, 0.019	0.092
3rd measurement	−0.190	−0.326, −0.054	0.007*
4th measurement	−0.219	−0.375, −0.065	0.007*
2019			
5th measurement	−0.171	−0.354, 0.012	0.067
6th measurement	−0.246	−0.463, −0.029	0.028*
7th measurement	−0.239	−0.450, −0.027	0.028*
8th measurement (Endline)	−0.307	−0.524, −0.090	0.007*
Effect on boys ($n = 1334$)			
Reference: 1st measurement			
2018 (Baseline)			
2nd measurement	−0.118	−0.247, 0.011	0.072
3rd measurement	−0.209	−0.360, −0.059	0.008*
4th measurement	−0.223	−0.392, −0.054	0.011*
2019			
5th measurement	−0.180	−0.383, 0.023	0.081
6th measurement	−0.272	−0.503, −0.040	0.023*
7th measurement	−0.228	−0.461, 0.006	0.056
8th measurement (Endline)	−0.291	−0.521, −0.060	0.015*
Effect on girls ($n = 1171$)			
Reference: 1st measurement			
2018 (Baseline)			
2nd measurement	−0.101	−0.246, 0.044	0.165
3rd measurement	−0.171	−0.315, −0.028	0.020*
4th measurement	−0.217	−0.372, −0.061	0.008*
2019			
5th measurement	−0.162	−0.349, 0.025	0.087
6th measurement	−0.219	−0.440, 0.002	0.052
7th measurement	−0.250	−0.460, −0.040	0.021*
8th measurement (Endline)	−0.325	−0.547, −0.102	0.005*

Used linear regression difference-in-difference, * Significant increase at $P < 0.05$.

Table 3
Effects of the intervention on height-for-age Z-scores (HAZ) comparing children in intervention and control schools.

Variable	Coefficient	95% CI	*P*-value
Effect on both sexes ($N = 2505$)			
Reference: 1st measurement			
2018 (Baseline)			
2nd measurement	0.011	−0.066, 0.087	0.778
3rd measurement	0.071	−0.004, 0.147	0.064
4th measurement	0.141	0.010, 0.271	0.036*
2019			
5th measurement	0.082	−0.063, 0.226	0.258
6th measurement	0.113	−0.065, 0.292	0.206
7th measurement	0.175	−0.016, 0.366	0.072
8th measurement (Endline)	0.207	−0.033, 0.446	0.089
Effect on boys ($n = 1334$)			
Reference: 1st measurement			
2018 (Baseline)			
2nd measurement	0.009	−0.650, 0.084	0.802
3rd measurement	0.070	−0.0070.146	0.073
4th measurement	0.135	0.009, 0.261	0.037*
2019			
5th measurement	0.063	−0.076, 0.202	0.361
6th measurement	0.094	−0.067, 0.254	0.243
7th measurement	0.155	−0.013, 0.323	0.070
8th measurement (Endline)	0.167	−0.041, 0.375	0.112
Effect on girls ($n = 1171$)			
Reference: 1st measurement			
2018 (Baseline)			
2nd measurement	0.012	−0.070, 0.094	0.767
3rd measurement	0.073	−0.008, 0.154	0.076
4th measurement	0.146	0.006, 0.286	0.042*
2019			
5th measurement	0.100	−0.059, 0.258	0.210
6th measurement	0.133	−0.073, 0.338	0.197
7th measurement	0.194	−0.029, 0.417	0.086
8th measurement (Endline)	0.194	−0.029, 0.417	0.086

Used linear regression difference-in-difference, * Significant increase at $P < 0.05$.

There was no significant difference comparing the changes in incidence rate of being stunted between the intervention and control groups and between boys and girls.

Discussion

The results from this study indicate that the *Dekthai Kamsai* Programme had favourable impacts on BMI, BAZ, HAZ in both sexes and overweight/obesity in girls after one school term. However, these favourable changes were interrupted by the long school break between the two school years. In terms of wasting, the programme had no positive impact among boys and may had a negative impact among girls. This programme might be effective in reducing the risks of becoming overweight or obese and stunted; however, there was a room for improvement, especially in addressing wasting.

These results for overnutrition are consistent with a recent cross-sectional analysis of the *Dekthai Kamsai* Programme,[11] which indicated that the programme reduced the overweight and obesity rates among children in the intervention compared with control schools.

The effect size of the *Dekthai Kamsai* programme on students' BAZ was greater than the pooled effect of 12 multicomponent school nutrition programmes implemented in Asia during the past decade (−0.190, −0.220, −0.246, −0.239 and −0.307 vs. −0.07).[7] Among these previous 12 school nutrition programmes, six interventions significantly reduced students' BAZ with effect sizes ranging from −0.03 to −0.14.[21–26] Similar to the *Dekthai Kamsai* programme, the previous interventions were multicomponent interventions; however, they differed in terms of the number of

Table 4
Effects of the intervention on the incidence rate of overweight comparing children in intervention and control schools in 2018 and 2019[b].

Variable	IRR[a]	95% CI	*P*-value
Effect on both sexes (*N* = 2505)			
Reference: 1st measurement 2018 (Baseline)			
2nd measurement	0.953	0.879, 1.034	0.249
3rd measurement	0.903	0.819, 0.995	0.039*
4th measurement	0.903	0.805, 1.013	0.082
2019			
5th measurement	0.987	0.807, 1.207	0.900
6th measurement	0.932	0.794, 1.093	0.384
7th measurement	0.963	0.803, 1.154	0.681
8th measurement (Endline)	0.969	0.805, 1.167	0.742
Effect on boys (*n* = 1334)			
Reference: 1st measurement 2018 (Baseline)			
2nd measurement	0.955	0.869, 1.049	0.337
3rd measurement	0.932	0.831, 1.046	0.235
4th measurement	0.945	0.833, 1.071	0.377
2019			
5th measurement	1.011	0.802, 1.274	0.927
6th measurement	0.937	0.783, 1.122	0.481
7th measurement	0.983	0.775, 1.247	0.890
8th measurement (Endline)	1.005	0.806, 1.254	0.961
Effect on girls (*n* = 1171)			
Reference: 1st measurement 2018 (Baseline)			
2nd measurement	0.953	0.839,1.082	0.460
3rd measurement	0.869	0.762,0.991	0.037*
4th measurement	0.858	0.727, 1.012	0.069
2019			
5th measurement	0.958	0.764,1.201	0.709
6th measurement	0.925	0.772, 1.109	0.399
7th measurement	0.938	0.762, 1.153	0.542
8th measurement (Endline)	0.922	0.743, 1.145	0.464

[a] IRR – incidence rate ratio.
[b] Used random effects Poisson regression difference-in-difference analyse, * Significant increase at $P < 0.05$.

Table 5
Effects of the intervention on the incidence rate of wasting comparing children in intervention and control schools in 2018 and 2019[b].

Variable	IRR[a]	95% CI	*P*-value
Effect on both sexes (*N* = 2505)			
Reference: 1st measurement 2018 (Baseline)			
2nd measurement	1.087	0.749, 1.577	0.662
3rd measurement	1.178	0.743, 1.867	0.487
4th measurement	1.199	0.783, 1.836	0.403
2019			
5th measurement	1.671	1.041, 2.682	0.033*
6th measurement	1.611	0.972, 2.669	0.064
7th measurement	1.771	1.082, 2.899	0.023*
8th measurement (Endline)	2.229	1.116, 4.453	0.023*
Effect on boys (*n* = 1334)			
Reference: 1st measurement 2018 (Baseline)			
2nd measurement	1.114	0.709, 1.750	0.640
3rd measurement	1.213	0.681, 2.162	0.513
4th measurement	0.824	0.451, 1.503	0.527
2019			
5th measurement	1.230	0.734, 2.061	0.431
6th measurement	1.419	0.834, 2.412	0.197
7th measurement	1.713	0.918, 3.198	0.091
8th measurement (Endline)	1.671	0.769, 3.634	0.195
Effect on girls (*n* = 1171)			
Reference: 1st measurement 2018 (Baseline)			
2nd measurement	1.040	0.620, 1.747	0.881
3rd measurement	1.147	0.752, 1.750	0.525
4th measurement	1.748	1.081, 2.826	0.027*
2019			
5th measurement	2.334	1.342, 4.058	0.003*
6th measurement	1.857	0.977, 3.530	0.059
7th measurement	1.822	1.033, 3.213	0.038*
8th measurement (Endline)	3.031	1.411, 6.511	0.004*

[a] IRR – incidence rate ratio.
[b] Used random effects Poisson regression difference-in-difference analyse, * Significant increase at $P < 0.05$.

components and intervention intensity. In general, the previous interventions focused on either physical activity and nutrition education or healthy food provision and nutrition education, whereas the more comprehensive *Dekthai Kamsai* programme aimed at improving physical activity, the provision of healthy school lunches, nutrition education, school sanitation and the school's capacity for monitoring and addressing malnutrition. Likewise, the level of physical activity implemented in the *Dekthai Kamsai* programme (i.e. 30-min per day of moderate to vigorous activity) was more intense than that implemented in five other programmes.[21,23–26] There was only one other programme with a more intense physical activity component (i.e. 60-min of daily vigorous activity).[22] Comprehensiveness and intensity of interventions may partially explain the different effect sizes of school nutrition interventions in Asia. Further research is needed to confirm the relationships between the comprehensiveness and intensity of interventions and effect sizes of school nutrition interventions in the Asian context.

The *Dekthai Kamsai* programme consisted of components that had been identified as key components for school-based obesity tackling by previous studies. Meta-analyses of school nutrition interventions confirm that physical activity, even as a single component, reduced children's BMI or BAZ, and that school gardening increased fruit and vegetable consumption among school-aged children.[6,7,27,28] School gardening and fun physical activities also increased the time spent in physical activity of moderate-to-vigorous intensity among school-aged children.[29–31] Two meta-analyses found that integrating agriculture, nutrition and health education into curricula increases the effectiveness of school-based nutrition interventions.[6,31] Real-time outcome monitoring was a key success factor of a successful adaptive community-based nutrition intervention[32] and a well-functioning feedback loop plays an important role in improving school-based nutrition interventions.[33] For diet interventions, the results are inconsistent, which might reflect the wide range of services in different school-based interventions.[7] Not all previous interventions provided school meals that met nutritional standards,[7] whereas those following dietary guidelines and school meal standards were effective.[34] The school lunches provided in the *Dekthai Kamsai* programme met one-third of the recommended nutrient reference values of children. Nevertheless, our findings suggested that one healthy school meal was not sufficient to address wasting in the intervention schools. Although our study adds to the current body of evidence that a combination of the *Dekthai Kamsai* components improved children's BMI, BAZ and HAZ and reduced the incidence rate of overweight and obesity, the contribution of individual components is unknown.

Interesting patterns were observed in anthropometric changes between the intervention and control groups. Firstly, the gap between the groups increased with time of exposure in each school year and decreased slightly during the 6-week school break between school years. This trend suggests that direct intervention exposure is important to maintain the intervention's effects. This finding is consistent with the finding from a recent cross-sectional study[11] that the impact on overnutrition of the *Dekthai Kamsai*

programme was not sustainable in dropped-out schools. Secondly, the differences were statistically significant after the first school term for BAZ (at the 3rd, 4th, 6th, 7th and 8th measurements) and HAZ (at the 4th measurement). This finding shows that this complex school nutrition intervention, in a semi-urban and mixed socio-economic status context, needs more than one school term to show significant changes. This finding highlights the importance of providing sufficient time for intervention exposure. At present, there is no evidence regarding the duration required to improve anthropometric outcomes in school nutrition programmes,[6,7,27] which is crucial for intervention programme planning and evaluation design. Our analyses and the previous analyses of the *Dekthai Kamsai* programme[11] indicate long-term continuity is important.

Our findings also highlight the importance of monitoring the anthropometric status of school children multiple times over the school year. Our study captured the pattern of changes over the school terms and school breaks, which encouraged the identification of the intervention gaps. Such data provides important insights to inform policy decisions on what works, for whom, and under what circumstances, which is required to inform policy decisions.[35,36]

Strengths and limitations

The strength of this study is that it provides evidence related to the double burden of malnutrition rather than obesity alone. Such evidence is scarce and yet it is important to obtain because in many parts of the world, school children suffer from both over- and/or under-nutrition.[4,5] School nutrition interventions and evaluations in Asia focused primarily on childhood obesity,[7] but not on wasting and stunting, which are also important problems in Asia.[3] In addition, it provides evidence regarding the impacts of school nutrition interventions implemented in Southeast Asia where relevant literature is very limited.

This study, however, has some limitations. Firstly, the collaborative nature of the *Dekthai Kamsai* programme and the ethical and equity considerations prevented a randomised control trial, which meant causal probability inferences could not be drawn given biases inherent to a quasi-experimental design. We partially adjusted for this limitation by using a propensity score matching method in conjunction with a difference-in-difference approach. These complementary statistical methods were initiated to reduce bias due to the non-randomised design of public policy impact assessments.[20] Secondly, the measurements of body weight and height were done using the school's measuring instruments by school staff who were not blinded to outcomes, which raises questions about the reliability of the data and the introduction of bias. However, the results of our reliability study and the data pattern continuity indicate that the quality of the data obtained from the schools was adequate. Thirdly, the *Dekthai Kamsai* programme was implemented with a realist approach, which meant it was implemented solely by local multisectoral actors and was adaptable to local capacities and needs. By this nature, it could lead to implementation variations among schools in the programme and reduce intervention fidelity. The evaluation design and nature of the programme limits our ability to assess the causal relationships between the individual components in the intervention and outcomes. However, this approach enhanced stakeholders' buy-in and context appropriateness.

Conclusion

This study adds to the current body of evidence that a school-based nutrition intervention with multifaceted components might be effective in reducing the incidence of overnutrition and increasing HAZ among Thai primary school-aged children after one school term. However, it was not effective in reducing wasting, especially among girls. This study stresses the need to provide a separate set of services within the programme, for wasted children, to strengthen its impact on the double burden of malnutrition. It also shows the feasibility of implementing an effective multiple-component school-based intervention within the routine practices of Thai public primary schools with sufficient financial and technical support to initiate and sustain the intervention.

Author statements

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Ethical approval

Ethical approval was granted by the Institute for the Development of Human Research Protections (IHRP 021-2563) and London School of Hygiene and Tropical Medicine (LSHTM Ref. No.26555).

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Competing interests

The authors declare that they have no conflict of interest.

Contributors

SP contributed to conceptualization, methodology, formal analysis, data curation and writing – original draft preparation; LL, EF, CD, VT, JB, SL and CW contributed to supervision, review and editing.

Patient and public involvement

Governmental agencies, non-governmental agencies and an inter-disciplinary working group responsible for school-based health policy were involved in the design, implementation and report of findings of this intervention. The staff of participating schools took part in designing strategies used in some components of the intervention.

Consent for publication

Not applicable.

Availability of data and materials

The data sets used during the current study are available from the corresponding author on reasonable request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.08.023.

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Chapter 5

Addressing the double burden of malnutrition among Thai school-aged children with a complex school nutrition intervention: A process evaluation

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Addressing the double burden of malnutrition among Thai school-aged children with a complex school nutrition intervention: A process evaluation

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Abstract

Background: The Dekthai Kamsai programme, a complex school nutrition intervention implemented in Thailand, demonstrated favourable outcomes in reducing the risk of developing obesity and stunting. This article aims to describe the intervention, contextual factors, and their interactions influencing the outcomes.

