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Effectiveness of school-based interventions to prevent obesity among children aged 4 to 12 years old in middle-income countries: A systematic review and meta-analysis

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Summary

Economic and accompanying nutrition transition in middle-income countries is resulting in rapidly increasing childhood obesity prevalence, exceeding acceleration rates in the West. Previous school-based obesity prevention reviews have mainly included studies from high-income countries. This review aimed to summarize the evidence from randomized controlled trials evaluating the effectiveness of school-based interventions in preventing childhood obesity in middle-income countries. Six electronic databases were searched: MEDLINE, EMBASE, CINAHL Plus, LILACS, IBECS and WPRIM. Eligibility criteria included middle-income country setting, randomized/cluster-randomized controlled trials, children aged 4–12 years and school-based interventions targeting dietary intake and/or physical activity. Twenty-one cluster-randomized controlled trials, conducted in Asia (n = 10), South America (n = 4), North America (n = 4) and the Middle East (n = 3), were included. Fifteen studies reported a significant intervention effect on at least one adiposity-related outcome. Characteristics of effective interventions included combined diet and PA interventions, school teacher-delivery, duration of >8 months, parental involvement, education sessions and school food modifications. The risk of bias in these trials was mixed. The pooled estimate of the odds ratio for obesity in intervention versus control schools (nine studies) was 0.77; 95% CI, 0.63 to 0.94; p = 0.009. In conclusion, there is some evidence to support school-based interventions in preventing childhood obesity in middle-income countries.

KEYWORDS

childhood obesity, prevention, school, middle-income country

Abbreviations: MICs, middle-income countries; HICs, high-income countries; PA, physical activity; WHO, World Health Organization; BMI, body mass index; RCTs, randomized controlled trials; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-analyses; CI, confidence interval; SD, standard deviation; IV, inverse variance; WC, waist circumference; %BF, body fat percentage; O, obesity; OW, overweight; MVPA, moderate to vigorous intensity physical activity.

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1 | INTRODUCTION

Childhood obesity is an international health concern affecting all socio-economic groups and ethnicities, and the worldwide prevalence has risen dramatically over the last four decades from 4% in 1975 to over 18% in 2016.[1] If current trends continue, researchers have predicted that childhood obesity will surpass moderate and severe underweight by 2022.[2] Middle-income countries (MICs) are of particular interest at the current time because these countries are undergoing rapid economic transition.[3] Alongside this MICs are experiencing a 'nutrition transition': a corresponding shift in energy intake and expenditure behaviours. In contrast with high-income countries (HICs), where economic growth and accompanying nutritional changes have occurred over a long period of time, the transition in MICs is occurring at an accelerated rate. Consequently, the prevalence of obesity in adults and children in MICs has rapidly increased in the last two decades, whereas the increase previously seen in HICs occurred at a slower rate, with a plateau in prevalence now being observed in these countries.[4–10]

There are differing contextual factors to take into account when considering the rapid rise in childhood obesity in MICs. The relationship between socio-economic status and childhood obesity in MICs is positive, with increasing wealth associated with higher prevalence, whereas in HICs, the higher childhood obesity prevalence is associated with deprivation.[11,12] Also in MICs, rapid urbanization, industrial modernization, adoption of new technologies and the increasing influence of mass media contribute to the increased access to and consumption of energy-dense foods as well as reductions in physical activity (PA).[6,13] The approach to noncommunicable disease prevention also differs in these settings, with lower prioritization of health promotion initiatives to address noncommunicable disease risk factors by governments, and less focus on health promotion policies in schools.[14] These particular contextual challenges and the current positioning of MICs within the obesity epidemic curve make them an important focus for childhood obesity prevention at the present time.[9,15,16]

In 2011, the World Health Organization (WHO) adopted the target of halting the rise in global obesity by 2025.[17,18] Since this time, there has been much activity relating to the development and evaluation of obesity prevention approaches, with a large majority targeting children.[19–22] Schools are frequently the focal point of obesity prevention efforts because most children spend a substantial proportion of their day in school. Furthermore, schools offer a natural setting for education, with the potential to reach parents as well as children, and teachers are often seen as role models.[22–24] Hence, school-based interventions have the ability to reach many children and families through a contained environment that provides sustained contact.

A Cochrane review published in 2019 presented some evidence to suggest that combined diet and PA interventions in schools resulted in lower body mass index (BMI) z-score in children aged between 6 and 12 years (mean difference of −0.05, 95% CI, −0.10 to −0.01; meta-analysis of 20 randomized controlled trials (RCTs), low certainty of evidence).[25] Other systematic reviews have reported similar findings.[26–31] However, in general, there has been substantial heterogeneity among the studies included in these reviews, and the majority have been conducted in HICs, so the applicability of the findings to MICs setting is limited. The most recent systematic review of school-based studies focusing on low- and middle-income countries was undertaken by Verstraeten et al,[32] before most programmes prompted by the WHO targets commenced. The authors concluded that school-based interventions have the potential to prevent obesity but acknowledged that a number of methodological limitations prohibited firm conclusions being drawn. Other systematic reviews linked to MICs have addressed one region only.[33,34] Feng et al[33] conducted a systematic review in 2017 comprising 34 school-based obesity prevention studies undertaken in China, which revealed that multicomponent interventions involving PA and health education were more effective than single PA component interventions in preventing childhood obesity. A systematic review focusing on Latin America, also undertaken several years ago (2013), identified seven school-based obesity prevention studies, three of which reported significant improvements in BMI, and two of which evaluated PA-only interventions.[34] Again, the small volume of trials, methodological issues and heterogeneity of interventions limited firm conclusions being drawn from this review.

As yet there has been no comprehensive review of the effectiveness of school-based interventions for the prevention of childhood obesity across all MICs. Moreover, methodological rigour of trials evaluating school-based interventions in MICs has improved since the Verstraeten review in 2012, and so it is the appropriate time for synthesis of this more robust evidence. Therefore, the aim of this systematic review is to summarize the evidence from RCTs evaluating the effectiveness of school-based interventions in preventing childhood obesity in MICs and thus inform future school-based interventions to prevent childhood obesity in these countries.[35]

2 | METHODS

2.1 | Protocol and registration

The protocol for this systematic review was registered on the International Prospective Register of Systematic Reviews (registration number CRD42019128058) and has been created according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines.[36]

2.2 | Eligibility criteria

2.2.1 | Population

The participants of interest were primary school children aged 4 to 12 years. Studies comprising populations of a wider age range were eligible for inclusion where the majority (>75%) of participants fulfilled the specified age range. Due to the variation in school systems and

age of school entry between countries, the specified age range was selected to allow inclusion of all children in primary, or equivalent, education. Participants were children who reflected the weight status profile within the general child population. Studies were excluded if the target population was children with excess weight only as these were considered to be trials of obesity treatment rather than prevention. Studies in which the target population was predominantly formed by children with co-morbidities or critical illnesses were also excluded.

2.2.2 | Intervention

Interventions targeting dietary intake and/or PA were included, irrespective of other intervention components. Eligible interventions were delivered through primary schools or equivalent settings but may have included components based within the family or community. No restrictions were placed on the intervention duration or the personnel delivering the intervention. Interventions that had been specifically designed for the treatment of childhood obesity were excluded.

2.2.3 | Comparator

Studies were included where the control group received either no intervention, usual school-based activities relating to health education or an intervention with no specific diet or PA content.

2.2.4 | Outcomes

The primary outcomes comprised BMI, BMI z-score, skinfold thickness, body fat percentage, waist circumference, waist: height ratio, prevalence of overweight, prevalence of obesity and other measures of obesity based on weight and height. The secondary outcomes considered were measures relating to PA, dietary intake and quality of life.

2.2.5 | Study design and setting

All relevant RCTs or cluster RCTs conducted in MICs were eligible for inclusion. MICs were defined according to the World Bank classification of countries by income level 2018-2019.[37] Studies reported as full-texts only were included; published and unpublished studies (identified through published protocols) were eligible, but the latter were included where results were made available upon contact with the authors within a 2-week timeframe.

2.3 | Search strategy

The following electronic databases were searched: MEDLINE (OVID interface, searched from 1946 until the 7th March 2019), EMBASE (OVID interface, searched from 1974 until the 7th March 2019), CINAHL Plus (EBSCO interface, searched from 1937 until the 7th March 2019), LILACS (Virtual Health Library interface, searched until the 7th March 2019), IBECS (Virtual Health Library interface, searched until the 7th March 2019) and WPRIM (globalindexmedicus.net, searched until the 7th March 2019). A search was conducted using text and index terms for 'excess weight' and 'school', using a filter for RCTs where possible. The search strategy for the MEDLINE database is presented in Data S1; modified versions of this search strategy were used for the other electronic databases. The electronic database search was supplemented by hand-searching the reference lists of included studies and relevant systematic reviews to locate any additional studies that had been missed. A citation search of included studies was further conducted, and three experts in the field of childhood obesity prevention were contacted and asked if they knew of any additional published or unpublished studies. No language or publication date limits were applied.

2.4 | Study selection

Literature search results were imported into the referencing software, Mendeley Desktop, to aid deduplication and organization of references for screening. Titles and abstracts of the studies were screened by JS. A random sample of 5% of the studies, generated via the random number function in Microsoft Excel, was independently screened by another review author (CH or MP). Full-texts of potentially relevant studies were assessed for inclusion independently by two reviewers (see Data S1). Middle-income setting was assessed at the abstract screening stage. If the study setting was unclear from the abstract, the study was included in the full-text assessment stage. Disagreements at the abstract and full-text screening stages were discussed within the author team, and consensus was reached in determining eligible studies. The PRISMA flow diagram is shown in Figure 1.

