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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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A B S T R A C T

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

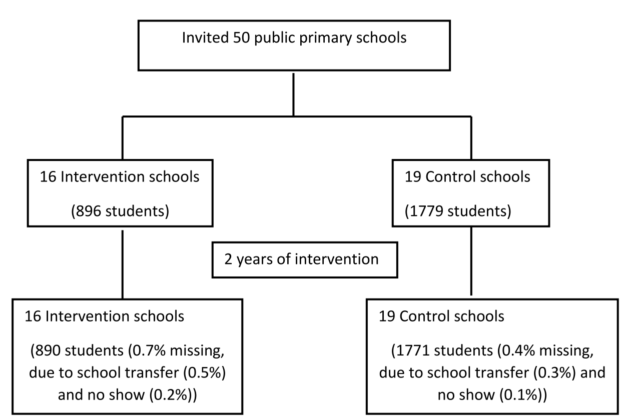

Fig. 1. Participant recruitment and retention.

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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