Methods: We conducted a process evaluation using data obtained from 1) 14 focus group interviews conducted with 69 school staff from 10 intervention schools and 4 control schools from January to February 2022, and 2) a document analysis.

Results: Perceived strengths of the programme included: 1) its multi-component design targeting both diet and physical activity using food and physical activity guidelines for children, close monitoring of students' anthropometric outcomes for ongoing nutrition improvements, and complementary components that synergistically enhanced and sustained its outcomes; and 2) a multi-sectoral support system to build schools' capacity and facilitate programme implementation. Perceived limitations included a lack of adequate effort to address wasting and suboptimal fidelity. Regarding contextual factors, child nutrition and well-being were not a priority for the education sector resulting in limited resources and the willingness of school staff to adopt and implement the programme. Schools in higher socio-economic urban neighbourhoods tended to receive greater external support and benefit more from better infrastructure of urban areas. The programme's impact in urban schools tended to be offset by urban obesogenic environments. School staff having interest in children's well-being tended to adopt and implement the programme intensively. A healthier food culture tended to enhance the intervention's success.

Conclusions: These findings highlight the importance of 1) implementing multifaceted interventions; 2) prioritising child nutrition and well-being across multiple sectors; and 3) improving school contexts notably policy, leadership, capacity, social capital, social and physical environments.

Keywords: school nutrition intervention, process evaluation, overnutrition, undernutrition

Introduction

Malnutrition in childhood was recently identified as a global leading health risk factor in children(1). While school nutrition interventions have proven effective in reducing overweight and obesity (2-4), solely acquiring evidence on programme impact is insufficient for effective decision-making. This is because there is no guarantee that the same intervention will provide similar effects in different populations and circumstances(5). The current body of evidence often falls short in explaining how or why these interventions were effective(2-4). This knowledge is crucial for informing policy decisions and replicating effective school nutrition interventions in other contexts. Hence, it is important to provide evidence on not only what works, but also for whom, in what circumstances, and why. This approach is necessary to improve intervention design, planning, and implementation.

Thailand is a middle-income country in which the double burden of malnutrition (the coexistence of undernutrition and overnutrition or diet-related diseases in the same population) has existed for decades (6). Obesogenic environments have become pervasive throughout the country (7, 8), while a considerable proportion of the population (9.9% in 2018) still experiences extreme poverty (9). These social determinants have accelerated overweight and obesity levels and prolonged underweight status in children (6). Over the past decade, regulatory interventions have been launched to counterbalance the obesogenic environments, including introducing sugar sweetened beverage (SSB) taxation and nutrition labelling (10). Free school lunch provision has been implemented in public primary schools since 1999 to address undernutrition (11). Despite these efforts, malnutrition in school-aged children has continued to grow with

66 a constant increase in overweight and obesity (from 5.8% to 18.1% between 1995 and 2014) alongside the
67 persistent wasting (from 15.0% to 8.2% between 1995 and 2014) and stunting (from 6.6% to 2.9%
68 between 1995 to 2014) (12).

69 The Dekthai Kamsai Programme (henceforth called the Programme) was developed by a multi-
70 disciplinary working group to address malnutrition and promote the development of school-aged children
71 (13). It is a complex intervention with multiple actors and components that integrate nutrition and child
72 development programmes into the academic performance-oriented education system. An impact
73 evaluation of this Programme showed favourable outcomes on Body Mass Index (BMI), BMI-for-age z-
74 score (BAZ), overweight/obesity, and height-for-age z-score (HAZ), but not wasting (14) (see S3 Table).
75 This study aimed to explore the Programme's internal factors, contextual factors, and their interactions
76 that determined the impact of the Programme.

77 Materials and Methods

78 About the Dekthai Kamsai programme

79 The Dekthai Kamsai Programme consisted of eight interlinked components: C1) healthy food
80 provision; C2) school farm and garden; C3) health and nutritional status monitoring; C4) personal
81 hygiene promotion; C5) agriculture, nutrition, and health education; C6) school cooperatives and
82 vocational training; C7) school sanitation and healthy school environment; and C8) basic health service
83 provisions. The programme's logic model and design are shown in Fig 1 and S1 (13).

84

85

86

87 **Fig. 1 The Programme programme's logic model**

89 **Process evaluation**

90 A process evaluation framework adapted from the Realist evaluation theory (5), RE-AIM
91 framework(15), and the Medical Research Council (MRC) process evaluation (16) was used to assess the
92 intervention adoption, implementation, observable outcomes, and the influence of school contexts. The
93 assessment of intervention adoption encompassed the following questions: "Why the intervention was
94 adopted or not adopted?" and "Whether the intervention institutionalized or integrated into routine
95 practices and How?". The intervention implementation examined "How the intervention was
96 implemented and adapted to assess intervention integrity and variation in delivery across intervention
97 schools? Who delivers and to Whom it is delivered and What was their participation?" and "What are the
98 control schools' routine practices to promote students' health, nutrition, and well-being?". Both
99 intentional and unintentional outcomes were included in the assessment of observable outcomes. The
100 influence of school contexts was assessed using the following questions: "What were the conditions under
101 which the intervention was introduced and What was the interplay between these conditions and the
102 intervention?".

103 This study used two different qualitative methods, which were focus group interviews (FGIs) and
104 document analysis.

105 **Focus Group Interviews**

106 The FGIs were conducted with 69 school staff (4-6 respondents per school) from 14 participating
107 schools comprising 10 intervention schools and four control schools. The participating schools consisted
108 of Group 1 (high impact): five intervention schools with the highest increase in the percentage of students
109 having normal weight; Group 2 (low impact): five intervention schools with the lowest increase in the
110 percentage of students having normal weight; and Group 3: four control schools agreed to participate in
111 the FGIs as shown in Table 1.

112 For the intervention schools, the respondents included schools' principals and staff who were
113 involved in the Programme implementation in the selected schools in 2018 and 2019. For control schools,
114 the respondents were schools' principals and staff who were responsible for school lunches and students'
115 health in general. These focus group interviews were conducted via video conferences from January to
116 February 2022, since face-to-face FGIs were considered unsafe during the COVID-19 pandemic. Each
117 interview took around one hour (±15 minutes) according to respondents' conveniences. After permission
118 by respondents, the FGIs were tape recorded, transcribed verbatim and saved on a code-protected
119 personal computer.

120 **Table 1. Participating schools' programmatic outcomes: changes* of wasting, normal BMI, and**
121 **overweight and obesity rates between 2018 and 2019**

School	Wasting	Normal BMI	Overweight and obesity
Group1: Intervention schools with maximum progress			
School#1	-7.4	9.0	-1.7
School#2	-2.5	6.6	-4.1
School#3	-8.7	5.3	3.4
School#4	-4.4	5.5	-1.1
School#5	-1.2	1.2	0.0
Group2: Intervention schools with minimum progress			
School#6	-1.6	-0.7	2.3
School#7	2.1	-2.6	0.5
School#8	-0.7	-5.6	6.3
School#9	6.9	-11.1	4.2
School#10	-0.5	-15.5	16.0
Group3: Control schools			

School	Wasting	Normal BMI	Overweight and obesity
School#11	-4.8	3.0	1.8
School#12	-3.4	0.4	3.0
School#13	-2.5	-4.7	7.2
School#14	0.2	-4.7	4.5

* Change = percentage at endline – percentage at baseline

Document analysis

The documents analysed were materials provided to participating schools by the Programme (i.e., school food standards and management guidelines and handbooks and pamphlets used to guide the implementation) (Document1), transcripts of semi-structured interviews conducted in 2019 by one of the authors assessing school practices for all intervention components in 2018 and 2019 with 45 school staff in 10 intervention schools (Document2), schools' progress reports (Document3), the Programme's progress reports in 2018 and 2019 (Document4), and the Programme's lessons learned reports published in 2018 (Document5) and 2019 (Document6).

Data analysis

The data from different methods and sources were triangulated to cross-check response agreement and reduce potential biases using a protocol adapted from the method of Farmer et. al.(17). The data from all methods and sources were analysed using the framework analysis technique (18), which used predetermined codes based on the evaluation framework, while remaining open to emergent new themes. Two researchers independently conducted coding, convergence and completeness assessments between the findings. Discrepancies were discussed among them until an agreement was reached. The Standards for Reporting Qualitative Research (SRQR) checklist (19) was used to guide the reporting of results. Researchers' characteristics and reflexivity are described in S3.

Ethics approval and consent to participate: This process evaluation received ethical approvals from the Institute for the Development of Human Research Protections (IHRP Ref. No.021-2563) and London School of Hygiene and Tropical Medicine (LSHTM Ref. No.26555). Informed consent was obtained from all subjects involved in the study.

Results

School routines

Thai school-aged children spend at least eight hours at school, from around 8am to 4pm, from Monday to Friday (School1-14). On each school day, all students join the 15- to 20-minute morning session to sing the national anthem, listen to school announcements, and do other activities depending on the school's policy (School1-14). After the morning session, students have classes with a one-hour lunch break (School1-14). Free school lunches were provided by all schools, as they have been fully subsidised by the Thai government since 1999 (11). All students have a one-hour session per week in health and physical education (School1-14).

Education policy and schools' contexts

In general, the priority of the Thai education system, and the parents' expectations, are related to academic performance rather than child health and well-being (School1-14). Instead, school health promotion activities were voluntary and depended on school staff's interest (School1-14).

Among the schools with the high impact (Group 1), there were two urban schools (School1,2) and three rural schools (School3-5). Of these schools, two schools were in the north (School2,4), and one each was in the south (School3), the northeast (School5), and the central (School1) regions of Thailand. Schools3 and 4 were in lower socio-economic status areas where most of the villagers were farmers and manual workers, while other three schools were in mixed socio-economic status areas (farmers or manual workers, professional or administrative workers, business owners).

Schools with low impact (Group 2) were in rural areas (School6-10) in the northeast (School7,8) and north (School6,9,10) regions. The socio-economic context was generally lower than schools in Group 1 (most people living around these schools were farmers and manual workers). Considerable proportions of students in schools 9 and 10 in the north were members of hill tribes. The control schools were in Bangkok, the capital city of Thailand, (School11,12), an urban area in the northeast (School13) and an urban area in the south (School14). Their local context had higher average household income compared to schools in Group 1 and 2. Table 2 presents the characteristics of sampled schools.

Table 2 Characteristics of sampled schools.

Group*		Region	Urban	Higher socio-economic status**	Ethnic minority***
Group 1	School1	Central	√	√	X
	School2	North	√	√	X
	School3	South	X	X	X
	School4	North	X	X	X
	School5	Northeast	X	√	X
Group 2	School6	North	X	X	X
	School7	Northeast	X	X	X
	School8	Northeast	X	X	X
	School9	North	X	X	√ (Hill tribes)
	School10	North	X	X	√ (Hill tribes)
Group 3	School11	Central	√	√	
	School12	Central	√	√	X
	School13	Central	√	√	X
	School14	South	√	√	X

*Group1: Intervention schools with high impact, Group2: Intervention schools with low impact, Group 3: Control schools

** Most of the people in the neighbourhoods were professionals or administrative workers, business owners (from school staff's views)

***Higher proportion of ethnic minority students than average (from school staff's views).

√= Yes, X = No

Different school environments determine the amounts of resources and social capital. Food culture also varies across region, for example, the central region's common dishes contain fewer vegetables and more sugar content than the common dishes of other regions. These diverse food cultures resulted in different food preferences and lunch menus to some extent (School1-14). Compared to schools in impoverished rural areas, schools in urban areas tended to have greater access to financial support from wealthy municipalities and parents (School1,2, 11-14). They also benefited more from the better infrastructure of urban areas. Such advantages enhanced these schools' capacities to execute most schools' activities, especially the provision of school breakfasts and lunches and school sanitation (School1,2, 11-14). However, the obesogenic environment (e.g., unhealthy food environment and lack of green and play spaces) in urban areas were barriers for these schools to address obesity (School1,2, 12,13,14). People living in big cities tended to consume more ready-to-eat meals than home-cooked food (School 11,12,14).

"As you may know, most parents spend a lot of time on their work and traffic, so they rely on ready-to-eat food. Convenience stores are everywhere, children are given money to buy food by their own, which most of the time are unhealthy." (School12)

On the other hand, schools in rural areas tended to have large spaces which facilitated physical activities and school farming (School 3-10). Furthermore, they were likely to have good relationships with their communities and local farms, so they mostly received in-kind support from the communities, such as local food supplies, farming assistance (e.g., land and guidance), and free handcraft and mechanic services (School 3-10). Among the rural schools, two schools regularly received financial support for school lunches from a foundation (School5) and a Muslim bank (donated by Muslim teachers and communities) (School3).

199 *"Since we are a small school, we are given small amounts of annual budget. We cannot make*
200 *changes with such a small amount of money, even to ensure quality school lunches. Luckily, the*
201 *community members and students' families are farmers, so they gave us rice for free."* (School3).

202 *"We are lucky we received good support from the municipality. They gave us extra resources for*
203 *many activities apart from our annual budget. Let's take an example of school lunch, they gave us the*
204 *budget for the kitchen equipment, kitchen staff, and gas. So, we can provide quality food to students*
205 *within the government school lunch budget."* (School2).

206 In rural areas, a considerable proportion of students were being taken care of by their
207 grandparents or other family members (up to 45%) because their parents had moved to urban areas to
208 work (School 5,6,7,9). Not living with one's parents was considered a barrier to gaining the cooperation
209 of families, especially when students' caretakers were elderly, extremely poor, or had a low level of
210 education (School 2, 5, 6, 9).

211 *"A lot of students live with grandparents because their parents moved to Bangkok for their jobs.*
212 *We find it hard to get families involved in some activities, such as limiting students' screen time and*
213 *providing healthy food at home. It was easier to reach the parents and receive their response. Besides,*
214 *children listen to their parents more than grandparents."* (School6)

215 **Programme adoption: Priority and Encouragement**

216 To gain attention from schools, the Programme advocated the potential benefits of implementing
217 a holistic approach to promote child development and portraying a school role model (School1-10 and
218 Document1,2). Schools that were interested in participating in the Programme applied for the
219 Programme's support by proposing a set of action plans for implementing the Programme together with
220 the support they needed (School1-10 and Document1,2). This bottom-up approach was used to ensure that
221 the intervention was suitable to the schools' needs and capacity. The Programme also encouraged schools
222 to form working groups, according to the willingness or skills of different school staff members, that were

223 in charge of different intervention components (School1-10 & Document1,2). An introductory course was
224 provided to school staff members who were responsible for the implementation followed by a training
225 course for staff responsible for each of the eight intervention components (School1-10). Handbooks and
226 video clips demonstrating the execution of each component were provided to school members to review
227 by those who attended the training, and self-study for those who missed it (School1-10 and
228 Document3,4). Also, onsite visits by Programme staff were carried out to supervise intervention schools
229 (School1-10 and Document3,4). The document analyses and FGIs indicate that all intervention schools
230 underwent the same process of training and supervision (School1-10).