2.5 | Data extraction

Data were extracted into data extraction forms, which had been designed and piloted a priori, shown in Data S1. The data of interest comprised location, study design, setting, duration, number of trial arms, number of participating schools, recruitment process, randomization method, participant characteristics, intervention (including personnel, duration and parental involvement), control, primary and secondary outcome data at baseline and follow-up time points, acknowledgement of adverse outcomes, response rate, attrition, method to deal with losses to follow-up, method of statistical analysis and a summary of study findings. This was carried out by JS for all studies, and each form was verified by one other reviewer (CH or MP). Missing data were sought, where possible, by email contact with study authors. Any discrepancies were identified and resolved through discussion within the author team. For the non-English

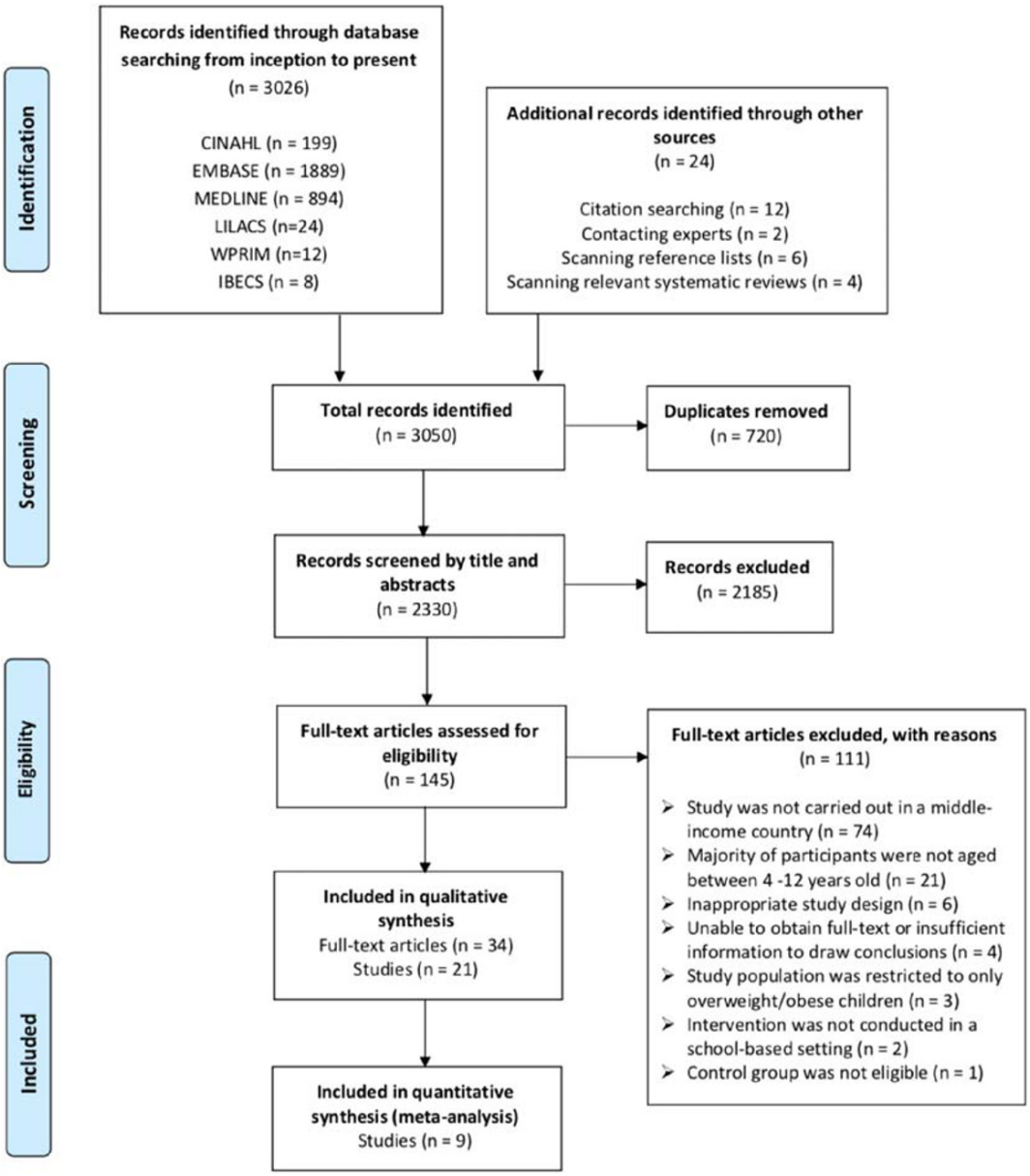

FIGURE 1 A PRISMA flow diagram outlining the identification, screening, eligibility and inclusion of studies in this review. Only studies for which estimates of effect were adjusted for clustering and reported in the appropriate format were eligible for inclusion in the meta-analyses

studies retrieved, translators with the relevant language skills provided assistance with the data extraction.

2.6 | Quality appraisal

The quality of the included studies was assessed independently and in duplicate using the Cochrane Collaboration's Tool for Assessing Risk of Bias, which was modified for use with cluster RCTs.[38,39] Any disagreements were resolved through discussion between the two review authors, and where necessary, consultation within the entire author team. Due to the nature of the intervention, performance bias was not considered because it is not possible to blind study personnel or participants. The additional risk of bias assessments for cluster RCTs included the following: recruitment bias, analysis bias, baseline imbalance and loss of clusters. A judgement of either 'low risk', 'high risk' or 'unclear risk' was assigned for each specific domain along with a support for the judgement. The results of the risk of bias assessments were exported to Review Manager 5.3 software to create a visual representation.[40]

2.7 | Synthesis of results

Trial outcomes expressed as mean differences, risk ratios and odds ratios were extracted. Study findings have been presented by outcome measures and grouped based on the following intervention characteristics to provide a narrative synthesis: type of intervention,

duration, personnel delivering the intervention and parental involvement. These specific intervention characteristics were evaluated because previous reviews indicate that these are important variables influencing the effectiveness of school-based interventions.[23,41,42] When it was deemed appropriate, based on the assessment of the clinical and methodological homogeneity of the studies, a meta-analysis was conducted to support the narrative synthesis. Meta-analyses of adiposity-related outcomes that had been reported in an appropriate format by five or more studies were carried out using the Review Manager 5.3 software.[40] Only studies for which estimates of effect were adjusted for clustering were included in the meta-analyses. We organized the forest plots by intervention type with the following subgroups: diet only, physical activity only and combined. We used these groupings to look at the relative effectiveness of these types of interventions to generate further hypotheses. A random effects model was applied because of the assumed clinical and methodological heterogeneity among the studies.[43] We used odds ratios as the statistical output for dichotomous outcomes, with 95% confidence intervals (CIs). For continuous data, we used mean differences with 95% CIs. We tested for statistical homogeneity of pooled estimates of effectiveness using the Chi^2 test and the I^2 statistic, for which a statistically significant (p value ≤ 0.1) value of the Chi^2 test together with I^2 value of at least 50% indicates heterogeneity.

3 | RESULTS

3.1 | Search results

The systematic search strategy identified 3014 articles. After the removal of duplicates, 2321 unique titles and abstracts were screened. A total of 21 studies (presented in 34 articles) were found to be eligible for inclusion in this review (see Figure 1).[44–77] Two of the 34 papers reporting two of the included studies required translation.[71,74]

3.2 | Description of studies

The characteristics of the included studies are presented in Table 1. All of the included studies were cluster-RCTs. The majority of the studies were conducted in Asia (n = 10), followed by South America (n = 4), North America (n = 4) and the Middle East (n = 3). Papers reporting the included studies were published between 1998 and 2019 (71.4% of studies published from 2012 onwards). The total number of participants per study ranged from 221 to 10 091, and the mean age of participants varied from 4.5 to 11.5 years. Fifteen of the 21 studies targeted populations in which the mean age of participants was between 9 and 12 years. Three of the studies from Brazil targeted low socio-economic areas, whereas the remaining 18 studies either did not specifically address socio-economic status or did not report this information.[68,69,77] Most studies (n = 19) used a control group that received routine school health education or no intervention. The remaining two studies either did not state the control or delivered general health sessions to participants in the control group.[53,77]

Three studies evaluated diet-only interventions, three studies evaluated PA-only interventions and 14 studies evaluated interventions involving diet and PA components (referred to as combined interventions for the purpose of this review), see Table 1. The remaining study had three trial arms investigating one PA-only and two separate diet-only interventions.[55] The duration of the interventions ranged from 3 to 36 months, whereas the interval between baseline and follow-up measures varied from 3.5 to 72 months. The personnel delivering the intervention included school staff (n = 12), external deliverers (individuals from the research team or health professionals; n = 6) or a mixture of both (n = 2). One study did not specify who delivered the intervention.[72] Only nine of the 21 studies addressed adverse intervention effects.[44–47,50,55,58,72]

All of the diet-only studies incorporated nutrition education sessions and parental involvement.[68,72,77] One diet-only study included modifications to the school food provision.[72] Two of the three PA-only studies provided additional PA sessions ranging from 100 to 105 min per week, which were integrated into the existing school curriculum.[45,67] The remaining PA-only study comprised monthly education sessions, changes to the school environment and an additional home setting component with parental involvement.[58] The key characteristics of the combined intervention studies were education sessions (n = 13), modifications to the school food provision (n = 11) and parental involvement (n = 13), outlined in Table 1. Four of the 14 combined intervention studies included daily PA sessions and four studies included an additional home setting component.

3.3 | Quality appraisal

The results of the methodological quality assessment are shown in Figure 2. Due to insufficient detail in the reporting of methods, 44.4% of judgements across all domains were 'unclear risk of bias'. Fifteen of the 21 studies had a 'high risk of bias' for at least one domain (12.2% overall). 'Low risk of bias' accounted for 43.4% of all judgements and was the most common assessment for the following five domains: baseline imbalance (n = 17), loss of clusters (n = 16), analysis bias (n = 12), random sequence generation (n = 11) and incomplete outcome data (n = 10). 'Unclear risk of bias' was the most common assessment for the remaining four domains: allocation concealment (n = 17), selective reporting (n = 17), blinding of outcome assessment (n = 11) and recruitment bias (n = 11). The key methodological limitations encountered (as indicated by a 'high risk of bias' assessment) included the following: unblinded outcome assessment (n = 5), discrepancies in the reporting of prespecified outcome data (n = 4), absence of reporting on losses to follow-up (n = 3), inappropriate data analysis method (n = 3) and loss of clusters (n = 3). Seven included studies were assessed as 'low risk of bias' for five or more domains.[46,47,50,58,68,75,77] Two of the more recent trials had predominantly low risk judgements and appear to be higher quality than the

TABLE 1 Characteristics of the included studies

Combined Interventions					
Study Reference	**Study and Participant Characteristics**	**Description of Intervention**	**Description of Control**	**Intervention Summary**	**Outcomes Measured**
Sgambato et al, Brazil, Rio de Janeiro, protocol (2016), unpublished.[69]	**Trial arms**: 2 **Schools**: 18 **Baseline participants**: 2743 **Mean age** (y): *I* = 11.50, *C* = 11.50 **Male** (%): *I* = 51.9, *C* = 52.1 **School grade**: 5th and 6th **Other**: Public schools and children from families of low socio-economic levels. **Method of randomization**: Not specified.	The PAAPPAS intervention combined primary prevention at school with an additional home intervention targeting children with excess weight. The primary prevention at school consisted of two monthly 30-min health education games with the main message of reducing consumption of sodas, cookies and sugar-sweetened beverages. Water consumption was promoted, culinary classes took place along with PA games relating to the Olympic Games.	Routine school health activities.	**Duration** (mo): 6 **Personnel**: School teachers. **Parental involvement**: Yes. **Secondary setting component**: Yes (secondary prevention). **Length of follow-up** : One academic school-year.	**Primary outcomes**: BMI, %BF, prevalence of OW, and prevalence of O. **Secondary outcomes**: Duration of PA per week, daily frequency intake of milk, beans, water, fruits, vegetables, cookies, sodas, processed meat and fruit-based drinks. **Adverse outcomes**: Not addressed.
Friedrich et al, Brazil, Rio Grande do Sul, 2015, published.[73]	**Trial arms**: 2 **Schools**: 12 **Baseline participants**: 600 **Mean age** (y): N/A. **Male** (%): N/A. **School grade**: 1st–4th **Other**: Afternoon school classes. **Method of randomization**: Cluster randomization computer software programme.	The TriAtiva programme was performed every 15 days during school hours. The nutrition education programme included provision of water bottles, school competitions to encourage healthy food consumption and modifications to the school food provision. The physical education programme included outdoor recreational activities and children were advised to reduce time spent watching the television, using the computer or playing video games. Two meetings were held per year for parents.	Routine school health activities.	**Duration** (mo): 6 **Personnel**: Research team, physical education school teachers, professors of nutrition and physical education. **Parental involvement**: Yes. **Secondary setting component**: No. **Length of follow-up (mo):** 9	**Primary outcomes**: BMI, BMI z-score, %BF, WC, prevalence of OW, prevalence of O, remission of OW, remission of O, incidence of OW, and incidence of O. **Secondary outcomes**: Measures relating to PA and eating habits. **Adverse outcomes**: N/A.

TABLE 1 (Continued)

Combined Interventions					
Study Reference	**Study and Participant Characteristics**	**Description of Intervention**	**Description of Control**	**Intervention Summary**	**Outcomes Measured**
Li et al, China, Guangzhou, protocol (2017), unpublished.[47]	**Trial arms:** 2 **Schools:** 40 **Baseline participants:** 1641 **Mean age (y):** *I* = 6.15, *C* = 6.14 **Male (%):** *I* = 55.6, *C* = 53.3 **School grade:** 1st **Other:** Nonboarding, state funded primary schools. **Method of randomization:** Stratified randomization performed by an independent statistician.	The CHIRPY DRAGON intervention consisted of six interactive educational workshops, four with school children, and two with parents or grandparents. Two weekly healthy eating or PA challenges for children took place along with modifications to the school food provision, 1-h of daily PA, family friendly games twice a year, and weekly family challenges.	Routine school health activities.	**Duration (mo):** 12 **Personnel:** 5 Chinese research staff. **Parental involvement**: Yes. **Secondary setting component:** Yes (Family environment). **Length of follow-up (mo):** 24	**Primary outcomes:** BMI z-score, %BF, WC, prevalence of OW, and prevalence of O. **Secondary outcomes:** Proportion of children who eat ≥5 portions of fruit and vegetables per day, daily average servings of fruit and vegetables, weekly average servings of unhealthy snacks and sugar-sweetened beverages, objectively measured daily moderate to vigorous intensity physical activity (MVPA), parent reported daily MVPA, proportion of children achieving ≥60 min of MVPA per day, and quality of life (PedsQL total score and CHU9D utility score). **Adverse outcomes**: Addressed.
Xu et al, China, Guangzhou, 2015, published.[50]	**Trial arms:** 2 **Schools:** 8 **Baseline participants:** 1182 **Mean age (y):** *I* = 10.20, *C* = 10.20 **Male (%):** *I* = 53.9, *C* = 59.2 **School grade:** 4th **Other:** Urban population. **Method of randomization:** Computer random number generator.	The intervention consisted of monthly 30-min health education lessons and parent-child interactive homework assignments. Posters and messages were spread around the school. Fun programmes and events were held throughout the school-year including competitions, 'no TV week', 'no unhealthy snack week' and 'no soft drink week'. Parents were invited to participate in an educational programme twice per semester.	Routine school health activities.	**Duration (mo):** 8 (one academic school year). **Personnel:** School teachers. **Parental involvement:** Yes. **Secondary setting component:** Yes (Family environment). **Length of follow-up (mo):** 8 (1 academic year).	**Primary outcomes:** BMI, change in BMI, WC, prevalence of O, change in nutritional status from obese to nonobese, and change in nutritional status from nonobese to obese. **Secondary outcomes:** Increase in participating frequency of jogging, running, walking and ball playing. Proportion of children with reduced consumption frequency of red meat, fried snacks and soft drinks, proportion of children with increased consumption frequency of vegetables, and proportion

(Continues)

TABLE 1 (Continued)

Combined Interventions					
Study Reference	**Study and Participant Characteristics**	**Description of Intervention**	**Description of Control**	**Intervention Summary**	**Outcomes Measured**
					of children with reduced viewing of TV/computer use. **Adverse outcomes**: Addressed.
Jiang et al, China, Beijing, 2006, published.[44]	**Trial arms:** 2 **Schools:** 5 **Baseline participants:** 2489 **Mean age (y):** *I* = 8.40, *C* = 8.20 **Male (%):** *I* = 51.6, *C* = 51.2 **School grade: 1st–4th** **Other:** N/A. **Method of randomization:** Not specified.	One classroom lesson every fortnight was provided based on a text designed by the research team on childhood obesity prevention. An additional intervention was provided to children with obesity or overweight and those failing physical education, who had 20-min after school lessons from Mondays to Thursdays. A nutritional lecture was given to parents once per semester by a researcher.	Routine school health activities.	**Duration (mo):** 36 **Personnel:** School teachers. **Parental involvement:** Yes. **Secondary setting component:** No. **Length of follow-up (mo):** 36	**Primary outcomes:** BMI, prevalence of OW, and prevalence of O. **Secondary outcomes**: N/A. **Adverse outcomes**: Addressed.
Li et al, China, Shanghai, Chongqing, Shandong province, Heilongjiang province, Guangdong province, 2017, published.[55]	**Trial arms**: 2 **Schools:** 30 **Baseline participants**: 7717 **Mean age (y):** *I* = 9.00, *C* = 9.00 **Male (%):** *I* = 50.9, *C* = 50.6 **School grade:** 1st–5th **Other:** Nonboarding schools. **Method of randomization:** Random number table.	The intervention consisted of six 40-min lectures, and the Happy 10 programme involving 10-min PA sessions twice daily. The school food provision was evaluated and modified accordingly. Two lectures were also provided to parents who were sent bulletins on nutrition.	No intervention.	**Duration (mo):** 8 (1 academic year). **Personnel:** School teachers. **Parental involvement:** Yes. **Secondary setting component**: No. **Length of follow-up (mo):** 8	**Primary outcomes:** BMI, BMI z-score, %BF, WC prevalence of OW and O, prevalence of OW, and prevalence of O. **Secondary outcomes**: N/A. **Adverse outcomes**: Addressed.
Cao et al, China, Shanghai, 2015, published.[53]	**Trial arms:** 2 **Schools:** 14 **Baseline participants:** 2446 **Mean age (y):** *I* = 7.01, *C* = 6.81 **Male (%):** *I* = 54.8, *C* = 52.6 **School grade:** 1st **Other**: N/A. **Method of randomization:** Not specified.	The FIS intervention consisted of a 6-h health education course per semester, during which teachers advised students on eating less unhealthy food and reducing their eating speed. Modifications were made to the school food provision to reduce fat content and increase availability of fruit and vegetables. 1-h of daily PA occurred, and	Not stated.	**Duration (mo):** 36 **Personnel:** School teachers. **Parental involvement**: Yes. **Secondary setting component:** Yes (Family environment). **Length of follow-up (mo):** 72	**Primary outcomes:** BMI z-score, prevalence of OW, and prevalence of O. **Secondary outcomes:** N/A. **Adverse outcomes**: Not addressed.