231 There were several reasons why schools decided to participate in this Programme. Firstly, the
232 intervention schools considered the Programme provided an opportunity to enhance the health and
233 nutritional status of children attending their school (School2,4,6,7,10). Secondly, the Programme goals
234 were perceived to synchronise with the education sector's vision of promoting human capital, where child
235 health and well-being is its foundation (School1, 2, 6, 7). Thirdly, although implementing the Programme
236 may increase workloads, the actions required were perceived to be doable and would not affect the
237 schools' common academic goals (School2,4,7,8,10). The reason control schools decided not to
238 participate in the programme was that it would increase workloads that were not related to the key
239 priorities of primary schools. Furthermore, for some schools, staff constraints limited their willingness to
240 participate (School11-12).

241 Some intervention schools had also participated in other programmes prior to the Programme,
242 including a health promotion programme (School1, 7, 8, 9, 10), a food safety programme (School1, 7, 8,
243 9, 10), and an environmental campaign (School5,7,8). The health promotion programme, which was
244 conducted by the Department of Health, Ministry of Public Health was similar to the Programme in terms
245 of scope of interest, aims, and health indicators; however, it used a different approach and strategy. The
246 most significant differences between the two programmes were the tools and approaches used. The health
247 promotion programme did not require the schools to use a computer programme to select nutritious

248 school lunch menus, school farms to provide ingredients for school lunches, and other guiding materials.
249 The health promotion programme did not provide resources, but applied stepwise certification granted by
250 the Department of Health as an incentive. The food safety and environmental campaigns shared the same
251 practices with the Programme and the same strategy with the health promoting school. The intervention
252 schools staff members thought that the Programme was more comprehensive than the previous
253 programme in revitalizing the schools' practices and strengthening their capacity to implement the
254 components through the Programme's financial and nonfinancial supports, clear instructions and goals,
255 and close supervision (School1, 7, 8, 9, 10).

256 **Programme implementation: Empowerment and Adaptability**

257 Intervention components were formulated based on the schools' current practices to gain schools'
258 acceptance and to make the intervention manageable using the existing infrastructure. To participate in the
259 Programme, the intervention schools continued to execute their routine practices, but with a wider scope
260 of interest, as well as additional sets of standards, goals and monitoring.

261 Among the eight components, the intervention schools were encouraged to be proficient in
262 implementing healthy food provision (C1) and health and nutritional status monitoring (C2) in the early
263 stage of implementation (School1-10 and Document1,2). The capacity of primary schools to implement
264 each component varied, depending on the schools' contexts and resources, so not all components began at
265 the same time or were fully implemented as planned (School1-10 and Document5,6). The variations in
266 Programme implementation are described in Table 3 and S2 Table.

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271 **Table 3 Comparison of practices between the 10 intervention schools**

Components and action required	Group1					Group2				
	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Healthy food provision										
- Use TSL to plan healthy lunch menus.	x	√	√	√	√	√	√	√	√	√
- Provide the required portions of vegetables 5 times/week, fruit 3 times/week, and desserts ≤1 time/week.	√	√	√	√	√	√	x	x	√	x
- Ban unhealthy snacks and drinks.	x	√	√	√	√	√	x	x	x	x
Note:	**Sc1:** Used menu plans provided by the city's nutritionists.									
School farm and garden										
- Provide produces to school lunch	x	√p	√p	√p	√p	√p	√p	√p	√p	√p
- Engage students	√	√	√	√	√	√	√	√	√	√
- Engage communities/local farms	√	√	√	√	√	x	√	√	x	x
Note:	**Sc1:** Had no land for school garden.									
Health and nutritional status monitoring										
- Monitor students' height and weight at the beginning and end of each school term.	√	√	√	√	√	√	√	√	√	√
- Report students' nutrition status to caretakers	x	x	x	√	x	x	√	x	x	x
- Address double burden malnutrition	√	√p	√p	√p	√p	x	√p	√p	√p	x
Note:	**Sc2&4:** Monitored students' weight and height monthly. **Sc1:** 1. Provided breakfasts to all students. Provided take-away dinners, extra milk and bananas to malnourished students					**Sch7:** 1. Daily 30-min MVPA for overweight/obese students, 2. Provided breakfasts to students who did not have breakfast at home, 3. Communicated with caretakers to promote a healthy diet.				

	when available. 2. Daily 10-min MVPA for overweight/obese students. **Sc2:** 1. Body weight and step challenges.2. Role model in maintaining a healthy weight.3. Active play and sport contests. **Sc3:** Provided breakfasts to all students. **Sc4:** 1. Daily 25-min MVPA for overweight/obese students. 2. A workshop for overweight/obese students and their caretakers. **Sc5:** Daily 25-min MVPA for overweight/obese students.					**Sch8:** 1. Provided extra milk and eggs to malnourished students when available. **Sch9#:** A workshop for overweight/obese students and caretakers when funding is available.				
Health and personal hygiene promotion										
- Promote personal hygiene	√	√	√	√	√	√	√	√	√	√
- 30 minutes of MVPA for all students	√p	√	√p	√p	√p	√	√p	√p	x	√p
Note:	**Sc1,3-5**: Daily 10-15 minutes of MVPA.					**Sc7:** Daily 10-15 minutes of MVPA. **Sc8**: 10-15 minutes of MVPA once/week. **Sc10**: 1-hour MVPA once/week.				
Agriculture, nutrition, and health education	√	√	√	√	√	√	√	√	√	√
School cooperatives and vocational training	√	√	√	√	√	√	√	√	√	√
School sanitation	√	√	√	√	√	√	√	√	√	√
Basic health service	√	√	√	√	√	√	√	√	√	√

272 * Group 1: High impact intervention schools, Group 2: Low impact intervention schools, TSL = Thai School Lunch computer programme, Sc=

273 school, √ = Fully implemented, √p= Partially implemented, x= No implementation, MVPA = moderate or vigorous physical activity.

The schools required two weeks (School,5,7,8) and one school term (School10) to master the healthy food provision component. The challenges to using TSL included the lack of local traditional dishes in the original TSL nutritional value database (School2,10,14), school staff had limited knowledge on food substitutions that would have an equivalent nutritional value to those listed in the TSL's recipes (School2,10,14), and the students' denial of healthy lunch menus (especially vegetable-based dishes) (School2,5,6,8,11,12). The first and second challenges were gradually resolved by the addition of more dishes and data on their nutritional values into the TSL database (School1-10). The third barrier on student's acceptance of lunch menus was gradually reduced after two to three months by the students involvement in school gardening (School2,3,4,5), nutrition education (School1-5, 6-8), students voting for lunch menus from the healthy lunch choices (School1-10), and the students eating lunches in groups with teachers (School1, 4) or friends who ate vegetables (School2,7). These strategies were shared with other intervention schools through Programme learning platform. Interestingly, some schools (school1 and 3) provided breakfasts to all students in addition to lunches. This activity is not commonly found in Thai primary schools because breakfasts are not funded by the government. The breakfasts provided by school1 and school3 were funded by the local municipality and community, respectively.

To implement the health and nutritional status monitoring component, most intervention schools measured the students' weights and heights at the beginning and end of each school term (School1,3,4,6-10). Only two intervention schools opted for monthly measurement with an intention to promptly manage students' malnutrition (School2,5). The strategies used to reduce overnutrition were 10 extra minutes of physical activity after school (School1), 25 minutes (School5), and 30 minutes (School7), use of physical activity combined with body weight maintenance challenges (School2), and food diaries and body weight management consultations (School4). To reduce undernutrition, extra meals or food was provided to malnourished students, including breakfasts, dinners, extra milk, and bananas (School1), breakfasts (school3), and extra milk and eggs (School8). Another school provided breakfasts for any students who

298 did not have breakfast at home (School7). Parents and caretakers were advised to provide their children
299 adequate and healthy diet at home to tackle all forms of malnutrition (School4,7,9).

300 All intervention schools implemented the school farm and garden component (School1-10).
301 Vegetables, mushrooms, eggs, and fish were produced in these gardens; however, with the quantities and
302 varieties of foods produced did not provide all ingredients required for the school lunch menus. To
303 address these limitations, the schools applied various strategies to secure food supplies for school lunches,
304 including purchasing from local markets (School1), making a contract with an organic food production
305 network (School2), or with local farmer networks (School7,8), and purchasing from local farms (School3-
306 6, 9,10). The schools that made contracts with food production networks were confident to receive food
307 ingredients as ordered and to provide lunches as planned (School2,7,8).

308 In terms of physical activity promotion, most intervention schools involved all students in active
309 play or other recreation activities (School1-8, 10), though the duration was shorter than the requirement of
310 the Programme (<30 minutes of moderate or vigorous physical activity) (School1,3-10). For personal
311 hygiene promotion module, the intervention schools managed it through the school routine practices,
312 including giving advice to students and monitoring their hygienic practices (School1-10).

313 To implement agriculture, nutrition, and health education, all intervention schools used the
314 "learning-by-doing" strategy by engaging students in all components of the Programme (School1-10). In
315 addition, some intervention schools used the Programme's teaching materials for certain subjects (e.g.,
316 health and physical education, mathematics, and active learning session) (School2) or active play to
317 demonstrate healthy body weight maintenance, healthy diet consumption, and home garden management
318 (School3), while one school trained high-risk students (who are undernourished or overweight) to record
319 their food intake and manage their own body weight (School6). All these empowered and enhanced the
320 students' self-efficacy.

School cooperative and vocational trainings component encouraged intervention schools to demonstrate agricultural cooperative management. The intervention schools used their school cooperative to manage the costs and revenues of school farms and gardens and volunteer students were involved to take part in the management (School1-10). The food products from school farms and gardens were purchased by the school cooperative to supply food ingredients for school lunches and the income earned from school cooperative was used to improve school farms and gardens (School1-10). These school cooperatives were small-scale, due to the small scale of the school farms and gardens (School1-10). For the school sanitation and basic health service provision components, intervention schools met the school sanitation standards, so major improvements were not required.

Non anthropometric outcomes

The respondents also reported the Programme's effects other than students' anthropometric outcomes. Firstly, the Programme increased their capacity and confidence in promoting and improving the nutritional status of students, especially school healthy lunch provision, anthropometric measurement and monitoring, and activities which empower students in self weight management (School1,2,3,5). Secondly, the students adopted healthier behaviours, including being more physically active (School2) and developing a positive attitude towards eating vegetables because of the intervention (School1-10). Thirdly, intervention schools won prizes more often in school nutrition competitions. Their experiences were broadcasted and disseminated through mass media and social media, which promoted their social recognition and increased external support (e.g., fundings for school lunches and gardens). These improvements increased schools' social capital and prestige, and external support (School2,3,5,7,8).

Context, Programme interventions and their influences on outcomes

Fig 2 presents contextual factors, Programme interventions, their interactions, and influence on outcomes. Regarding interventions (see Table 3 and S2 Table), the Programme components strengthened the intervention schools' routine practices across almost all components, except the school sanitation and

345 basic health services, as they have met standards prior to participating in the Programme. However, none
346 of the intervention schools followed the Programme's guidelines entirely.

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351 **Fig.2 Potential factors which have positive and negative influence on Programme adoption,**
352 **implementation and outcomes**

353

354 Among the eight components, intervention fidelity was moderate across almost all components,
355 except sanitation (C7) and health services (C8). Implementation variations were observed across schools;
356 clearly schools with maximum progress complied with the Programme implementation guidelines more
357 than the schools with minimum progress, especially for healthy food provision (C1), health and
358 nutritional status monitoring (C3), and health and personal hygiene promotion (C4). Therefore, these
359 components may have key impacts on Programme outcomes, while other components (C2, C5, C6) may
360 or may not directly contribute to the outcomes. In terms of students' participation, all of them engaged in
361 C1 and C3. Overweight or obese students participated in C4 (especially 30-minute moderate to vigorous
362 physical activity daily) more than normal or underweight students, and the students' participation in C2,
363 C5 and C6 varied with students' interest and ages. Food provision standards and close monitoring of
364 nutritional status, and engagement by students in managing their nutritional status through fun and
365 competitive activities to achieve nutrition goals substantially contributed to programmatic outcomes.

366 Contextual factors that presented barriers included the education policy and system, limited
367 financial and nonfinancial support, and an obesogenic environment. Thai education policy focused on

368 academic performance but not child health and well-being, which led to limited resources and
369 encouragement for implementing the Programme. Inadequate support discouraged schools from
370 participating in the Programme. Urban obesogenic environments offset the ability of the Programme in
371 addressing overnutrition.

372 Regarding enabling factors, the healthier food culture in certain regions facilitated healthy lunch
373 menus acceptance, especially vegetable dishes. Furthermore, wealthier urban municipalities provided
374 better financial support to schools than impoverished areas; it enhanced healthy lunch provision and
375 school sanitation. In addition, commitment by school actors, their interests in children's health well-being
376 were intrinsic factors for the Programme's adoption, commitment, and effective implementation.

377

378 Discussion

379 The promising nutritional outcomes of the Programme appear to be related to the
380 comprehensiveness of the programme, synergies across the eight components, the integrity of
381 implementation, the schools' contexts such as local socio-economic status, physical environments, local
382 food culture, and school social networks that provided financial and non-financial support. This study
383 highlights the importance of students' engagement, through locally innovative strategies, in school food
384 provision, physical activity, gardening, and health and nutritional status monitoring.

385 The major barriers to favourable outcomes included lack of national and school level policy
386 towards enhancing health and wellbeing of school children, and obesogenic environments in the
387 communities.

388 **The Programme components and degree of implementation**

389 The key advantage of the content of this Programme lies in the combination of multiple active
390 components and complementary strategies. The strengths of integrating diet intervention and physical

activity promotion in contributing to nutritional outcomes has been corroborated by other studies (20-22). Physical activity alone, with a wide range of duration and intensity, has been shown to yield a favourable effect in reducing BMI and BAZ (2-4), whereas the effect of diet intervention is inconsistent (4, 23).

The inconsistent effect of diet intervention may be influenced by the presence of nutritional standards. A systematic review reporting no significant effect of diet interventions pointed out that most school nutrition interventions in Asia did not use nutrition standards or nutrient profiling to define the nutritional quality of food, and thus efforts for "diet improvement" were diverse, ranging from selling water and fruit juices in canteens to providing food with less sodium, sugar, and fat and increased fruits and vegetables(4). Another systematic review concluded that applying precise food guidelines or school meal standards are effective strategies enhancing the positive outcomes of diet interventions implemented in Western countries (24). Nutritional standards enable a scientific-based evaluation of the nutritional quality of food, which increases precision when selecting healthy food (25).

The Programme provided healthy lunches that met nutritional standards while restricting access to snacks that are high in sodium and fat and sugary drinks. Another study found that students in schools participating in the Programme consumed more vegetables and fruit daily in the past seven days than in control schools (72.1% versus 59.5% for vegetables and 53.1% versus 46.1% for fruit, $p<0.05$), and a lower proportion of students who consumed desserts (6.2% versus 12.8%, $p<0.05$), savoury/fried snacks (13.3% versus 22.4%, $p<0.05$), and sugary drinks (15.1% versus 23.4%, $p<0.05$) than students in control schools (26). Improving the school food environment that meet nutritional standards is a key factor contributing to the Programme's favourable outcomes.

Promoting healthy eating among children is challenging due to children's preferences for unhealthy food (27) and refusal to consume fruit and vegetables (28), lack of motivation, and limited nutrition-related knowledge (29-32). This study indicated that the complementary components of the Programme were important for overcoming these barriers, especially the school farms and gardens (C2) as well as agriculture, nutrition, and health education (C3). However, previous studies showed that the

effects of school gardening on students' fruit and vegetable intake are mixed (33), which could be explained by the differences in programmes' component combinations and implementation. School gardens complemented by nutrition education alone did not improve vegetable intake (34) unless it was implemented with close supervision and community involvement (35), or involved nutrition and cooking classes for children and parents (31). Collectively, these results indicate the importance of integrating multiple components to improve knowledge and skills related to fruit and vegetable production and preparation, and the health benefits to increase fruit and vegetables consumption among school children.