TABLE 1 (Continued)

Combined Interventions					
Study Reference	**Study and Participant Characteristics**	**Description of Intervention**	**Description of Control**	**Intervention Summary**	**Outcomes Measured**
		participation was ensured in extracurricular activities. A parent-school meeting occurred every semester, and parents were provided information on healthy eating. Parents supervised an appropriate level of PA for their children at home.			
Liu et al, China, Beijing, 2019, published.[46]	**Trial arms:** 2 **Schools:** 12 **Baseline participants:** 1889 **Mean age (y):** *I* = 9.15, *C* = 9.06 **Male (%):** *I* = 53.0, *C* = 50.5 **School grade:** 3rd–5th **Other**: N/A. **Method of randomization:** Computer random number generator.	The intervention targeted school-level policies and implemented health education activities. Four 40-min health education lessons were delivered every 2 weeks. At least three 45-min physical education classes were provided each week of moderate to vigorous intensity. Students were encouraged to exercise at home and were provided with instruction manuals. The school lunches were evaluated and modified for improvement. As part of school policies, children were told not to drink sugar-sweetened beverages or eat unhealthy food in school.	Routine school health activities.	**Duration (mo):** 12 **Personnel:** School teachers. **Parental involvement:** No. **Secondary setting component**: No. **Length of follow-up (mo):** 12	**Primary outcomes:** BMI, BMI z-score, prevalence of OW, and prevalence of O. **Secondary outcomes:** Median number of days doing more than 1 h of MVPA per week, median number of days per week for consumption of vegetables, fruits and meat. **Adverse outcomes**: Addressed.
Habib-Mourad et al, Lebanon, Beirut, 2014, published.[75]	**Trial arms:** 2 **Schools:** 8 **Baseline participants:** 374 **Mean age (y):** *I* = 10.30, *C* = 10.10 **Male (%):** *I* = 57.0, *C* = 53.0 **School grade:** 4th and 5th **Other:** Private and public schools containing children of various socio-economic	The Health E-PALs programme consisted of twelve 45-min culturally appropriate sessions conducted once a week. Healthy food choices were provided in school food shops and lunch boxes brought by students were evaluated. Posters were hung around school	Routine school health activities.	**Duration (mo):** 3 **Personnel:** Researchers (nutritionist). **Parental involvement:** Yes. **Secondary setting component**: No. **Length of follow-up (mo):** 3.5	**Primary outcomes:** BMI, WC, prevalence of OW and O, and prevalence of O. **Secondary outcomes:** Proportion of children with the following dietary habits: breakfast intake, ≥3 snacks per day, eating in front of the TV, and eating out ≥3 times per week. Proportion

(Continues)

TABLE 1 (Continued)

Combined Interventions					
Study Reference	**Study and Participant Characteristics**	**Description of Intervention**	**Description of Control**	**Intervention Summary**	**Outcomes Measured**
	levels and of the following religious backgrounds: Muslim Shiite, Muslim Sunni and Christians. **Method of randomization:** Coin tossing.	encouraging healthy food choices. A parent meeting was held followed by a healthy breakfast as well as a health fair. Information packets, food samples and recipes were sent home.			of children consuming the following snacks between meals: chips, chocolates, soft drinks, sweetened drinks, fruits, sandwiches. Purchase of the following snacks from the school shop: chips, chocolates, soft drinks, sweetened drinks, manoushe (Lebanese pastry) and croissants. Proportion of children with the following PA habits: playing at recess, at least one after school PA per week, and playing at home after school. **Adverse outcomes:** Not addressed.
Bacardí-Gascón et al, Mexico, Tijuana, 2012, published.[65]	**Trial arms:** 2 **Schools:** 4 **Baseline participants:** 532 **Mean age (y):** *I* = 8.50, *C* = 8.40 **Male (%):** *I* = 52.0, *C* = 50.0 **School grade:** 2nd and 3rd **Other**: 2 private and 2 public schools in semi-rural areas. **Method of randomization:** Coin tossing.	The intervention consisted of eight weekly 30-min interactive lesson focusing on increasing fruit and vegetable consumption, reducing consumption of soda and unhealthy snacks, sports and activities, and reducing time spent watching the television. The classroom curriculum was modified to promote healthy eating behaviours and increase PA. Four monthly 60-min sessions were delivered to parents.	No intervention. After the study period, the control group received the intervention.	**Duration (mo):** 6 **Personnel:** Nutrition graduate students, nutrition and PA professionals. **Parental involvement**: Yes. **Secondary setting component**: No. **Length of follow-up (mo):** 6	**Primary outcomes:** BMI, BMI z-score, WC, prevalence of OW, and prevalence of O. **Secondary outcomes**: N/A. **Adverse outcomes**: Not addressed.
Safdie et al, Mexico, Mexico City, 2013, published.[62]	**Trial arms:** 3 (basic intervention; plus intervention; and control). **Schools:** 27 **Baseline participants:** 886 **Mean age (y):** Basic *I* = 9.70, Plus *I* = 9.70, *C* = 9.80	The nutrition programme involved modification of foods sold in the school with increased availability of healthy food and a reduced availability of energy-dense foods as well as	Routine school health activities.	**Duration (mo):** 18 (Two academic school years). **Personnel:** School teachers and specialized PE teachers. **Parental involvement**: No. **Secondary setting component**: No.	**Primary outcomes:** BMI, and prevalence of OW and O. **Secondary outcomes:** Food consumption (purchase) at school, and MVPA of children during PE and recess time.

TABLE 1 (Continued)

Combined Interventions					
Study Reference	**Study and Participant Characteristics**	**Description of Intervention**	**Description of Control**	**Intervention Summary**	**Outcomes Measured**
	Male (%): Basic *I* = 51.6, Plus I: 46.0, *C* = 51.4 **School grade:** 4th–5th **Other**: N/A. **Method of randomization:** Not specified.	sugar-sweetened beverages. The number of eating opportunities during the school day was also reduced. The PA intervention consisted of increased availability of sports equipment and promotion of PA during recess. The existing PE lesson (one 50-min lesson per week) was also improved. The PLUS intervention group received an additional physical education class each week and were offered 15–20 min of moderate PA four days a week.		**Length of follow-up (mo):** 18	**Adverse outcomes:** Not addressed.
Levy et al, Mexico, State of Mexico, 2012, published.[60]	**Trial arms:** 2 **Schools:** 60 **Baseline participants:** 1020 **Mean age (y):** N/A (>75% children were aged 10 in both the intervention and control group). **Male (%):** *I* = 48.4, *C* = 50.3 **School grade:** 5th **Other**: N/A. **Method of randomization:** Not specified.	The Nutrition on the Go programme involved 6 nutrition and PA workshops. Daily PA occurred prior the start of classes and a puppet theatre was performed was once a week by the 5th grade students to younger children. The school shop sold fruits, vegetables and water. Parents were provided with recipe calendars.	Not stated.	**Duration (mo):** 6 **Personnel:** School teachers. **Parental involvement**: Yes. **Secondary setting component**: No. **Length of follow-up (mo):** 6	**Primary outcomes:** BMI, prevalence of OW, and prevalence of O. **Secondary outcomes:** Dietary intake: energy, carbohydrates and lipids. Classification of students according to their PA levels: non active, moderately active and active. **Adverse outcomes:** Not addressed.
Alvirde-García et al, Mexico, State of Mexico, 2013, published.[71]	**Trial arms:** 2 **Schools:** 2 **Baseline participants:** 2682 **Mean age (y):** *I* = 9.00, *C* = 9.10 **Male (%):** *I* = 50.7, *C* = 47.4 **School grade:** 1st- 6th **Other**: Semi-rural populations. **Method of randomization:** Not specified.	The CATCH Programme consisted of education on health habits, PA sessions and modifications to the school food provision. The implementation of the intervention was supervised by the researchers.	No intervention.	**Duration (mo):** 36 **Personnel:** School teachers. **Parental involvement**: No. **Secondary setting component**: No. **Length of follow-up (mo):** 36	**Primary outcomes:** BMI, prevalence of at risk of O, and prevalence of O. **Secondary outcomes**: Daily calorie consumption and food portions per day of the following items: full-fat milk, semi-skinned milk, meat, bread, vegetables, fruit, fat and sugar. **Adverse outcomes**: Not addressed.

(Continues)

TABLE 1 (Continued)

Combined Interventions					
Study Reference	**Study and Participant Characteristics**	**Description of Intervention**	**Description of Control**	**Intervention Summary**	**Outcomes Measured**
Akdemir et al, Turkey, Antalya 2017, published.[70]	**Trial arms:** 2 **Schools:** 2 **Baseline participants:** 1360 **Mean age (y):** *I* = 10.36, *C* = 10.15 **Male (%):** *I* = 53.6, *C* = 51.9 **School grade:** 1st–8th **Other:** N/A. **Method of randomization:** Coin tossing and drawing of lots.	The intervention consisted of five 40-min education sessions that were provided at 1-month intervals. Fresh fruits were sold daily at the school restaurant and two additional BMI measurements were performed for participants. Two 1-h education sessions were provided to families who were also sent a healthy nutrition brochure.	Routine school health activities.	**Duration (mo):** 8 **Personnel:** Research team members. **Parental involvement**: Yes. **Secondary setting component**: No. **Length of follow-up (mo):** 8	**Primary outcomes:** BMI, prevalence of OW, prevalence of O, 'normal weight' status maintenance, and alteration from 'overweight/obese' to 'normal weight' status. **Secondary outcomes:** Dietary behaviours: daily no. of meals, regular daily breakfast, daily consumption of fresh fruits and vegetables, consumption of pastry, consumption of fried food, consumption of sweets or chocolate, and eating at a fast food restaurant. PA behaviours: playing computer games/TV watching, inactivity during PE lessons and walking exercise with family members. **Adverse outcomes:** Not addressed.
Diet-Only Interventions					
Study Reference	**Study and Participant Characteristics**	**Description of Intervention**	**Description of Control**	**Intervention Summary**	**Outcomes Measured**
Cunha et al, Brazil, Rio de Janeiro, 2013, published.[68]	**Trial arms:** 2 **Schools:** 20 **Baseline participants:** 574 **Mean age (y):** *I* = 11.20, *C* = 11.20 **Male (%):** *I* = 52.3, *C* = 51.4 **School grade:** 5th **Other:** Public schools in low socio-economic areas. **Method of randomization:** Not specified.	The PAPPAS intervention consisted of monthly 1-h classroom sessions and dissemination of positive messages relating to intake of water, fruits, rice and beans. Illustrated booklets and recipes were sent to families.	No intervention. At the end of the study, the control group received a 1-h session on general health and advice on healthy eating.	**Duration (mo):** 9 **Personnel:** Trained nutritionists. **Parental involvement**: Yes. **Secondary setting component**: No. **Length of follow-up (mo)**: 9	**Primary outcomes:** BMI, change in BMI, %BF, prevalence of OW, and prevalence of O. **Secondary outcomes:** Daily consumption of beans, fruit, cookies and sugar-sweetened beverages. **Adverse outcomes**: Not addressed.

TABLE 1 (Continued)

Diet-Only Interventions					
Study Reference	**Study and Participant Characteristics**	**Description of Intervention**	**Description of Control**	**Intervention Summary**	**Outcomes Measured**
Sichieri et al, Brazil, Rio de Janeiro, 2009, published.[77]	**Trial arms:** 2 **Schools:** 22 (47 classes). **Baseline participants:** 1134 **Mean age (y):** *I* = 10.90, *C* = 10.90 **Male (%):** *I* = 46.9, *C* = 47.4 **School grade:** 4th **Other**: Low socio-economic areas. **Method of randomization:** Stratified permuted block randomization.	The intervention consisted of ten 1-h education sessions and three 1-h musical activity sessions on drinking water and reducing sugar-sweetened beverage consumption. Children were provided with water bottles and school banners were hung to encourage water consumption. Parents were sent fliers and a fridge magnet to remind them to cut down on carbonated beverages.	Two 1-h sessions on general health and the control group received printed material on healthy eating.	**Duration (mo):** 7 **Personnel:** Research assistants, musicians and school teachers. **Parental involvement:** Yes. **Secondary setting** component: No. **Length of follow-up (mo)**: 7	**Primary outcomes:** BMI, prevalence of OW, and prevalence of O. **Secondary outcomes**: Daily consumption of carbonated beverages and juices. **Adverse outcomes:** Not addressed.
Li et al, China, Beijing, 2017, published.[55]	**Trial arms**: 3 (nutrition intervention; PA intervention; and control). **Schools:** 9 **Baseline participants**: 2150 **Mean age (y):** Nutrition *I* = 9.20, PA *I* = 9.20, *C* = 9.30 **Male (%):** Nutrition *I* = 52.7, PA *I* = 54.5, *C* = 59.1 **School grade:** 1st–5th **Other:** Non-boarding schools. **Method of randomization:** Random number table.	The nutrition education intervention consisted of six 40-min lectures. The school food provision was evaluated and modified accordingly. Two lectures were also provided to parents who were sent bulletins on nutrition.	No intervention.	**Duration (mo):** 8 (1 academic year). **Personnel:** School teachers. **Parental involvement:** Yes. **Secondary setting component**: No. **Length of follow-up (mo):** 8	**Primary outcomes:** BMI, BMI z-score, %BF, WC, prevalence of OW and O, prevalence of OW, and prevalence of O. **Secondary outcomes**: N/A. **Adverse outcomes**: Addressed.
Keshani et al, Iran, Shiraz, 2016, published.[72]	**Trial arms:** 2 **Schools**: 8 **Baseline participants:** 221 **Mean age (y):** N/A (age range of 9.50–10.50). **Male (%):** *I* = 49.4, *C* = 47.7 **School grade**: 4th **Other:** N/A. **Method of randomization:** Not specified.	The intervention consisted of six 2-h education sessions consisting of games, lectures, animation videos etc. The school lunch was evaluated and modified for improvements. Dietary posters were hung on classroom walls. Four 2-h education sessions were provided to mothers. Pamphlets and booklets on	Routine school health activities.	**Duration (mo):** 12 **Personnel:** Not stated. **Parental Involvement:** Yes. **Secondary setting component:** No. **Length of follow-up (mo):** 12	**Primary outcomes**: BMI, WC, prevalence of OW, and prevalence of O. **Secondary outcomes:** Nutritional knowledge score, food intake: fast food, sweets, plain sugar, dairy products, fruits and vegetables. **Adverse outcomes**: Addressed.

(Continues)

TABLE 1 (Continued)

Diet-Only Interventions					
Study Reference	**Study and Participant Characteristics**	**Description of Intervention**	**Description of Control**	**Intervention Summary**	**Outcomes Measured**
		healthy eating were prepared for parents who were also sent nutritional text messages.			
Physical Activity-Only Interventions					
Study Reference	**Study and Participant Characteristics**	**Description of Intervention**	**Description of Control**	**Intervention Summary**	**Outcomes Measured**
Li et al, China, Beijing, 2010, published.[45]	**Trial arms:** 2 **Schools:** 20 **Baseline participants**: 4700 **Mean age (y):** *I* = 9.30, *C* = 9.30 **Male (%):** *I* = 54.3, *C* = 50.4 **School grade:** 3rd and 4th **Other**: N/A. **Method of randomization:** Not specified.	The Happy 10 Programme consisted of two daily 10-min PA sessions of moderate to vigorous intensity conducted during classroom breaks. The programme was incorporated into the curriculum and did not replace any regular activities.	No intervention.	**Duration (mo):** 12 **Personnel:** School teachers. **Parental involvement**: No. **Secondary setting component:** No. **Length of follow-up (mo):** 24	**Primary outcomes:** change in BMI, change in BMI z-score, and change in %BF. **Secondary outcomes**: N/A. **Adverse outcomes**: Addressed.
Li et al, China, Beijing, 2017, published.[55]	**Trial arms**: 3 (nutrition intervention; PA intervention; and control). **Schools:** 9 **Baseline participants**: 2150 **Mean age (y):** Nutrition *I* = 9.20, PA *I* = 9.20, *C* = 9.30 **Male (%):** Nutrition *I* = 52.7, PA *I* = 54.5, *C* = 59.1 **School grade:** 1st- 5th **Other:** Nonboarding schools. **Method of randomization:** Random number table.	The PA intervention (Happy 10 programme) involved 10-min sessions of moderate exercises twice daily.	No intervention.	**Duration (mo):** 8 (1 academic year). **Personnel:** School teachers. **Parental involvement:** Yes. **Secondary setting component**: No. **Length of follow-up (mo):** 8	**Primary outcomes:** BMI, BMI z-score, %BF, WC, prevalence of OW and O, prevalence of OW, and prevalence of O. **Secondary outcomes**: N/A. **Adverse outcomes**: Addressed.
Wang et al, China, Nanjing, 2018, published.[58]	**Trial arms:** 2 **Schools:** 48 **Baseline participants:** 10091 **Mean age (y):** *I* = 10.50, *C* = 10.50 **Male (%):** *I* = 53.2, *C* = 52.8 **School grade:** 4th and 7th	The intervention consisted of monthly 45-min sessions for each classroom curriculum. Posters and slogans were hung around the school to encourage PA. Three special 1-week activities took place with the assistance of families	Routine school health activities.	**Duration (mo):** 12 **Personnel:** School teachers. **Parental involvement:** Yes. **Secondary setting component:** Yes (Family environment). **Length of follow-up (mo):** 12	**Primary outcomes:** BMI, BMI z-score, prevalence of O or OW, and prevalence of O. **Secondary outcomes:** Mean value of MVPA time per week. **Adverse outcomes**: Addressed.

TABLE 1 (Continued)

Physical Activity-Only Interventions					
Study Reference	**Study and Participant Characteristics**	**Description of Intervention**	**Description of Control**	**Intervention Summary**	**Outcomes Measured**
	Other: 32 primary and 16 junior schools. **Method of randomization:** Computer random number generator.	e.g. helping parents do physical housework at home for a week. Fun events and programmes were organized throughout the school-year such as team competitions and composition writing focused on obesity. One health class was provided to parents in each semester.			
Mo-suwan et al, Thailand, Songkhla province, 1998, published.[67]	**Trial arms:** 2 **Schools:** 2 **Baseline participants:** 310 **Mean age (y):** *I* = 4.50, *C* = 4.50 **Male (%):** *I* = 55.8, *C* = 60.7 **School grade:** 2nd **Other:** Private kindergartens. **Method of randomization:** Not specified.	The intervention consisted of a 15-min walk before the morning class and a 20-min aerobic dance session in the afternoon. These activities occurred three times a week and did not interfere with routine school activities.	Routine school health activities.	**Duration (mo):** 7.5 **Personnel:** Research team members. **Parental involvement**: No. **Secondary setting component**: No. **Length of follow-up (mo):** 7.5	**Primary outcomes**: BMI, triceps skinfold thickness, the ratio of weight in kilograms divided by height cubed in metres, and prevalence of O. **Secondary outcomes:** N/A. **Adverse outcomes:** Not addressed.