To gain students' participation in PA promotion, intervention schools used the agriculture, nutrition and health education component to advocate the benefits of an active lifestyle to students and by adopting enjoyable active recreation or PA challenges and rewards, which promoted students' engagement in physical activity. These strategies are in line with key motivations for children to engage in physical activity that have been identified by other studies, which include enjoyment (3, 36), skill level match (37), personal value and belief in physical activity (37), and rewards for PA achievement (38).

When comparing the ten intervention schools (shown in Table 3 and S2 Table), it is obvious that the schools demonstrating the highest impact put more effort into providing healthy food (e.g., adhered to TSL and managed the availability of unhealthy snacks and drinks) and implementing close monitoring of nutritional status and intensively taking actions to correct both over- and undernutrition problems. Different intensity among these ten schools may have contributed to the different degrees of outcome.

Furthermore, the Programme promoted the continued monitoring of students' nutritional status at the schools, so that early detection of nutrition problems and responses with diverse approaches was put in place. In addition, the monitoring outcomes stimulated school staff to innovate effective approaches that suited each group of students. Although continued monitoring enhances continuous improvement for real-world school nutrition interventions, it is usually considered as an outcome evaluation measure rather than an intervention component. Therefore, students' anthropometric outcome measurements were only taken at baseline and end of interventions (2-4).

441 However, there was no support or separate set of services for wasted students. The Programme
442 aimed to improve the nutritional quality of school lunches, snacks and drinks available in schools. This
443 approach is inadequate to reduce wasting. The practices of school1 and 3 demonstrated that providing
444 breakfasts to all students and providing extra milk or snacks to wasted students could be a good option
445 since the percentage of wasting in these schools reduced greater that other schools (see Table 1).

446 **The interaction between the Programme and context.**

447 Policy and school context played important roles in both the Programme successes and its
448 shortcomings. This study highlights the importance of making health one of the priorities in education
449 policy; education policy determines the willingness of relevant actors to implement school nutrition
450 interventions, and the adequacy and sustainability of resources (e.g., labour and budget), infrastructure,
451 and support systems (e.g., capacity building activities and multi-sectoral supporting networks). Therefore,
452 lack of political will and commitment by the Ministry of Education and schools limited the adoption,
453 implementation, and outcomes of the Programme. These findings support the global standards for health
454 promoting schools (39), which stated that government policies and resources are the overarching factor
455 which determines the existence, implementation, and effectiveness of school-based health interventions.
456 The importance of integrating nutrition promotion into national policy was also emphasised by a process
457 evaluation of a school-based nutrition intervention in the UK (40). While the role of policy context on
458 school-based fruit and vegetables promotion was not explicitly indicated in the results of 24 process
459 evaluation studies, reported barriers indicated inadequate support from the education sector (i.e., limited
460 funding and teachers' time constraints) (41).

461 Other contexts included obesogenic environments especially in urban communities, food cultures,
462 schools' social networks, and actors' personal interest in child well-being. Most process evaluation of
463 school-based nutrition interventions focused on schools' environments, but not food culture, school social
464 network and obesogenic environment in the communities (36, 40-45), for which this study adds to the
465 current knowledge gaps. In the absence of political will, external support to the Programme relied heavily

466 on the schools' social networks. The importance of external support is demonstrated by this study that
467 financial support from the local government and community enabled school1 and 3 to provide breakfasts
468 to students and the percentage of wasting in these schools reduced notably. The participation of families
469 and communities were reported as enablers to school-based interventions in promoting fruit and vegetable
470 consumption (40) and in promoting a healthy diet and physical activity (41). This study also adds to the
471 current evidence that individual actors' personal interest in children's well-being also contributed to the
472 adoption and implementation of the Programme, as this factor is not addressed in the existing literature
473 (36, 40-45).

474 **Strengths and limitations of this study**

475 There are two major strengths of this study. Firstly, it describes a well-designed comprehensive
476 school nutrition intervention and the favourable contextual environments for addressing the double
477 burden of malnutrition. Secondly, multiple sources of data were used for data triangulation. However, this
478 study does not represent the perceptions of the students and their families who are key beneficiaries of the
479 Programme. The control schools were predominantly from big cities, so it is possible that the lessons
480 learned on how to increase uptake of the programme are limited to urban contexts. In addition, the results
481 of the focus group interviews may be affected by recall bias and socially desirable biases, so we
482 triangulated these results with data from other sources to reduce bias.

483 **Lessons learned**

484 Several lessons can be drawn to inform effective school nutrition interventions in addressing the
485 double burden of malnutrition. Firstly, it is crucial to include child health and well-being in the priorities,
486 goals, and targets of education policy and systems to ensure adequate resources (e.g school meal budget,
487 technical support and skilled labours), school engagement, and interventions' sustainability. Secondly,
488 equitable resource allocation is needed in a context where there are resource gaps between schools in high
489 and low socio-economic neighbourhoods. Thirdly, multiple synergistic components are a promising

model for school nutrition interventions, despite compromised fidelity of implementation (which is common in real-world policy implementation). Fourthly, in a context where the double burden of malnutrition is prevalent, school nutrition interventions should adequately address both over- and undernutrition. Fifthly, it is important to build schools' capacities and create a support system equivalent to, or better than, the support provided by the Programme to promote fidelity and sustainability.

Conclusion

This study indicated that both internal and external factors were important to the Programme's success. In terms of internal factors, key success factors included the comprehensive design of the Programme, which incorporated multiple synergistic components and a support system aimed at empowering schools. Barriers to the Programme's success included the lack of strong actions to address wasting and suboptimal fidelity. Enabling external factors included a supportive national policy (that ensure adequate resources, encourage school engagement, and promote sustainability), favourable socio-economic situation and supportive community, and healthy environments.

List of abbreviations: PA: physical activity, BMI: Body Mass Index, BAZ: BMI-for-age z-score, HAZ: height-for-age z-score, MRC: Medical Research Council, FGIs (focus group interviews, SRQR: Standard for Reporting Qualitative Research, TSL: Thai School Lunch computer programme

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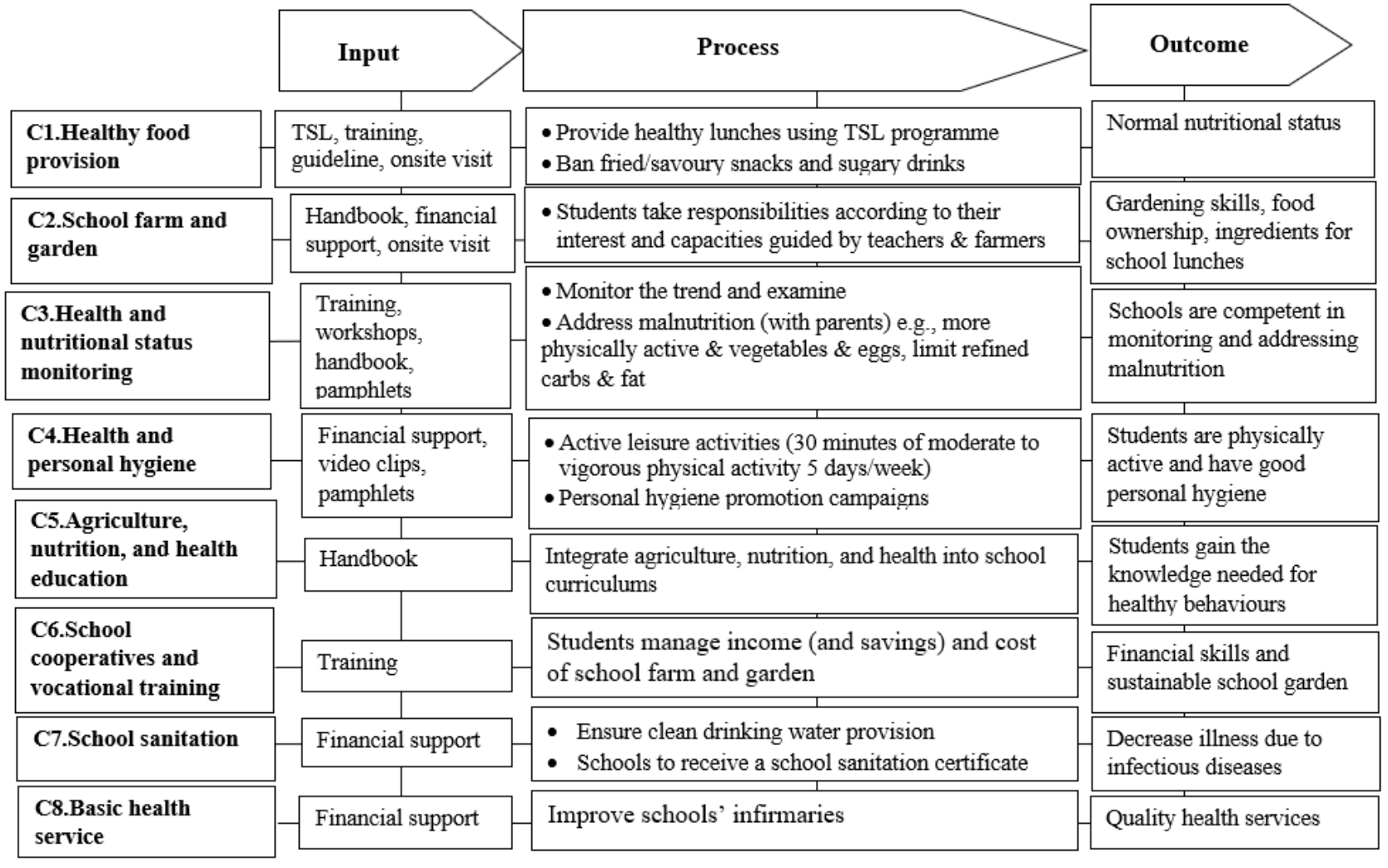
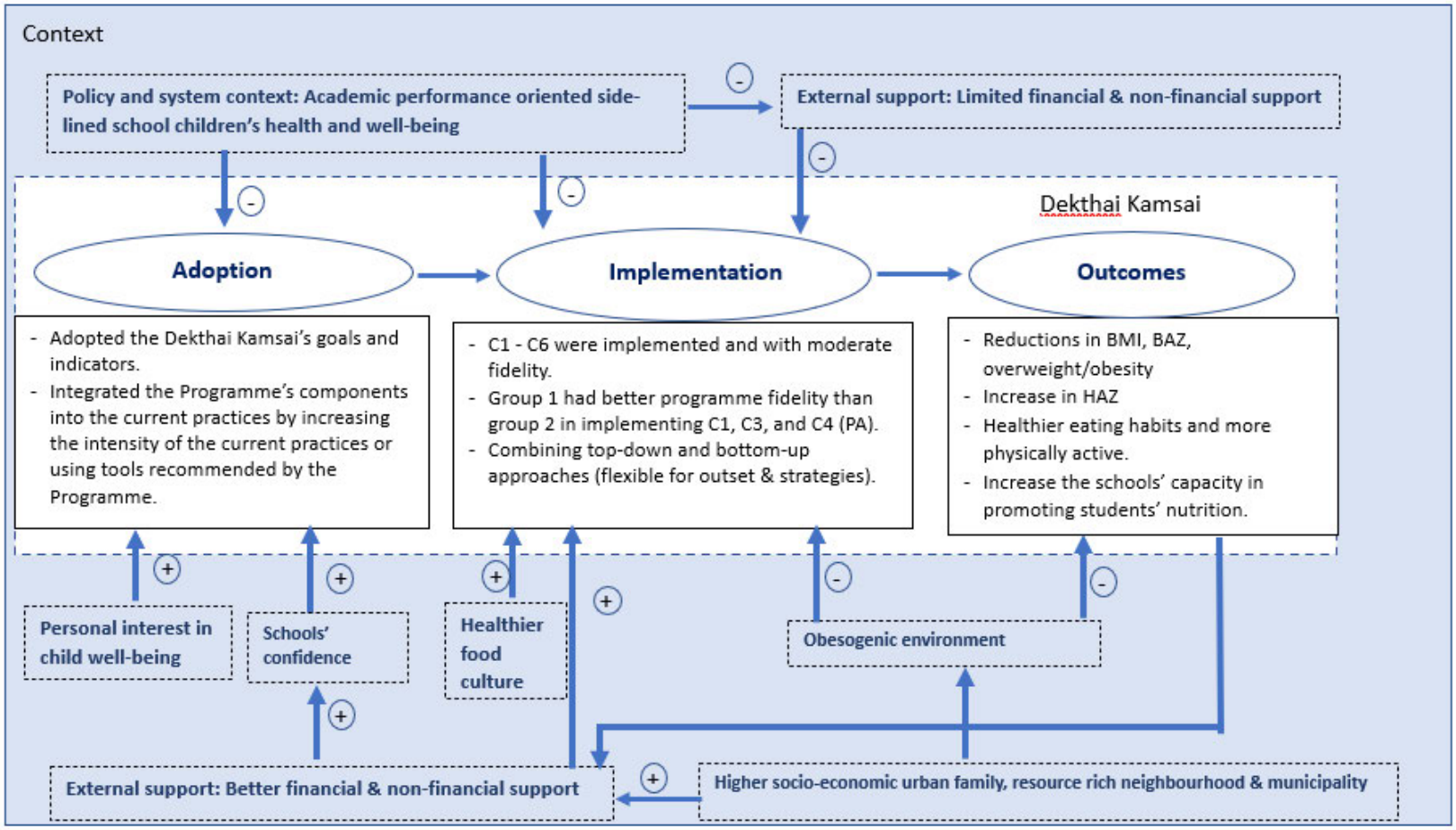


Fig. 1 The Programme's logic model



C1: Healthy food provision, C2: School farm and garden, C3: Health and nutritional status monitoring, C4: Health and personal hygiene promotion, C5: Agriculture, nutrition, and health education, C6: School cooperatives and vocational training, C7: School sanitation, and C8: Basic health service. PA: Physical activity. BMI: Body Mass Index. BAZ: BMI for age z-score. HAZ: Height for age z-score. (+) = enabling factors, and (-) = barriers

Fig.2 Potential factors which have positive and negative influence on the Programme adoption, implementation and outcomes

Supplementary

S1. The Programme's design

The Programme was led by a non-government organisation (NGO) supported by a national semi-autonomous funder and governmental organizations (13). It was developed by a multi-disciplinary working group. This programme aimed to promote child development (nutrition, health, and social emotional skills) and well-being through eight interlinked components, which are as follows: 1) healthy food provision; 2) school farm and garden; 3) health and nutritional status monitoring; 4) health and personal hygiene; 5) agriculture, nutrition school education; 6) cooperatives and vocational training; 7) school sanitation and healthy school environment; and 8) basic health service provisions. The components are described further below and are shown in the intervention's logic model (Figure 1). Those eight components were designed to be adaptable to suit schools' routines, and feedback from schools was used to continually improve the programme implementation. A supporting system was created to facilitate the implementation of this programme by having five government organisations signed a Memorandum of Understanding (MOU), which included the Ministry of Education, Ministry of Public Health, Ministry of Interior, and Ministry of Agriculture and Cooperatives, and National Electronics and Computer Technology Center (NECTEC), who all agreed to provide support to intervention schools.