Abbreviations: WC, waist circumference; %BF, body fat percentage; O, obesity; OW, overweight.

rest of the field.[47,58] Confidence in the results from these trials is higher than those which have likely sources of bias.

3.4 | Effectiveness of interventions

Table 2 summarizes the findings of individual studies and is categorized according to adiposity-related, dietary and PA behaviour outcomes. Outcomes have only been included where a statistical comparison between the intervention and control group has been provided.

3.4.1 | Adiposity outcomes

Fifteen of the 21 studies reported significant intervention effects on at least one adiposity-related outcome.[44–47,53,55,58,60,65,68,70,71,73,77] Ten of the 14 combined intervention studies and 12 of the 16 intervention studies with parental involvement reported a significant intervention effect on at least one adiposity-related outcome. Of the 13 studies with an intervention duration of at least 8 months (one academic school year), 11 reported a significant intervention effect on at least one adiposity-related outcome. A summary of the results grouped by intervention characteristics is shown in Table 3.

3.4.2 | Body mass index

Seven of the 19 studies with BMI as an outcome reported a significant effect in favour of the intervention group.[44,45,55,58,65,71,73] Five of the seven studies reporting positive effects evaluated combined diet and PA interventions. Other characteristics of the seven studies reporting significant intervention effects on BMI included the following: parental involvement (n = 5), delivery by school teachers (n = 5), education sessions (n = 5) and an intervention duration of at least 12 months (n = 4). Two of the 19 studies reported a statistically significant effect in favour of the control; both of these studies evaluated diet-only interventions that were delivered by health professionals or unspecified personnel.[68,72] Eight studies did not observe significant effects on BMI.[46,50,55,60,67,70,75,77] The remaining two studies did not statistically compare outcomes across study groups.[62,69]

Six of the 19 studies, with a total of 15 754 participants, reported data in the appropriate format to be pooled in a meta-analysis, shown in Figure 3.[44,46,58,67,75,77] Participants in the intervention group had a marginally lower BMI compared with the control group; however, this difference was not statistically significant (mean difference = −0.23; 95% CI, −0.82 to 0.35; p = 0.43). Very high levels of heterogeneity were observed among the studies (I^2 = 98%; p < 0.00001).

3.4.3 | BMI z-score

Five of the nine studies which included the outcome of BMI z-score reported a significant decrease in this outcome in the intervention group compared with the control group.[45,47,55,58,73] Three of the five studies reporting positive effects evaluated combined diet and PA interventions. Other characteristics of the five studies reporting significant intervention effects included the following: parental involvement (n = 4), delivery by school teachers (n = 4), intervention duration of at least 12 months (n = 3) and daily PA sessions (n = 3). All four studies with parental involvement provided at least two health education sessions for parents. Two studies did not report significant effects on BMI z-score.[46,55] The remaining two studies did not statistically compare outcomes across study groups.[53,65]

3.4.4 | Body fat percentage

Only two of the seven studies reporting body fat percentage found a significant intervention effect.[45,55] One of the two studies reporting positive effects evaluated a combined diet and PA intervention. Both studies comprised the 'Happy 10' programme, consisting of 20-min daily PA sessions that were delivered by school teachers in the classroom for a duration of at least 8 months. Four studies did not observe significant effects on body fat percentage.[47,55,68,73] Characteristics of these studies included an intervention duration of less than 12 months (n = 3) and delivery by researchers or health professionals (n = 3). The remaining study did not statistically compare outcomes across study groups.[69]

3.4.5 | Waist circumference

Three of six studies assessing waist circumference reported significant effects in favour of the intervention, of which two evaluated combined diet and PA interventions.[55,73] Other characteristics of the three studies reporting significant intervention effects included the following: parental involvement (n = 3), delivery by school teachers (n = 3), intervention duration of at least 8 months (n = 2) and daily PA sessions (n = 2). All three studies provided at least two health education sessions for parents and involved modifications to the existing school food provision. The remaining three studies did not report significant effects on waist circumference.[47,72,75]

3.4.6 | Prevalence of obesity

Four of 14 studies assessing obesity prevalence reported significant intervention effects, of which three evaluated combined diet and PA interventions.[44,53,58,73] Other characteristics of these studies included the following: parental involvement (n = 4), delivery by school teachers (n = 4), intervention duration of at least 12 months (n = 3) and education sessions (n = 3). Six studies did not report significant effects on prevalence of obesity.[46,55,60,72,77] The characteristics of these studies were similar to those with significant intervention effects: delivery by school teachers (n = 4), combined diet and PA intervention (n = 3) and an intervention duration of at least 12 months

(n = 2). The remaining four studies did not statistically compare outcomes across study groups.[65,67–69]

Nine of the 14 studies, with a total of 19 762 participants, reported data in the appropriate format to be pooled in a meta-analysis, shown in Figure 4.[44,46,58,60,67–69,73,77] There was a significantly lower prevalence of obesity in the intervention group compared with the control group (odds ratio = 0.77; 95% CI, 0.63 to 0.94; p = 0.009). However, substantial heterogeneity was detected among the studies (I^2 = 78%; p < 0.0001).

3.4.7 | Prevalence of overweight

Only two of the 11 studies with data on prevalence of overweight reported significant intervention effects.[44,73] Both of these studies evaluated combined diet and PA interventions, delivered over a duration of at least 6 months and provided at least two education sessions for parents. Five studies did not report significant effects on prevalence of overweight.[55,60,72,77] The characteristics of the studies reporting nonsignificant effects were similar to those with significant intervention effects: intervention duration of at least 6 months (n = 5), parental involvement (n = 5), delivery by school teachers (n = 3) and a combined diet and PA intervention (n = 2). The remaining four studies did not statistically compare outcomes across study groups.[53,65,68,69]

Six of the 11 studies, involving a total of 7723 participants, reported data in the appropriate format to be pooled into a meta-analysis, shown in Figure 5.[44,60,68,69,73,77] Although there was a lower prevalence of overweight in the intervention group compared with the control group, the difference was not significant (odds ratio = 0.89; 95% CI, 0.74 to 1.09; p = 0.26). Substantial levels of heterogeneity were observed for this comparison (I^2 = 65%; p = 0.01).

3.4.8 | Dietary outcomes

Thirteen studies assessed outcomes relating to dietary behaviour, of which nine found significant intervention effects on at least one outcome.[46,50,62,68,70–72,75,77] Six of these nine studies evaluated combined diet and PA interventions, whereas the remaining three studies comprised diet-only interventions. Other characteristics of the nine studies reporting significant intervention effects for dietary-related outcomes included the following: an intervention duration of at least 8 months (n = 8), parental involvement (n = 7) and delivery by researchers or health professionals (n = 5). Five of the interventions resulting in positive dietary changes provided printed materials to families, for example, recipes and booklets on healthy eating. Others focused on the school setting itself by modifying the available food choices (n = 7) and displaying posters to encourage healthy food choices (n = 4). One recent Chinese study evaluating a combined dietary and PA intervention, included a school policy restricting the consumption of sugar-sweetened beverages and unhealthy foods.[46] This study reported effects on dietary outcomes. Six of the nine studies that reported positive effects on dietary behaviour also reported significant intervention effects on at least one adiposity-related outcome.[46,47,68,70,71,77] One study did not report significant intervention effects on dietary outcomes.[69] The remaining three studies did not statistically compare outcomes across study groups.[60,62,73]

3.4.9 | Physical activity outcomes

Ten of the included studies reported outcomes relating to PA behaviour, of which six found significant intervention effects on at least one outcome.[46,50,58,69,70,75] Five of the six studies reporting positive effects evaluated combined diet and PA interventions, whereas the remaining study evaluated a PA-only intervention. Other characteristics of these six studies included the following: parental involvement (n = 5), delivery by school teachers (n = 4), an intervention duration of at least 8 months (n = 4) and additional PA sessions (n = 1). Two Chinese intervention studies found to have positive effects on PA-related outcomes incorporated special events, with the assistance of families, involving activities in the home setting to reduce sedentary behaviour.[50,58] Three of the six studies that reported positive effects on PA behaviour also reported significant intervention effects on at least one adiposity-related outcome.[46,58,70] One study did not report significant intervention effects on physical activity outcomes.[47] The remaining three studies did not statistically compare outcomes across study groups.[60,62,73]

Table 3 summarizes intervention characteristics of the included studies and the reported effects on dietary, PA and adiposity-related outcomes. This table was also used as a visual aid to help identify the intervention components with greater treatment benefits and to explore the heterogeneity in the forest plots. No clear patterns were identified to suggest that relative to one another diet, PA or combined interventions had a greater effect.

3.4.10 | Quality of life outcomes

The 'Chirpy Dragon' trial (Li et al[47]) was the sole study to report on quality of life, for which a significant intervention effect was found (mean difference in CHU9D utility score = 0.008; 95% CI, 0.000 to 0.015; p = 0.034).

4 | DISCUSSION

4.1 | Summary of findings

This systematic review explored the effectiveness of school-based interventions to prevent obesity among children aged 4 to 12 years in MICs. In total, 21 cluster RCTs from Brazil, China, Iran, Lebanon, Mexico, Thailand and Turkey, published from 1998 onwards, met the inclusion criteria. Fifteen studies, conducted in China (n = 8), Brazil (n = 3), Mexico (n = 3) and Turkey (n = 1), reported significant intervention effects on at least one adiposity-related

TABLE 2 Results of individual studies grouped according to adiposity-related, dietary behaviour or physical activity outcomes

Study Reference	Study Details	Adiposity-Related Outcomes	Dietary Behaviour Outcomes	Physical Activity Behaviour Outcomes
[a] DB Cunha et al, Brazil, 2013, published.[68]	**Intervention:** Diet. **Total no. of clusters analysed**: 20 schools. **Total no. of participants analysed:** 559	**Change in BMI:** Mean difference = 0.006; $p = 0.02$ *(increase in the intervention group).*	**Change in daily bean consumption:** Mean difference = −0.01; $p = 0.54$. **Change in daily fruit consumption:** Mean difference = −0.16; $p = 0.04$ *(increase in the intervention group).* **Change in daily cookies consumption:** Mean difference = 0.13; $p < 0.001$ *(decrease in the intervention group).* **Change in daily soda consumption:** Mean difference = 0.13; $p = 0.02$ *(decrease in the intervention group).* **Change in daily juice consumption:** Mean difference = 0.03; $p = 0.66$.	
[a] Sgambato et al, Brazil, protocol (2016), unpublished.[69]	**Intervention:** Diet and PA. **Total no. of clusters analysed**: 18 schools. **Total no. of participants analysed:** 2276		**Daily intake of milk at follow-up:** Mean difference = −0.009 ± 0.53; $p > 0.05$. **Daily intake of beans at follow-up:** Mean difference = −0.025 ± 0.02; $p > 0.05$. **Daily intake of water at follow-up:** Mean difference = −0.018 ± 0.02; $p > 0.05$. **Daily intake of fruits at follow-up:** Mean difference = 0.016 ± 0.02; $p > 0.05$. **Daily intake of vegetables at follow-up:** Mean difference = 0.006 ± 0.01; $p > 0.05$. **Daily intake of soda at follow-up:** Mean difference = −0.025 ± 0.02; $p > 0.05$. **Daily intake of processed meat at follow-up:** Mean difference = −0.011 ± 0.01; $p > 0.05$. **Daily intake of fruit-based drinks at follow-up**: Mean difference = 0.023 ± 0.02; $p > 0.05$.	**Duration of PA at follow-up:** Mean difference = 12.50 ± 6.17; $p < 0.05$ *(increase in the intervention group).*
[a] Friedrich et al, Brazil, 2015, published.[73]	**Intervention:** Diet and PA. **Total no. of clusters analysed**: Not stated. **Total no. of participants analysed:** 539 (estimate).	**BMI at follow-up:** Standardized mean difference = −0.18; 95% CI, −0.27 to −0.08; $p = 0.002$ *(decrease in the intervention group).* **BMI z-score at follow-up:** Standardized mean difference = −0.19; 95% CI, −0.29 to −0.09; $p = 0.002$ *(decrease in the intervention group).*		

TABLE 2 (Continued)

Study Reference	Study Details	Adiposity-Related Outcomes	Dietary Behaviour Outcomes	Physical Activity Behaviour Outcomes
		%BF at follow-up: Standardized mean difference = −0.07; 95% CI, −0.28 to 0.14; $p = 0.47$. **WC at follow-up:** Standardized mean difference = −0.07; 95% CI, −0.13 to 0.02; $p = 0.06$. **Prevalence of OW at follow-up:** Odds ratio = 0.77; 95% CI, 0.61 to 0.97; $p = 0.02$ *(decrease in the intervention group).* **Prevalence of O at follow-up:** Odds ratio (intervention: control) = 0.54; 95% CI, 0.44 to 0.67; $p < 0.001$ *(decrease in the intervention group).* **Remission of OW:** Odds ratio (intervention: control) = 3.57; 95% CI, 1.39 to 9.09; $p = 0.008$ *(increase in the intervention group).* **Remission of O:** Odds ratio (intervention: control) = 7.69; 95% CI, 3.94 to 14.28; $p < 0.001$ *(increase in the intervention group).* **Incidence of OW:** Odds ratio (intervention: control) = 0.57; 95% CI, 0.20 to 1.61; $p = 0.29$. **Incidence of O:** Odds ratio (intervention: control) = 0.18; 95% CI, 0.18 to 4.28; $p = 0.88$.		
[a] Sichieri et al, Brazil, 2009, published.[77]	**Intervention:** Diet. **Total no. of clusters analysed**: 47 classes (22 schools). **Total no. of participants analysed:** 927	**Change in BMI:** Mean difference = −0.003; $p = 0.33$. **Change in BMI among girls with overweight at baseline:** Mean difference = −0.01; $p = 0.009$ *(decrease in the intervention group).*	**Change in daily consumption of carbonated beverages:** Mean difference = −56.0; 95% CI, −119.0 to −7.0 *(decrease in the intervention group).*	
[a] Li et al, China, protocol (2017), unpublished.[47]	**Intervention:** Diet and PA. **Total no. of clusters analysed**: 40 classes (40 schools). **Total no. of participants analysed:** 1562	**BMI z-score at follow-up:** Mean difference = −0.13; 95% CI, −0.26 to 0.00; $p = 0.048$ *(decrease in the intervention group).* **%BF at follow-up:** Mean difference = −0.01; 95% CI, −0.03 to 0.01; $p = 0.171$. **WC at follow-up:** Mean difference = −0.37; 95% CI, −0.85 to 0.11; $p = 0.128$.	**Proportion of children who eat ≥5 portions of fruit and vegetables per day at follow-up:** Odds ratio (intervention: control) = 2.00; 95% CI, 1.45 to 2.76; $p < 0.001$ *(increase in the intervention group).* **Daily intake of fruit and vegetables at follow-up:** Mean difference = 0.33; 95% CI, 0.14 to 0.52; $p = 0.001$ *(increase in the intervention group).*	**Objectively measured daily MVPA at follow-up:** Mean difference = 3.24; 95% CI, −3.46 to 9.94; $p = 0.343$. **Parent reported daily MVPA at follow-up:** Mean difference = 1.20; 95% CI, −9.44 to 11.85; $p = 0.825$. **Objectively measured proportion of children achieving ≥60 min of MVPA in 24 h at follow-up:** Odds

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TABLE 2 (Continued)

Study Reference	Study Details	Adiposity-Related Outcomes	Dietary Behaviour Outcomes	Physical Activity Behaviour Outcomes
		Prevalence of O or OW at follow-up: Odds ratio = 0.53; 95% CI, 0.27 to 1.05; $p = 0.067$.	**Weekly average servings of unhealthy snacks and sugar-sweetened beverages at follow-up:** Mean difference = −0.81; 95% CI, −1.42 to −0.20; $p = 0.010$ *(decrease in the intervention group).*	ratio = 1.16; 95% CI, 0.69 to 1.95; $p = 0.564$. **Parent reported proportion of children achieving ≥60 min of MVPA in 24 h at follow-up:** Odds ratio = 0.97; 95% CI, 0.64 to 1.46; $p = 0.883$.
[a] Xu et al, China, 2015, published.[50]	**Intervention:** Diet and PA. **Total no. of clusters analysed**: 8 schools. **Total no. of participants analysed:** 1108	**Change in BMI:** Mean difference = 0.14; 95% CI, −0.24 to 0.53; $p = 0.43$.	**Reduced consumption frequency of red meat at follow-up:** Odds ratio (intervention: control) = 1.50; 95% CI, 1.15 to 1.95 *(increase in the intervention group).* **Reduced consumption frequency of fried snacks at follow-up:** Odds ratio (intervention: control) = 1.08; 95% CI, 0.81 to 1.44 *(increase in the intervention group).* **Reduced consumption frequency of soft drinks at follow-up:** Odds ratio (intervention: control) = 0.89; 95% CI, 0.67 to 1.19. **Increased consumption frequency of vegetables at follow-up:** Odds ratio (intervention: control) = 1.20; 95% CI, 0.92 to 1.55.	**Increase in participating frequency of jogging or running at follow-up:** Odds ratio (intervention: control) = 1.55; 95% CI, 1.18 to 2.02 *(increase in the intervention group).* **Increase in participating frequency of walking at follow-up:** Odds ratio (intervention: control) = 0.98; 95% CI, 0.74 to 1.25. **Increase in participating frequency of ball playing at follow-up:** Odds ratio (intervention: control) = 1.21; 95% CI, 0.93 to 1.58. **Reduced screen time at follow-up:** Odds ratio (intervention: control) = 1.41; 95% CI, 1.09 to 1.84 *(increase in the intervention group).*
[a] Jiang et al, China, 2006, published.[44]	**Intervention:** Diet and PA. **Total no. of clusters analysed**: 5 schools. **Total no. of participants analysed:** 2425	**Prevalence of OW at follow-up:** Odds ratio (intervention: control) = 0.614; 95% CI 0.465 to 0.788; $p = 0.001$ *(decrease in the intervention group).* **Prevalence of OW among girls at follow-up**: Odds ratio (intervention: control) = 0.670; 95% CI, 0.461 to 1.068; $p = 0.085$. **Prevalence of OW among boys at follow-up:** Odds ratio (intervention: control) = 0.564; 95% CI, 0.391 to 0.756; $p = 0.001$ *(decrease in the intervention group).* **Prevalence of O at follow-up:** Odds ratio (intervention: control) = 0.556; 95% CI, 0.413 to 0.738; $p = 0.001$ *(decrease in the intervention group).* **Prevalence of O among girls at follow-up**: Odds ratio (intervention: control) = 0.568; 95% CI, 0.389 to		

TABLE 2 (Continued)