In terms of the programme's components, healthy food provision (C1) was intended to provide healthy school lunches and create healthy eating habits among children by providing a healthy school food environment. Participating schools were required to use Thai School Lunch (TSL) to plan lunch menus. TSL is a computer programme developed to grade the nutritional

quality of lunch menus against the nutritional standard requirement for Thai children. The programme also shows recommended amounts of each food ingredient suitable for a given number of students and the cost of the selected menu. The school menu plans made by school staff are automatically recorded into the TSL database. In terms of snack and drinks management, participating schools were required to ban sugary drinks and savoury/fried snacks. By these practices, students were supposed to consume the required portions of vegetables 5 times/week, fruit 3 times/week, and desserts ≤1 time/week in school. Trainings were provided to school staff to enable them to use TSL and provide healthy school food. Onsite visits were conducted following the training to monitor food provision and to provide advice.

The school farm and garden (C2) was aimed to create farming and gardening skills and a sense of ownership among students, and also to supply safe food ingredients for school lunches. Technical and financial support was provided to participating schools to initiate farm and garden in schools or surrounding areas provided by communities. All students were engaged in the activities in accordance with their interests and capacities. Where available, local farmers were involved to transfer their knowledge and skills to students.

The aim of the health and nutritional status monitoring (C3) was to enable the school to perform early detection of health and nutrition problems and respond to such problems at an early stage. Training courses were provided to school staff to be able to measure students' weights and heights twice a term, analyse the data, and work with parents to improve the nutritional status of students experiencing malnutrition. Diet and physical activity guidelines for under- and overweight children were provided to schools and parents through handbooks and pamphlets. Where available, workshops for under- or overweight children and their parents were organised by local health personnel.

The health and personal hygiene promotion (C4) consisted of physical activity and personal hygiene promotion. This component encouraged schools to engage students in active leisure activities (such as dancing and active play) to ensure 30 minutes of moderate to vigorous physical activity 5 days/week. The programme provided video clips to demonstrate leisure activities for kids and financial support for sports equipment. For personal hygiene promotion, the Programme encouraged schools to launch campaigns and communicate with children regularly using the standard personal hygiene guidelines for children.

The component of agriculture, nutrition, and health education (C5) aimed to integrate agriculture, nutrition, and health knowledge into school curriculums and activities. The programme provided a handbook guiding teachers on how to integrate nutrition-related knowledge into school curriculums and other school activities.

The school cooperatives and vocational training (C6) was developed with an intention to equip students with financial management skills and promote the sustainability of school farms and gardens. Training was provided to school staff to be able to guide students on how to manage income and cost of school farms and gardens.

The school sanitation component (C7) supported schools to reach the national school sanitation standard and maintain themselves at that quality level. Participating schools were required to provide clean drinking water and to pass the school sanitation standard. The Programme programme provided advice specifically to each school and financial support upon request from schools.

66 The basic health service provision (C8) was intended to improve health services in
67 schools, where necessary. The programme provided financial support to schools, upon request, to
68 improve the quality of school infirmaries.

69 The Dekthai Kamsai programme strengthened these conventional practices by; 1)
70 providing healthy school lunches that are selected using information technology (TSL computer
71 programme) to plan lunch menus that meet national nutritional standards for children 2) scaling-
72 up school farming and gardening programs to provide ingredients for the school lunches and
73 promote an understanding of food and nutrition among students, 3) additional physical activity
74 sessions per week, 4) additional lessons on nutrition and health that are integrated into the "daily
75 active learning hour" through multiple learning activities e.g., school garden and active play, and
76 5) utilisation of the students' anthropometric data to prompt schools' early response to
77 malnutrition.

78 Some intervention schools had also participated in other programmes prior to the
79 Programme, including a health promotion programme (School1, 7, 8, 9, 10), a food safety
80 programme (School1, 7, 8, 9, 10), and an environmental campaign (School5,7,8). The health
81 promotion programme, which was conducted by the Department of Health, Ministry of Public
82 Health was similar to the Programme in terms of scope of interest, aims, and health indicators;
83 however, it used a different approach and strategy. The most significant differences between the
84 two programmes were the tools and approaches used. The health promotion programme did not
85 require the schools to use a computer programme to select nutritious school lunch menus, school
86 farms to provide ingredients for school lunches, and other guiding materials. The health
87 promotion programme did not provide resources, but applied stepwise certification granted by
88 the Department of Health as an incentive. The food safety and environmental campaigns shared

the same practices with the Programme and the same strategy with the health promoting school. The intervention schools staff members thought that the Programme was more comprehensive than the previous programme in revitalizing the schools' practices and strengthening their capacity to implement the components through the Programme's financial and nonfinancial supports, clear instructions and goals, and close supervision (School1, 7, 8, 9, 10).

105 **S2 Table Comparison of practices between the ten intervention and the four control schools**

Intervention components	Schools with maximum progress (Group1)	Schools with minimum progress (Group2)	Control schools
Healthy food provision	- **School#1:** 1. Applied lunch menu plans provided by the city's nutritionists, 2. Provided both breakfasts and lunches to all students. - **School#3:** Provided both breakfasts and lunches to all students. - **School#2-5:** Schools provided healthy lunches (approved by TSL*) with sufficient amounts of vegetables (every school meal) and fruit (≥3 times/week), and low sugar dessert (1 time/week).	- **School#8:** Used a computer programme aimed at facilitating schools to comply with the government financial regulations. - **School#7:** Provided breakfasts (in addition to lunches) to students who did not have breakfast at home. - **School#7,8:** Sugary drinks and biscuits were available in school canteens. - **School#6,7,9,10:** Used TSL.	**School#11-14:** 1. Did not use TSL but provided food according to students' preferences, 2. Considerable proportions of students denied consuming vegetable dishes, 3. Regular school meals were rice with meat-based side dishes. **School#12:** 1. Used lunch menu plans provided by the city's nutritionists, 2. Provided both breakfasts and lunches to all students.

	- **School#2:** Meatballs and cakes were sold in the school canteen. - **School#3-5:** School staff were TSL trainers.	- **School#10:** Provided dessert 2 times/week. - **School#9:** Snacks and sugary drinks were not available in schools but available in shops nearby schools.	
School farm and garden	**School#1:** Involved students in small scale school gardening. Food ingredients were mostly from major markets in Bangkok. **School#2:** Involved all students in school gardening, which had limitations in the variety and quantity of the food products. The school made a contract with a certified organic food product network (managed by a university). The network planned their	**School#7,8:** Involved all students in school gardening, which had limitations in terms of variety and quantity of the food products. The school made a contract with local farmer networks. Lunch menus were occasionally different from the menu plans due to the shortages of food supplies. **School#6,9,10:** Involved all students in school gardening, which	**School#11-14:** Small scale school gardening, which was not intended to promote nutrition.

	production according to school menu plans to ensure the schools were able to provide lunches as planned. **School#3,4,5:** Involved all students in school gardening, which had limitations in the variety and quantity of the food products. Food supplies were primarily from local farms.	had limitations in the variety and quantity of the food products. Food supplies were primarily from local farms.	
Health and nutritional status monitoring	***Monitoring*** **School#1,3,5:** Measured weight and height at the beginning and end of each school term. **School#2,4:** Measured weight and height monthly to manage the risks. ***Malnutrition management*** **School#1:** 1. Provided breakfasts & lunches for all students and take away dinners for underweight students, 2.	***Monitoring*** **School#6-10:** Measured weight and height at the beginning and end of each school term. ***Malnutrition management*** **School#7:** 1. Involved overweight students in 30-min after school exercise session, 2. Provided breakfast to students who did not have breakfast at home, 3.	***Monitoring*** **School#11-14:** Measured weight and height at the beginning and end of each school term.

	Extra daily 10- minute jumping rope or aerobic dance for overweight students, 3. Provided extra milk and bananas to stunted and wasted students. **School#2:** 1. Involved overweight students in body weight and step challenges and provided rewards, 2. Employed a teacher and student role model strategy in maintaining a healthy weight, 3. Active play 4. Traditional dance and row your boat contests. **School#4:** 1. Involved overweight students in after school exercise (25-min active games & jumping rope), 2. Local health personnel involved high-risk students to record daily food intake, diet analysis, and involved	Communicated with caretakers to promote a healthy diet. **School#8:** 1. Provided extra eggs and milk to wasted students. **School9#:** Organised workshops for caretakers and students to promote a healthy eating when funding is available.	

	caretakers in a workshop to promote healthy eating.		
Health and personal hygiene promotion	***Physical activity*** **School#1:** 1. Extra PA 10-15 minutes once/week. 2. **School#2:** Daily 1-hour after school active play or aerobic dance led by teachers. **School#3,4:** Daily 10-15 minutes active play or aerobic dance led by teachers. ***Personal hygiene promotion*** **School#1-5:** Continued their routine practices (no extra activity).	***Physical activity*** **School#6:** Daily 1-hour after school active play. **School#7:** 1. Daily 10-15 minutes aerobic dance led by student role models, 2. 30-min school gardening or traditional dance twice a week. **School#8:** 10-15 minutes aerobic dance led by student once/week **School#10:** 1-hour traditional dance once/week. ***Personal hygiene promotion*** **School#6-10:** Continued their routine practices (no extra activity).	**School#11-14:** 10-15 minutes aerobic dance led by students once/week.
Agriculture, nutrition, and health education	**School#1,4,5:** Used the learning by doing strategy by involving students in	**School#6-10:** Used the learning by doing strategy by involving students	**School#11-14:** Health and physical education 1 class/week

School cooperatives and vocational training	**School#1-5:** Manage cost and income from schools' gardens (earned income from the school lunch budget).	**School#6-10:** Manage cost and income from schools' gardens (earned income from the school lunch budget).	**School#11-14:** no action.
School sanitation	**School#1-5:** Met the Programme standard.	**School#1-5:** Met the Programme standard.	**School#11-14:** School sanitation remained the same, which mostly met the requirements of the Department of Health.
Basic health service	**School#1-5:** No needs for improvement.	**School#6-10:** No needs for improvement	**School#11-14:** No needs for improvement

106 * TSL = Thai School Lunch computer programme

S3. Anthropometric outcomes

The impact evaluation of the Programme was carried out in grade 1-3 students from 16 intervention schools (890 students) and 19 control schools (1771 students) in 2018 and 2019 (14). The results of this impact evaluation showed that the intervention could constrain the increases in BMI, BAZ, overweight/obesity and promote the increase in HAZ. However, the outcomes were statistically significant at $p<0.05$ only in some school terms. Interestingly, these desirable anthropometric trends were interrupted by the school long break between each school year before continuing to improve, as shown in Table S1.

123 **S3 Table Impact of the Programme on students' BMI, BAZ, and HAZ**

Measurement	BMI (β, 95%CI)	BAZ (β, 95%CI)	Overweight/obesity (IRR, 95%CI)	Wasting (IRR, 95%CI)	HAZ (β, 95%CI)
2018 (reference: baseline)					
2nd (end of term 1)	-0.147 (-0.340,0.046)	-0.110 (-0.238,0.019)	0.953 (0.879, 1.034)	1.087 (0.749,1.577)	0.011 (-0.066, 0.087)
3rd (beginning of term 2)	-0.267 (-0.476,-0.058)*	-0.190 (-0.326, -0.054)*	0.903 (0.819,0.995)*	1.178 (0.743,1.867)	0.071 (-0.004,0.147)
4th (end of term 2)	-0.333 (-0.602,-0.065)*	-0.219 (0.375,-0.065)*	0.903 (0.805,1.013)	1.199 (0.783,1.836)	0.141 (0.010,0.271)*
2019					
5th (beginning of term 1)	-0.145 (-0.442,0.151)	-0.171 (- 0.1354,0.012)	0.987 (0.807, 1.207)	1.671 (1.041,2.682)*	0.082 (-0.063,0.226)
6th (end of term 1)	-0.255 (-0.625,0.115)	-0.246 (-0.463,-0.029)*	0.932 (0.794,1.093)	1.611 (0.972, 2.669)	0.113 (-0.065,0.292)
7th (beginning of term 2)	-0.265 (-0.629,0.099)	-0.239 (-0.450,-0.027)*	0.963 (0.803,1.154)	1.771 (1.082,2.899)*	0.175 (0.033,0.446)
8th (end of term 2)	-0.390 (-0.802,0.022)	-0.307 (-0.524,-0.090)*	0.805 (0.805,1.167)	2.229 (1.116,4.453)*	0.207 (-0.033, 0.446)

124 Source: Pongutta S, Ferguson E, Davey C, Tangcharoensathien V, Limwattananon S, Borghi J, et al. The impact of a complex school nutrition
125 intervention on double burden of malnutrition among Thai primary school children: a 2-year quasi-experiment. Public Health. 2023;224:51-
126 7.
127 *Significantly different at p value <0.05, CI =Confidence interval

128

S3. Researchers' characteristics and reflexivity

Focus group discussions (FGDs) and documentary analysis were conducted by SP, SC, and NP. These researchers had 2- to 10-year experiences in conducting research (both quantitative and qualitative research) related to food and nutrition policy. They are personally interested in the area of school health promotion because they think schools are a key setting for child nutrition promotion. The FGDs were carried out via zoom video conferences, which were used frequently by both researchers and school staff during the COVID19 pandemic. They had no personal relationships with the participants, and they had contacted the participants prior to the FGDs to prepare the data collection. The researchers were aware of the risks of having desirability and recall biases, so they explained the participants information sheet to the participants clearly and triangulated the data received from FGDs with data from other sources. They received consent from the participants prior to the FGDs. SP moderated the FGDs, and other researchers were observers. After conducting the FGDs, SP acknowledged the challenges that school staff were handling with staff shortages and limited financial support for school health promotion. The document analysis was conducted by SP and NP. SP and NP were responsible for data coding. They worked independently in terms of reviewing documents and coding the data, then discussed among them to reach agreement when there were discrepancies.

Chapter 6

Discussion

In this chapter, I synthesise the key findings from the three studies done (Chapters 3, 4 and 5). In this chapter, I first summarise the key findings from the studies and discuss their contribution to the current body of knowledge about the effectiveness of school nutrition interventions on students' anthropometric outcomes, and then I discuss the strengths and limitations of the three studies done for the PhD.

6.1 Summary of the key findings from the studies

My thesis encompasses three interlinked studies aiming to assess the impacts of school nutrition interventions implemented in primary schools in Asia and Thailand on the double burden of malnutrition in school-aged children and to provide insight into the process that explains why they may have been effective or ineffective.

My first study (Chapter 3), which is a systematic review and meta-analysis, presents the findings extracted from relevant studies conducted in Asian countries. My second (Chapter4) and third studies (Chapter5) are an impact evaluation and a process evaluation of a primary school nutrition intervention in Thailand. More details are described below.

For the systematic review and meta-analysis (Chapter 3), I presented findings extracted from 28 intervention trials, including 15 cluster randomized control trials (CRCTs), 10 quasi-experiments, and 3 randomized controlled trials (RCTs) from China and territories (54%), Turkey (11%), Israel (7%), Lebanon (7%), and others (21%). The interventions in five of these 28 studies were codesigned with responsible authorities. Six interventions were carried out by the health sector, while the remaining interventions were carried out by academic institutions. In terms of implementers, five interventions were conducted entirely by investigators and 23 studies

engaged school staff and/or parents in the implementation of the interventions. All of these studies implemented new actions in the intervention schools. Most of the school nutrition interventions (27 out of 28 studies) aimed to address overnutrition, while only one study addressed wasting. The most common design of the interventions was a combination of nutrition education, physical activity, and either counselling for the parents and children or recommendations to schools to provide healthy food. One-third were single-component interventions, which consisted of five nutrition education interventions and three physical activity interventions. The meta-analysis of the 20 interventions suggested that the interventions were effective in reducing BAZ with a pooled effect of -0.05 (95% CI: -0.08, -0.03). My subgroup analysis of 12 multi-component interventions showed that they reduced mean BAZ by -0.07 (95%CI: -0.08, -0.05), while the eight single component interventions showed no significant change. Comparing outcomes between single physical activity and single food provision interventions, showed that single physical activity reduced mean BMI by -0.23 kg/m^2 but did not reduce mean BAZ, while single food provision neither reduced BMI nor BAZ. Combining the components of parental involvement and food provision did not improve the interventions' effects. Overweight/obesity treatment programmes reduced BAZ to a greater extent than overweight/obesity prevention programmes with the reductions of -0.15 (95% CI: -0.28, -0.02) and -0.05 (95% CI: -0.07, -0.02), respectively. This review indicated that school nutrition interventions implemented in Asian countries, especially multi-component interventions, were effective in reducing or preventing overweight/obesity, but their impacts were small. Interventions to increase physical activity were key interventions for achieving these favourable outcomes. In the published literature reviewed, there were few interventions

targeting undernutrition, which meant there was insufficient data to produce a pooled effect. Finally, the studies included in this review did not evaluate external or contextual factors that influenced programme implementation and effectiveness, which is important to inform efforts aiming to strengthen and scale-up school nutrition intervention programmes in different contexts. Most of the studies also did not examine sex differences in programme effectiveness. In summary, the review and meta-analyses done in this first study indicated that school nutrition interventions, especially multi-component interventions, can reduce the rising prevalence of over-weight and obesity in Asian school children. However, only one study assessed the impact of school nutrition interventions on under-nutrition. There was clearly a need to evaluate the effectiveness of a multi-component school nutrition intervention for addressing the double burden of malnutrition i.e., both over- and under-nutrition.

Chapter 4 presented results from an impact evaluation, using a quasi-experimental design, of the Dekthai Kamsai programme implemented in primary schools in Thailand. This programme is a complex school nutrition intervention consisting of eight components: 1) healthy food provision; 2) school farm and garden; 3) health and nutritional status monitoring; 4) school cooperatives and vocational training; 5) personal hygiene promotion; 6) school sanitation and healthy environment; 7) basic health service provisions; and 8) agriculture, nutrition, and health education. In this study I analysed the programme's impact on the double burden of malnutrition among children in grades 1 to 3 between 2018 and 2019 (eight measurement points). In total, 896 treated and 1612 untreated participants from 16 intervention and 19 control schools were matched and changes in their anthropometric outcomes were compared over time. The findings indicated that over 2 years this intervention

reduced the rise in BAZ (β=-0.190, -0.219, -0.246, -0.239, -0.307 at the 3rd, 4th, 6th, 7th, and 8th measurements, respectively), promoted an increase in HAZ (β=0.141 at the 4th measurements), and reduced the rising incidence rate of being overweight/obese (IRR=0.903 at the 3rd measurement). Categorised by sex, the favourable changes in BAZ and HAZ were found in both boys and girls, while the favourable change in the incidence rate of overweight/obesity was found in girls only. The programme did not reduce wasting. Instead, the control group had a higher decrease in the incidence rate of being wasted than the intervention group (IRR=1.671, 1.771, and 2.229 at the 5th, 7th and 8th measurements), but this effect was found in girls only. The prevalence of wasting, however, was higher in the control than intervention group at baseline, declining to a comparable level at endline. There also was no significant difference between the groups in terms of the changes in incidence rates of being stunted. However, the prevalence of stunted growth at baseline was low in both groups. In summary, this study indicated that this complex school nutrition intervention could be effective in improving anthropometric outcomes related to overweight/obesity and linear growth, in Thai school-aged children, but it was not effective in reducing the relatively high prevalence of wasting in these school children. However, given its quasi-experimental design, these results must be interpreted with caution, especially given that the intervention schools might have had more interest in child health and development than control schools, because they had to submit a proposal with an action plan for entry into the programme.

Chapter 5 provided insights into the internal and external factors that may have influenced the decision to implement the programme, and among schools choosing to

implement it, the factors contributing to its successful implementation and consequently impacts of the programme. The key internal factors that were perceived to strengthen the programme were the programme's design which included: 1) the provision of a school lunch and promotion of physical activity based on diet and physical activity standards for Thai children, 2) close monitoring of anthropometric outcomes to detect malnutrition early which allows timely contextualised responses to reduce malnutrition, 3) complementary components, such as a school farm and garden and nutrition education, to synergistically enhance and sustain outcomes, 4) a multi-sectoral support system which strengthened the schools' capacity to implement the programme, and 5) a flexible approach that allowed each school to develop a contextualised action plan within the programme's framework to implement. However, the programme did not provide additional funds to support the provision of additional services (e.g., extra meals or snacks provision) for students who were wasted to ensure normal body weight among the students, which might explain why it was not effective in reducing wasting. In this real-life programmatic intervention, the programme fidelity was moderate. External factors encompassed: 1) orientation of education policy and system towards academic performance but not nutrition that led to limited resources for nutrition promotion and lack of the willingness to participate in the programme, 2) wealthy urban communities that provided additional external support and urban infrastructure, though with obesogenic environments, and 3) a healthier food culture in the community was a supportive environment for the programme. This study suggested that a comprehensive design that is adaptable to the schools' contexts, and supportive national policy and local context are important enabling factors contributing to the success of the school nutrition intervention. Where the double burden of

malnutrition is prevalent, tailor-made supplementary services for undernutrition must be incorporated into school nutrition interventions to address it.

Figure 4 integrates the key findings from the studies described in chapters 3, 4 and 5 through my PhD's evaluation framework. It reflects: 1) how the interventions in Thailand and other Asian countries were adopted, implemented and maintained, 2) what their impacts were on malnutrition among school-aged children, and 3) how the interventions interacted with contexts.

In terms of the programmes' adoption, the programme in Thailand formed a supporting system (multi-sectoral non-governmental and governmental cooperation) to facilitate the implementation and integration of nutrition into the schools' current practices, and provided both non-financial and financial support to upgrade the schools' current practices to promote nutrition (e.g., created large school gardens and participatory educational activities), while most interventions reviewed, in my systematic review for Asia, did not engage governmental authorities or external actors (other than the research teams, schools, and parents) to support the intervention implementation, introduced new components rather than integrated the interventions' components into schools' current practices, and did not provide financial support.

Regarding the intervention contents, the school nutrition programme in Thailand is more complex than those reviewed regarding the number of connecting components (e.g., healthy school lunch, healthy school food environment, physical activity, close monitoring of nutritional status, and participatory educational activities), actors (a multi-sectoral non-

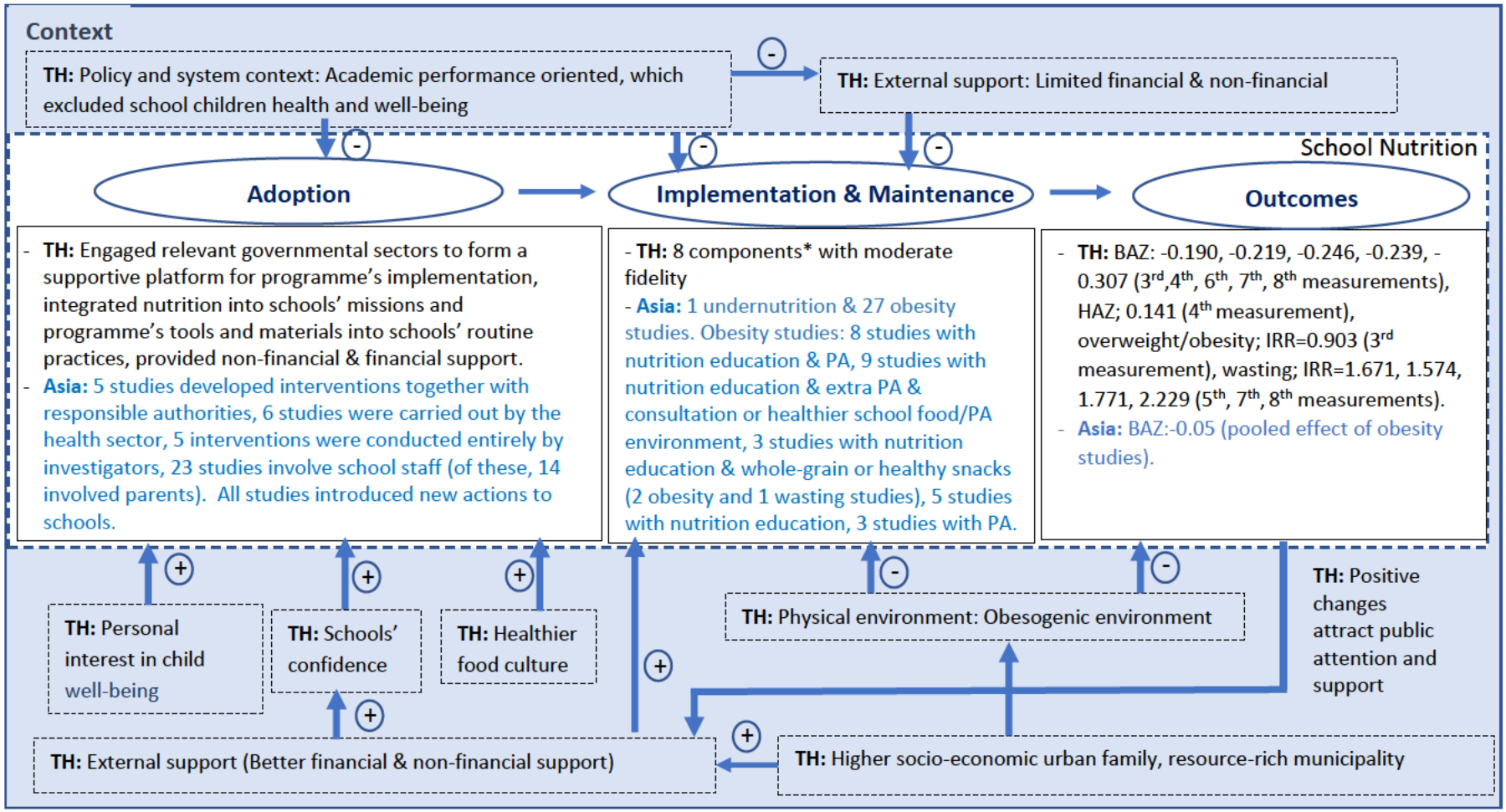
governmental and governmental cooperation) and expected outcomes (both over- and undernutrition). In terms of intervention fidelity and key influential external factors, sufficient information was not reported to make a comparison across the interventions. For the programme in Thailand, the key external influential factors were the government's policy, the socio-economic environment of the neighbourhoods, the presence of an obesogenic environment, the local food culture, the schools' self-confidence and interest in implementing the programme to promote the students' development and well-being.

In terms of outcomes, school nutrition programmes in Asia and a school nutrition programme in Thailand were effective in reducing BMI and BAZ in school-aged children. In addition, the evaluation of a school nutrition programme in Thailand also showed that a complex school nutrition intervention provided favourable impacts on anthropometric changes related to overnutrition and HAZ, but not wasting. However, the favourable impacts were unsustainable. My analyses of the Thai programme showed that during the long break, when children were not actively engaged in the programme that the anthropometric benefits were not sustained. These results underscore the importance of continued participation in the programme, and the need to identify strategies that will sustain the intervention benefits when outside of the school environment.

Comparing the effect sizes of the programme in Thailand and the interventions reviewed in other Asian countries, the school nutrition programme in Thailand provided a greater effect in reducing BAZ than those implemented in many Asian countries (see figure 4). This difference could reflect differences in internal factors (e.g., the intervention components,

adoption, and implementation) and/or external factors (e.g., the context) of the programme in Thailand compared with other programmes in Asian countries.

Based on the information above, factors that may contribute to the larger effect size of the programme in Thailand compared with programmes in other Asian countries include 1) a multi-sectoral supporting system, 2) integration of nutrition into schools' current practices, 3) provision of multiple forms of support for the implementation according to the needs, and 4) intervention design that encompasses free healthy school lunch, healthy school food environment, physical activity, close monitoring of nutritional status, and participatory educational activities. However, the effect size of the programme in Thailand was the result of moderate level of programme fidelity, which was influenced by factors related to national policy and the local context.



Notes:

- *8 components of an intervention in Thailand included 1. Healthy food provision, 2. School farm and garden, 3. Health and nutritional status monitoring, 4. Health and personal hygiene promotion, 5. Agriculture, nutrition, and health education, 6. School cooperatives and vocational training, 7. School sanitation, and 8. Basic health service.
- TH: findings from the impact and process evaluations of the Dekthai Kamsai programme.
- Asia: findings from a systematic review and meta-analysis in assessing impacts of school nutrition interventions in Asia. PA: Physical activity. BMI: Body Mass Index. BAZ: BMI for age z-score. HAZ: Height for age z-score. IRR: Incidence rate ratio. Positive sign means enabling factors, negative sign means barriers.

Figure 4 Key findings of this thesis

6.2 Contribution to the current body of evidence

There is a growing interest in the implementation of school-based nutrition programmes to improve the health, growth, well-being and development of school children given the rising rates of the double burden of malnutrition. However, as outlined in Chapter 1 (section 7) there are key gaps in the evidence that may limit the successful implementation and effectiveness of school nutrition interventions. This thesis addresses these gaps by providing evidence on the effectiveness of school-based nutrition interventions in Asia and on factors that will improve the design of nutrition interventions in primary schools, especially in Asia and Thailand. This contribution is summarised in Table 5.

Table *5* Previous gaps in evidence and contribution of this thesis

Gaps in evidence	Contribution of this thesis
1. Evidence on impacts of overweight and obesity interventions	
1.1 Up until 2021, a systematic review and meta-analysis had not been done to summarise the evidence showing the impact of school nutrition interventions implemented in Asia for reducing the risks of developing	Chapter 3 of this thesis showed that school nutrition interventions implemented in nine Asian countries and two territories reduced mean BMI and BAZ among school-aged children.

	Gaps in evidence	Contribution of this thesis
	overweight and obesity in school-aged children. Most relevant studies previously reviewed in Asia were from China, which does not completely represent the Asian context.	Some of my findings agreed with findings from other parts of the world that: 1) school nutrition interventions provide mild to moderate impacts, 2) multi-component and standalone physical activity interventions significantly reduced BMI, and 3) obesity treatment provided greater impacts than obesity prevention interventions in reducing BMI and BAZ. In terms of discrepancies, my meta-analysis found that including a food component and parent involvement in complex interventions did not improve the effect of the interventions, which contradicted with findings from previous meta-analyses drawn from western countries. However, it might be due to the inadequate degree of implementation of the components in the interventions in Asia.
1.2	The impacts of the complex school nutrition intervention in Thailand (the Dekthai Kamsai programme) on	Findings from Chapter 4 indicated the Dekthai Kamsai programme reduced the risk of developing overweight and obesity in primary school children.

Gaps in evidence	Contribution of this thesis
overweight and obesity were not known when the analyses presented in this study were done (Chapter 4).	Subsequently, another study was published which confirmed the findings from my study.
2. Evidence on wasting and stunting	
There is a paucity of evidence on the impact of school nutrition interventions on wasting and stunting among school-aged children.	Chapter 4 provided evidence that a 2-year school nutrition intervention (the Dekthai Kamsai programme) increased mean HAZ but it did not reduce the incidence rate of being wasted in Thai school-aged children.
3. Evidence on internal and external factors	
There is a paucity of evidence is regarding the internal and external	<u>Internal factors: (e.g., intervention components and effective period)</u> • Intervention components

Gaps in evidence	Contribution of this thesis
factors influencing programme effectiveness i.e., the underlying reasons why and how those interventions were effective.	Results from Chapter 4 and 5 align with evidence from previous studies that a multi-component approach reduces the risk of developing overweight and obesity. The findings also provided additional evidence that a complex school nutrition intervention with a diet component using diet standards for children might be effective in reducing the risk of developing overweight and obesity and stunting. Findings from Chapter 3 indicates that among single-component interventions, only physical activity is promising for reducing overweight and obesity. The provision of quality school food that meets dietary standards and close monitoring of malnutrition are key components that distinguish the Dekthai Kamsai programme from other programmes implemented in other Asian countries. The free school lunch scheme, using of the TSL computer programme to plan affordable and nutritious menus, in Thailand is an important enabling foundation for the provision of healthy school food.

Gaps in evidence	Contribution of this thesis
	Close monitoring of malnutrition encourages early detection of malnutrition and responses. • Effective period Results in Chapter 3 did not find a significant effect of intervention duration. Results in Chapter 4 provided additional evidence that a complex school nutrition, the Dekthai Kamsai programme, showed promising outcomes after one school term, although the effects disappeared during the school break of six weeks. <u>Internal, external factors and their interactions</u> Results in Chapter 5 indicated that both internal and external factors and their interactions played an important role in determining the success of the school nutrition intervention implemented in Thailand. • Internal factors

Gaps in evidence	Contribution of this thesis
	Perceived internal enabling factors were the multi-component design of the intervention that followed standards for both nutrition and physical activity, the flexibility within programme guidelines to implement a contextualised approach, and the multi-sectoral support system to facilitate programme implementation. Internal factors limiting the success were suboptimal implementation and the lack of specific services to address wasting. • External factors Perceived external enablers that facilitate the adoption and implementation of the intervention were access to adequate resources and external support, good infrastructure of urban areas, school staff's personal interest in child well-being and the population's healthy food culture. Barriers included an education policy and system that focuses mainly on improving academic

Gaps in evidence	Contribution of this thesis
	performance but not child well-being and the obesogenic environment.

6.3 Methodological considerations

In this section, I discuss potential biases or limitations that relate to my studies and what I have done to reduce the limitations and improve the robustness of the analyses.

6.3.1 Systematic review and meta-analysis

In general, there are a number of possible biases with systematic reviews and meta-analysis that have to be addressed including reporting bias, evidence selection bias, primary studies' bias (e.g., selection bias, detection bias, performance bias, attrition bias, and reporting bias of primary studies) (109, 110).

Reporting bias can occur when reviewers modify inclusion and/or exclusion criteria after exploring the data with an aim to obtain positive findings (110). In this study, I have registered the protocol of my systematic review and meta-analysis at PROSPERO (available at https://www.crd.york.ac.uk/prospero/) and strictly applied the Preferred Reporting Items for Systematic review and Meta-Analysis Protocols (PRISMA-P) reporting guideline to ensure the transparency of my study report.

Evidence selection bias covers a wide range of incidents including publication bias, language bias, and time lag bias. Publication bias refers to the absence of unpublished studies in a systematic review and meta-analysis (109). Language bias occurs when literature is excluded or included based on its language (109). Time lag bias occurs when the opportunities of studies to be included are different because of the different speeds of publication process (109), which is unmanageable for reviewers. Apart from the unavoidable lag time bias, my meta-analysis was prone to publication and language biases because it did not include

unpublished or non-English literature. To test for these biases, funnel plots are recommended (110, 111). To track the bias in my meta-analysis, I used the Egger's test (92), which is a funnel plot tool (a weighted regression of treatment effect on its standard error) that reports bias if an analysis shows an asymmetric scatter plot. The Egger's test reported no publication bias. My analysis included more than 10 primary studies, so the power of the Egger's test was adequate. In terms of primary studies' bias, 55.6% of the studies included in my analysis had high risk of bias. The quality of the studies included in the review influence the quality of the results (110). Since the majority of the studies included in my systematic and meta-analysis had high risk of bias, the interpretation and utilisation of the findings should be done with caution.

6.3.2 Quantitative analysis

There were some limitations with my research as follows: 1) Suboptimal-quality control of the outcome assessment, 2) the non-randomised research design, 3) unobserved covariates for the propensity score matching method, and 4) not using Asian-specific growth reference.

1. Suboptimal-quality control of outcome assessment

The anthropometric measurements that were used to generate the outcome indicators were done by class teachers using the school's measuring instruments, which raises questions about the reliability of the outcomes (112). For this reason, I did an outcome reliability study, which indicated that the quality of the data obtained from the schools was adequate to some extent because the agreement between the research anthropometrist and the teachers was high.

2. Non-randomised research design

For ethical and logistical reasons, a randomised control trial was not feasible for this study. Not randomising schools into intervention and control schools can lead to biased results, especially if baseline characteristics of participants differ between the intervention and control schools (84). In my quasi-experimental study, some of the baseline characteristics of the intervention and control participants were significantly different (i.e., living in urban areas, HAZ, overweight/obesity, and wasting), which indicated a potential bias.

To reduce the potential bias, a combination of the difference-in-difference and propensity score matching methods was used to imitate a randomised design. The difference-in-difference method encompasses both the pre-post and treatment-control approaches, so this method has the potential to reduce history bias or change in outcomes due to events other than the intervention provided, as long as the events over time are similar between the intervention and control groups and the inter-group differences are constant over time (99). However, with a non-randomised design, there is no guarantee if the parallel trends between the groups are always valid. Thus, to increase the robustness, I used propensity score methods to match the intervention and control observations based on their observed characteristics (99). I chose to use these methods instead of multivariate logistic regressions because they provide more robust results in addressing bias related to non-randomisation in observational data (113). There are four propensity methods: propensity score matching, stratification on the propensity score, inverse probability of treatment weighting, and covariate adjustment using the propensity score (102). Among the propensity score methods, propensity score matching performed better in removing systematic differences in baseline characteristics (102, 114). There are many matching methods, which include nearest

neighbour matching, exact matching, optimal matching, radius matching, kernel matching (weighting) and stratified matching (115, 116). Selection of matching methods involves a trade-off between bias and variance (116). Matching methods with quality match (such as exact matching or 1:1 matching) perform better in reducing bias related to systematic characteristic differences; however, they may exclude large unmatched controls. On the other hand, matching methods that keep all controls (such as optimal, kernel, and stratified matchings) might provide inferior performance in reducing the bias. The most commonly used method is nearest neighbour matching, which matches treated samples with their nearest neighbours (117). It can result in a wide range of matching quality from very good (e.g., 1:1 matching) to poor (e.g., many to 1 matching); however, the matching quality can be adjusted by using caliper that allows only matched pairs having propensity scores within a fixed distance (115, 117). Therefore, I chose to use nearest neighbour matching with caliper to help reduce the bias inherent in a quasi-experimental design.

3. Unobserved covariates for the propensity score matching method.

Although a combination of the difference-in-difference and propensity score matching improves the robustness of treatment effect estimations, it cannot account for unobserved covariates (100). In my quantitative study, the data of other potential confounders, which were identified by the process evaluation (Chapter 5) i.e., food culture and actors' personal interests in child well-being, were not available for the propensity score matching model to balance the probability to participate in the programme. The unavailability of these data potentially restricts the internal validity of this study (118), which means the results must be interpret in light of this potential bias.

4. The WHO growth reference for children aged 5-19 years old (98) used in this study is not specific to the growth of Thai school-aged children. Instead this reference data were derived from the growth of children primarily from the United States of America (119). Previous studies showed that the WHO growth reference does not fit perfectly with Southeast Asian children growth curve (120, 121). However, the WHO growth reference is used globally. Therefore, the secondary outcomes of this study were suitable for international comparisons but may be less suitable for examination of the nutritional status of Thai school-aged children.

Qualitative analysis

There are some limitations to consider when interpretating the results from the focus group interviews used in my qualitative study.

Firstly, this approach could have led to a social desirability bias because the participants might not be willing to provide information that may affect the schools' reputations, the relationships among school staff, or their careers. To reduce this bias and ensure honest information sharing and full engagement, it is recommended to only include participants who share similar characteristics (122) and to avoid holding a focus group where pre-existing relationships/organisation hierarchy exists among participants (123). However, for this study, I had to involve school staff who had been implemented the Dekthai Kamsai programme together for many years. Thus, to minimise the bias I informed the participants that personal or school identifiable information will be kept confidential, there will be no judgements made, and their straightforward answers would enhance the validity of my study and provide beneficial feedback to the policy making process. In addition, I used a data source triangulation technique (107) by assessing the convergence and completeness of the data

from the focus group interviews I conducted and from other sources (e.g., semi-structured interviews, progress report, and lessons learned reports) to enhance the validity and credibility of the results and to enrich the information used for the process evaluation.

Secondly, the number of schools, where I collected the qualitative data, might be too small, especially the control schools. I purposefully selected five intervention schools with high impact on anthropometric outcomes, five intervention schools with low impact on these outcomes, and four control schools. For qualitative research, the appropriate number of focus group interviews to hold is not strictly defined. It depends on when data saturation is perceived to be achieved. The intervention schools included in this qualitative study accounted for 62.5% of the intervention schools participating in the impact evaluation of the Dekthai Kamsai programme and they were purposely selected based on the anthropometric outcomes in the schools. This method of sampling meant the characteristics of the schools were diverse; and the information obtained from them is likely generalisable to the intervention schools participating in the impact evaluation of the Dekthai Kamsai programme. In terms of control schools, however, the number of schools sampled accounted for 21.1% of the control schools participating in the impact evaluation of the Dekthai Kamsai programme and they were schools in urban areas. Therefore, the information obtained from these four control schools may not have completely captured the perceptions of actors from the control schools participating in the impact evaluation of the Dekthai Kamsai programme. Initially, I planned to purposively collect data from control schools both in urban and rural areas in order to gain information from different contexts. However, there were some school closures in some areas due to COVID19 outbreaks and school staff in some rural areas could not attend

an online FGI at home. I had to end the data collection before data could be collected from control schools in various contexts due to time constraints and the uncertainty of COVID19 situation.

Chapter 7 Conclusion and implications

7.1 Conclusions

My systematic review and meta-analysis indicated that school nutrition interventions implemented in Asia are effective in reducing BMI and BAZ among school-aged children. The intervention characteristics that made an important contribution to reducing BMI and BAZ are multi-components in the intervention or extra exercise sessions. Treatment among overweight/obese children provided greater effects than prevention among participants with mixed-nutritional status. Most studies focused on addressing overweight/obesity and the content of these interventions most often included nutrition education and increasing physical activity. Studies assessing the impacts of school nutrition interventions on wasting or stunting among children, in Asia, are rare; hence the impacts are unknown. In addition, the studies reviewed did not provide sufficient information to inform policy regarding the process explaining why and why not the interventions were effective in reducing BMI and BAZ, which is critical for decisions on intervention design and for scaling-up a school nutrition intervention.

The results from the 2-year quasi-experimental impact evaluation of a complex school nutrition intervention in Thailand showed similar results to those reported in other Asian countries in terms of the effectiveness in reducing overnutrition. It also adds to the current body of evidence that a school-based nutrition intervention with multifaceted components can be effective in reducing the risks of developing overweight or obesity and improve linear growth among Thai primary school-aged children after one school term. Unfortunately, the intervention did not reduce wasting in these children. This finding emphasises the need to also provide services for wasted children, in this school nutrition intervention, to strengthen its

impact on the double burden of malnutrition. This study also shows the integration of an effective multiple component school-based intervention into the routine practices of Thai public primary schools is feasible; however, additional financial and technical support is needed to initiate and sustain the intervention.

The process evaluation of this complex school nutrition intervention in Thailand identified key internal and external factors that were perceived to influence its effectiveness. In terms of internal factors, the programme's strengths included the intervention's multi-component design, targeting both diet and physical activity using food and physical activity guidelines for children, close monitoring of students' anthropometric status to detect early malnutrition and contextualised prompt responses, and complementary components that synergistically enhanced and sustained its outcomes; and 2) a multi-sectoral support system to build the schools' capacity and facilitate programme implementation. The weakness of the intervention was lack of services to address wasting and suboptimal implementation. Contextual factors could be categorised into policy and school contexts. Regarding the policy context, child nutrition and well-being are not a priority for the education sector, which resulted in limited resources, external support, and the willingness of staff in some schools to adopt and implement the programme. In terms of school context, schools located in higher socio-economic urban neighbourhoods tended to receive more external support and benefited more from better infrastructure in the well-off urban areas. However, the programme's impact in urban schools tended to be offset by urban obesogenic environments. Schools receiving sufficient external support and where school staff had an interest in their students' well-being tended to adopt and implement the programme intensively. A healthier

food culture in the local community enhanced the intervention success. This study, therefore, highlighted the importance of implementing a comprehensive school nutrition intervention, having supportive national policies to improve the adoption and implementation of the school nutrition intervention, and creating an enabling environment for the school nutrition intervention at the local level.

7.2 Policy Implications and areas for future research

Policy Implications

1. Comprehensive school nutrition interventions have the potential to reduce the double burden of malnutrition in school-aged children in an Asian context, especially in Thailand. A comprehensive intervention here is not limited to a multi-component intervention, but it also requires the following important attributes.

First, in a context where the double burden of malnutrition is prevalent, it is important to pay attention to both over- and undernutrition and each form requires specific services.

Second, an intervention to address the double burden of malnutrition should include intensive actions to improve diet and physical activity, it should closely monitor and respond early to both over- and undernutrition with specialised services, and it should include complementary components that amplify and sustain the programme's effects.

Third, supportive education and health policies are needed to ensure adequate and equitable resources (e.g., budget, skilled staff, and infrastructure) for the intervention, which promotes the willingness of local multi-stakeholders to adopt and implement the interventions and creates a supportive school context (including school policy, leadership,

capacity, external support, social and physical environments) for the intervention to improve interventions' fidelity.

Fourth, there should be strategies to 1) empower schools to invent and use contextualised effective strategies to implement the intervention and 2) builds ownerships among local stakeholders, including school staff, local communities, and local governmental agencies to enhance local support and intervention sustainability.

2. Healthy school food provision: A key intervention component that needs improvement.

Diet components in previous school nutrition interventions were inadequately implemented in Asia. Except for Thailand, there was a lack of free healthy school meal provision and many diet components did not apply or adhere to diet standards. The Thai case study demonstrated that provision of free healthy school lunches is possible and effective in reducing some forms of malnutrition. Key inputs required for success included adequate financial support, school/local farms, and tools for healthy menu planning (TSL). However, this case also revealed that providing free high-quality lunches alone is inadequate in addressing child wasting, especially in a context where many families have limited income or the ability to provide adequate amounts of nutritious food to their children. Some Thai primary schools showcased the feasibility of addressing child wasting by providing additional school meals in addition to lunches. Nevertheless, to achieve this, schools require substantial external support, including adequate financial support and skilled staff, well-defined and realistic guidelines, the cooperation of local government agencies and local communities.

Areas for future research/evidence generation

To maximise the use of evidence, research should take into account pragmatism and governance principles (124). Research should provide information to inform the entire policy making process, which include the identification of problems, identification of solutions and justification for the solutions to facilitate 'policy adoption', and information for 'policy implementation' (125).

Therefore, I would emphasise the need for future research or evidence generation in the Asian and Thai contexts in key areas for informing policy making processes as follows.

Malnutrition problem identification

To inform policy and support a timely response to malnutrition in school-aged children in Asia, I recommend setting-up surveillance systems at schools and national levels to monitor anthropometric outcomes in school-aged children. All primary schools should receive regular standardised training in anthropometric measurements, quality equipment and tools to generate and help interpret the outcomes to obtain quality data. All school staff responsible for school health should be engaged in regular training on how to use the tools correctly.

Identification of solutions and justification for the solutions

Since the double burden of malnutrition is a major nutrition problem in the region and the current evidence is overnutrition-oriented, future research should assess the effectiveness in reducing both over-and undernutrition and the economic impacts of complex school nutrition interventions that include the component of healthy school food provision (preferably healthy meals (e.g., breakfasts and lunches) that meet diet standards or at least healthy lunches), especially in disadvantaged populations. Well-designed evaluations of

effectiveness and economic impact are needed to inform policy decisions on whether the interventions will provide desirable outcomes and be worth investing in.

Information for 'policy implementation'

There is a dearth of process evaluations and implementation research to inform programme implementers and policymakers on how to design or strengthen the implementation of their programmes in different contexts to improve their effectiveness. Process evaluation explaining why and how school nutrition interventions are effective/ineffective in addressing the double burden of malnutrition should be conducted more often to facilitate interventions replication and scaling up.

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Appendix 1 Ethical approvals

COA No. IHRP2020027

IHRP No. 021-2563

คณะกรรมการจริยธรรมการวิจัยในมนุษย์
ในสถาบันพัฒนาการคุ้มครองการวิจัยในมนุษย์
อาคาร 8 ชั้น 7 ห้อง 702 กรมวิทยาศาสตร์การแพทย์ กระทรวงสาธารณสุข นนทบุรี 11000

เอกสารรับรองโครงการวิจัย

โครงการวิจัย: การศึกษาบทบาทและกลไกในการพัฒนาเด็กวัยเรียนของโครงการเด็กไทยแก้มใส
ผู้วิจัยหลัก: น.ส.สุลัดดา พงษ์อุทธา
หน่วยงานที่รับผิดชอบ: มูลนิธิเพื่อการพัฒนานโยบายสุขภาพระหว่างประเทศ
เอกสารรับรอง:

1. โครงร่างการวิจัย: 13 มีนาคม 2563/version 2
2. เอกสารแนะนำสำหรับผู้เข้าร่วมการวิจัย: 13 มีนาคม 2563/version 2
3. ใบยินยอมจากความเข้าใจถ่องแท้: 13 มีนาคม 2563/version 2
4. เครื่องมือที่ใช้ในการวิจัย: 13 มีนาคม 2563/version 2
5. แบบแสดงรายการ/ประมาณค่าใช้จ่ายในการวิจัย: 13 มีนาคม 2563/version 2
6. ประวัติผู้วิจัยทุกคน: 12 กุมภาพันธ์ 2563/version 1

คณะกรรมการจริยธรรมการวิจัยในมนุษย์ฯ ในสถาบันพัฒนาการคุ้มครองการวิจัยในมนุษย์ ได้พิจารณาโครงการวิจัยดังกล่าว โดยได้คำนึงถึงประเด็นทางด้านวิชาการ ICH-GCP และด้านจริยธรรม และมีมติอนุมัติให้ดำเนินการศึกษาวิจัย ตามโครงการวิจัยดังกล่าวแล้ว อนึ่ง ขอให้ผู้วิจัยปฏิบัติตามจรรยาบรรณนักวิจัยสภาวิจัยแห่งชาติด้วย

(ลงนาม).....
(นายแพทย์วิชัย โชควิวัฒน)
ประธานคณะกรรมการจริยธรรมการวิจัยในมนุษย์ฯ

(ลงนาม).....
(นายแพทย์ปราโมทย์ เสถียรรัตน์)
เลขานุการคณะกรรมการจริยธรรมการวิจัยในมนุษย์ฯ

วันที่ประชุมครั้งแรก: 12 มีนาคม พ.ศ.2563
รับรองตั้งแต่วันที่: 17 มีนาคม พ.ศ.2563

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Observational / Interventions Research Ethics Committee

Miss SULADDA PONGUTTA
LSHTM

20 January 2022

Dear Miss SULADDA PONGUTTA

Study Title: The impact of the Dekthai Kamsai school programme on the nutritional status of Thai school-aged children

LSHTM Ethics Ref: 26555

Thank you for responding to the Observational Committee's request for further information on the above research and submitting revised documentation.

The further information has been considered on behalf of the Committee by the Chair.

Confirmation of ethical opinion

On behalf of the Committee, I am pleased to confirm a favourable ethical opinion for the above research on the basis described in the application form, protocol and supporting documentation as revised, subject to the conditions specified below.

Conditions of the favourable opinion

Approval is dependent on local ethical approval having been received, where relevant.

Approved documents

The final list of documents reviewed and approved by the Committee is as follows:

Document Type	File Name	Date	Version
Investigator CV	CV_ Suladda1	27/09/2021	1
Investigator CV	CV_LEESA K LIN_2021	27/09/2021	1
Investigator CV	CV-Elaine-Ferguson_2020	27/09/2021	1
Investigator CV	calum cv	27/09/2021	1
Other	Research_Ethics_online_training_certificate	27/09/2021	1
Information Sheet	Information for Participants	27/09/2021	1
Protocol / Proposal	Research protocol	27/09/2021	1
Information Sheet	Consent form children	29/11/2021	1
Local Approval	local ec	29/11/2021	1
Information Sheet	consent	07/01/2022	2
Information Sheet	permission of data use	07/01/2022	1
Information Sheet	children consent Thai	07/01/2022	1
Covering Letter	Cover Letter 18 1 2022	18/01/2022	3

After ethical review

The Chief Investigator (CI) or delegate is responsible for informing the ethics committee of any subsequent changes to the application. These must be submitted to the Committee for review using an Amendment form. Amendments must not be initiated before receipt of written favourable opinion from the committee.

The CI or delegate is also required to notify the ethics committee of any protocol violations and/or Suspected Unexpected Serious Adverse Reactions (SUSARs) which occur during the project by submitting a Serious Adverse Event form.

An annual report should be submitted to the committee using an Annual Report form on the anniversary of the approval of the study during the lifetime of the study.

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At the end of the study, the CI or delegate must notify the committee using an End of Study form.

All aforementioned forms are available on the ethics online applications website and can only be submitted to the committee via the website at: http://leo.lshtm.ac.uk

Additional information is available at: www.lshtm.ac.uk/ethics

Yours sincerely,

[redacted]

Professor Jimmy Whitworth
Chair

ethics@lshtm.ac.uk
http://www.lshtm.ac.uk/ethics/

Improving health worldwide

Appendix 2 Questionnaire for the family background variables used for the quantitative study

School No……

Student ID……..

Family general information

Use √ in a box and fill in blank spaces (…….) to answer the questions.

1. You are ☐ a boy ☐ a girl
2. Who is your caretaker(s) (people in your family who are taking care of you and give you permission to do things)
   You can choose more than one
   ☐ Father
   ☐ Mother
   ☐ Other

3. What is the job of your caretaker no.1 (if you do not know, please ask your caretaker)?

Father	Mother	Other
☐ Business owner ☐ Employee of private company ☐ Civil servant ☐ Daily wage worker ☐ Farmer ☐ Retired ☐ Unemployed ☐ Other ……..	☐ Business owner ☐ Employee of private company ☐ Civil servant ☐ Daily wage worker ☐ Farmer ☐ Retired ☐ Unemployed ☐ Other ……..	☐ Business owner ☐ Employee of private company ☐ Civil servant ☐ Daily wage worker ☐ Farmer ☐ Retired ☐ Unemployed ☐ Other ……..

4. What is the job of your caretaker no.2 (if you do not know, please ask your caretaker)?

Father	Mother	Other
☐ Business owner ☐ Employee of private company	☐ Business owner ☐ Employee of private company	☐ Business owner ☐ Employee of private company

Father	Mother	Other
☐ Civil servant ☐ Daily wage worker ☐ Farmer ☐ Retired ☐ Unemployed ☐ Other ……..	☐ Civil servant ☐ Daily wage worker ☐ Farmer ☐ Retired ☐ Unemployed ☐ Other ……..	☐ Civil servant ☐ Daily wage worker ☐ Farmer ☐ Retired ☐ Unemployed ☐ Other ……..

5. At home, usually, who cook for you?
   - ☐ Father
   - ☐ Mother
   - ☐ Your older brother/sister and how many of them……..
   - ☐ Yourself
   - ☐ Your father's father
   - ☐ Your father's mother
   - ☐ Your mother's father
   - ☐ Your mother's mother
   - ☐ Uncle and how many of them……..
   - ☐ Aunt and how many of them……..
   - ☐ Other and how many of them……..

Appendix 3 Information sheet for participants and consent form for focus group interviews

Information for Participants

Study Title: The impact of the Dekthai Kamsai school programme on the nutritional status of Thai school-aged children

Principal Investigator: Miss Suladda Pongutta

I am a PhD student at the London School of Hygiene and Tropical Medicine. I am planning to conduct a research study, which I invite you to take part in. This form has important information about the reason for doing this study, what we will ask you to do if you decide to be in this study, and the way we would like to use information about you if you choose to be in the study.

Why am I doing this study?

You are being asked to participate in a research study. The aim of this study is to improve the nutrition status of Thai school-aged children. I am conducting this study to understand the role and mechanism of impact of the 'Dekthai Kamsai' nutrition programme on Thai school-aged children.

What will you do if you choose to be in this study?

You will be participating in a focus group interview along with other staff who have been conducting the Dekthai Kamsai programme in this school. Similar to other participants, you will be asked to share your views, observations, and your experiences in implementing this programme. I will audio-record the session for my data analyses, if only I am allowed to. I may quote your remarks in presentations or articles resulting from this work. You do not have to reveal your name. Your personal information will be kept confidentially. A pseudonym will be used to protect your identity unless you specifically request that you be identified by your true name.

Study time: Study participation will take approximately 1 hour. The focus group interview will be held at participants' convenient time.

Study location: The focus group interview will be held online so you can participate from anywhere that suit you.

What are the possible risks or discomforts?

Your participation in this study does not involve any physical or emotional risk to you beyond that of conversations in everyday life. It is your right to ask for a break or withdraw at any time.

As with all research, there is a chance that confidentiality of the information we collect from you could be breached – we will take steps to minimise this risk, as discussed in more detail below in this form.

What are the possible benefits for you or others?

Taking part in this research study may not benefit you or the school personally, but the findings will inform school nutrition policy in Thailand.

How will I protect the information, and how will that information be shared?

Results of this study may be used in publications and presentations. The data will be handled as confidentially as possible. If the results of this study are published or presented, individual names and other personally identifiable information will not be used.

To minimize the risks to confidentiality, I will keep your consent away from other data. Also, the interview records will be kept in an electronic form in a password-protected computer, and it will only be used by me.

I may share the data, excluding your personal information, for use in future research studies or with other researchers.

Financial Information

Participation in this study will involve no cost to you.

What are your rights as a research participant?

Participation in this study is voluntary. You do not have to answer any question you do not want to answer. If at any time and for any reason, you would prefer not to participate in this study, please feel free not to. If at any time you would like to stop participating, please tell me. We can take a break, stop and continue at a later date, or stop altogether. You may withdraw from this study at any time, and you will not be penalised in any way for deciding to stop participation.

If you decide to withdraw from this study, the researchers will ask you if the information already collected from you can be used.

Who can you contact if you have questions or concerns about this research study?

If you have any queries, you may contact me, Miss Suladda Pongutta. Tel. 096-1128438. Email: suladda.pongutta@lshtm.ac.uk, suladda@ihpp.thaigov.net.

Address: International Health Policy Programme, Ministry of Public Health, Muang, Nonthaburi 11000, Thailand. Tel. 02-5902376.

Thank you for your corporation.

Best regards,

Suladda Pongutta

Consent form for focus group interviews

Research title: The impact of the Dekthai Kamsai school programme on the nutritional status of Thai school-aged children

Principal researcher: Suladda Pongutta

Do you agree to the following statement?	**√ or X**
I confirm that I have read and understand the participant information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered fully.	( )
My questions concerning this study have been answered.	( )
I understand that my participation is voluntary, and I am free to withdraw at any time, without giving any reason, without my medical care or legal rights being affected.	( )
I understand that sections data collected during the study may be looked at by responsible individuals. I give permission for these individuals to access my records.	( )
I agree to being recorded as part of this study, subject to data protection and confidentiality safeguards explained in the participant information sheet. OR I do not wish to be recorded as part of this study. (tick one only)	( ) ( )
Quotations are to be used anonymously and in such a way that I cannot be identified. OR I do not want to be quoted at all, even anonymously. (tick one only)	( ) ( )
I agree to take part in this study.	( )

……. ……. ……./……/……

Name of Participant Signature Date

……. ……. ……./……/……

Principal Investigator Signature Date

Appendix 4 Topic guide for focus group interviews

1. Please introduce yourself what is your role and responsibility both as a teacher and as an implementer of the Dekthai Kamsai (or staff who were responsible for the school lunches and student's health in the control schools)?
2. How long have you been involved in the programme (or the activities in the control schools)?

Adoption:

3. How the programme was introduced to this school and why did this school join/did not join the programme?
4. How did this school start this programme? Who have been involved and what are their responsibilities?

Implementation:

5. How has this school implemented the programme (or the activities in the control schools)? Was there any difficulty and if so, how it was addressed?
6. Are there any changes in terms of Dekthai Kamsai implementation? How and why is that?
7. Any other health or nutrition promotion interventions implemented in this school? How the school manage to do all of them?
8. What factors contribute to the school's ability to implement the programme?
9. Do you think all students benefit from the programme equally? Why is that? If not, what makes it different between each student in terms of participating or benefiting from the programme?

Effectiveness:

10. What do you and the school expect to see from this programme?
11. Are there any changes happen to students? Is it because of the programme or other things? Why do you think so?
12. Any other changes (could be in and outside school and could be positive and negative) have you seen? Any evidence of the changes you can share with me? Do you think it is purely because of the programme or other factors too?

Context:

13. What is it about the school characteristics that could determine the adoption, implementation, outcomes, and sustainability of the Dekthai Kamsai programme?
14. Anything outside school affects the implementation or the effectiveness of the programme (or the activities in the control schools) (e.g., urbanisation, social norm, local culture, socio-economic of people living around, policies or regulations that school have to follow)?
15. Any suggestions to make things better?
16. Anything else do you want to reflect?

Thank you very much for your valuable time and support. I may need to ask for further clarification or verification of information. I was wondering if that is possible?