Study Reference	Study Details	Adiposity-Related Outcomes	Dietary Behaviour Outcomes	Physical Activity Behaviour Outcomes
		0.901; $p = 0.036$ *(decrease in the intervention group).* **Prevalence of O among boys at follow-up:** Odds ratio (intervention: control) = 0.502; 95% CI, 0.383 to 0.785; $p = 0.001$ *(decrease in the intervention group).* **Incidence of O:** Odds ratio (intervention: control) = 0.338; 95% CI, 0.214 to 0.538; $p = 0.002$ *(decrease in the intervention group).* **Remission of O:** Odds ratio (intervention: control) = 1.668; 95% CI, 1.030 to 2.610; $p = 0.001$ *(increase in the intervention group).*		
[c] Li et al, China, 2010, published.[45]	**Intervention:** PA. **Total no. of clusters analysed**: 132 classes (20 schools). **Total no. of participants analysed:** 4120	**Change in BMI:** Year 1 mean difference = −0.15; 95% CI, −0.28 to −0.02; $p = 0.03$ *(decrease in the intervention group).* Year 2 mean difference = −0.13; 95% CI, −0.25 to −0.01; $p = 0.04$ *(decrease in the intervention group).* **Change in BMI z-score:** Year 1 mean difference = −0.07; 95% CI, −0.13 to −0.01; $p = 0.03$ *(decrease in the intervention group).* Year 2 mean difference = −0.05; 95% CI, −0.10 to −0.01; $p = 0.03$ *(decrease in the intervention group).* **Change in %BF:** Year 1 mean difference = −0.22; 95% CI, −0.70 to 0.24; $p = 0.34$. Year 2 mean difference = −0.53; 95% CI, −1.00 to −0.05; $p = 0.03$ *(decrease in the intervention group).* **Change in fat mass:** Year 1 mean difference = −0.15; 95% CI, −0.37 to 0.07; $p = 0.18$. Year 2 mean difference = −0.27; 95% CI, −0.53 to −0.02; $p = 0.03$ *(decrease in the intervention group).* **Change in fat free mass:** Year 1 mean difference = −0.18; 95% CI, −0.41 to 0.05; $p = 0.12$. Year 2 mean		

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TABLE 2 (Continued)

Study Reference	Study Details	Adiposity-Related Outcomes	Dietary Behaviour Outcomes	Physical Activity Behaviour Outcomes
		difference = −0.03; 95% CI, −0.30 to 0.24; $p = 0.82$.		
[c] Li et al, China, 2017, published.[55]	**Intervention:** Diet and PA. **Total no. of clusters analysed**: 30 schools. **Total no. of participants analysed:** 6874	**BMI at follow-up:** Mean difference = −0.3 kg m^2; 95% CI, −0.4 to −0.2; $p < 0.001$ *(decrease in the intervention group).* **BMI z-score at follow-up:** Mean difference = −0.15; 95% CI, −0.18 to −0.11; $p < 0.001$ *(decrease in the intervention group).* **%BF at follow-up:** Mean difference = −0.8; 95% CI, −0.9 to −0.6; $p < 0.001$ *(decrease in the intervention group).* **WC at follow-up:** Mean difference = −0.5; 95% CI, −0.6 to −0.3; $p < 0.001$ *(decrease in the intervention group).* **Prevalence of OW and O at follow-up:** Odds ratio (intervention: control) = 0.9; 95% CI, 0.7 to 1.0; $p = 0.061$. **Prevalence of OW at follow-up:** Odds ratio (intervention: control) = 0.9; 95% CI, 0.8 to 1.1; $p = 0.198$. **Prevalence of O at follow-up:** Odds ratio (intervention: control) = 1.0; 95% CI, 0.9 to 1.1; $p = 0.972$.		
[c] Li et al, China, 2017, published.[55]	**Intervention:** Diet or PA. **Total no. of clusters analysed**: 8 schools. **Total no. of participants analysed:** 1699	**BMI at follow-up:** *Nutrition intervention group:* Mean difference = 0.00, 95% CI, −0.26 to 0.26; $p = 0.990$. *PA intervention group:* Mean difference = 0.07; 95% CI, −0.19 to 0.34; $p = 0.584$. **BMI z-score at follow-up:** *Nutrition intervention group*: Mean difference = −0.02, 95% CI, −0.13 to 0.08. *PA intervention group:* Mean difference = 0.05; 95% CI, −0.06 to 0.16; $p = 0.337$. **%BF at follow-up:** *Nutrition intervention group:* Mean difference = 0.56; 95% CI, 0.09 to		

TABLE 2 (Continued)

Study Reference	Study Details	Adiposity-Related Outcomes	Dietary Behaviour Outcomes	Physical Activity Behaviour Outcomes
		1.04; $p = 0.019$ *(increase in the intervention group).* *PA intervention group:* Mean difference = −0.26; 95% CI, −0.71 to 0.20; $p = 0.269$. **WC at follow-up:** *Nutrition intervention group:* Mean difference = −0.40; 95% CI, −0.77 to −0.02; $p = 0.036$ *(decrease in the intervention group).* *PA intervention group:* Mean difference = −0.20, 95% CI, −0.60 to 0.21; $p = 0.337$. **Prevalence of OW and O at follow-up:** *Nutrition intervention group:* Odds ratio (intervention: control) = 0.93; 95% CI, 0.57 to 1.51; $p = 0.572$. *PA intervention group:* Odds ratio (intervention: control) = 0.89; 95% CI, 0.54 to 1.47; $p = 0.637$. **Prevalence of OW at follow-up:** *Nutrition intervention group:* Odds ratio (intervention: control) = 0.59; 95% CI, 0.26 to 1.36; $p = 0.413$. *PA intervention group:* Odds ratio (intervention: control) = 0.89; 95% CI, 0.54 to 1.47; $p = 0.517$. **Prevalence of O at follow-up:** *Nutrition intervention group:* Odds ratio (intervention: control) = 1.57; 95% CI, 0.74 to 3.31; $p = 0.151$. *PA intervention group:* Odds ratio (intervention: control) = 0.86; 95% CI, 0.45 to 1.65; $p = 0.774$.		
[c] Cao et al, China, 2015, published.[53]	**Intervention**: Diet and PA. **Total no. of clusters analysed**: 14 schools. **Total no. of participants analysed:** 1813	**BMI z-score at follow-up (normal weight at baseline):** Regression coefficient = 0.002; 95% CI, −0.007 to 0.011; $p = 0.638$. **BMI z-score at follow-up (OW at baseline):** Regression coefficient = −0.030; 95% CI, −0.049 to −0.011; $p = 0.002$ *(decrease in the intervention group).*		

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TABLE 2 (Continued)

Study Reference	Study Details	Adiposity-Related Outcomes	Dietary Behaviour Outcomes	Physical Activity Behaviour Outcomes
		BMI z-score at follow-up (O at baseline): Regression coefficient = −0.046; 95% CI, −0.072 to −0.021; $p < 0.001$ *(decrease in the intervention group).* **Prevalence of O at follow-up:** Odds ratio (intervention: control) = 0.583; 95% CI, 0.428 to 0.794; $p = 0.001$ *(decrease in the intervention group).* **Prevalence of O among girls at follow-up:** Odds ratio at 3 years (intervention: control) = 0.299; 95% CI, 0.120 to 0.749; $p = 0.01$ *(decrease in the intervention group).* **Prevalence of O among boys at follow-up:** Odds ratio at 3 years (intervention: control) = 0.972; 95% CI, 0.605 to 1.562; $p = 0.906$. **Prevalence of O or OW at follow-up:** Odds ratio (intervention: control) = 0.625; 95% CI, 0.493 to 0.793; $p < 0.001$ *(decrease in the intervention group).* **Prevalence of O or OW among girls at follow-up:** Odds ratio at 3 years (intervention: control) = 0.493; 95% CI, 0.283 to 0.860; $p = 0.013$ *(decrease in the intervention group).* **Prevalence of O or OW among boys at follow-up:** Odds ratio at 3 years (intervention: control) = 1.019; 95% CI, 0.687 to 1.512; $p = 0.926$.		
[a] Liu et al, China, 2019, published.[46]	**Intervention**: Diet and PA. **Total no. of clusters analysed**: 12 schools. **Total no. of participants analysed:** 1889	**BMI at follow-up:** Mean difference at 6 months = 0.06; 95% CI, −0.29 to 0.18; $p = 0.64$. Mean difference at 12 months = 0.07; 95% CI, −0.16 to 0.31; $p = 0.54$. **BMI z-score at follow-up:** Mean difference at 6 months = −0.02; 95% CI, −0.11 to 0.08; $p = 0.72$. Mean difference at 12 months = −0.02; 95% CI, −0.08 to 0.11; $p = 0.73$. **Prevalence of OW and O at follow-up:** Odds ratio at 6 months (intervention: control) = 1.16; 95% CI, 0.70 to 1.92;	**Proportion of children consuming at least 1 portion of vegetables per day at follow-up:** Odds ratio (intervention: control) = 1.04; 95% CI, 0.79 to 1.37; $p = 0.77$. **Proportion of children consuming at least 1 portion of fruit per day at follow-up:** Odds ratio (intervention: control) = 1.19; 95% CI, 0.93 to 1.51; $p = 0.16$. **Proportion of children consuming at least 1 portion of meat per day at follow-up:** Odds ratio (intervention:	**No. of days doing more than 1 h of MVPA per week at follow-up:** Mean difference = 1.37; 95% CI, 1.49 to 1.60; $p < 0.0001$ *(increase in the intervention group).*

TABLE 2 (Continued)

Study Reference	Study Details	Adiposity-Related Outcomes	Dietary Behaviour Outcomes	Physical Activity Behaviour Outcomes
		p = 0.58. Odds ratio at 12 months (intervention: control) = 0.95; 95% CI, 0.57 to 1.58; p = 0.85. **Prevalence of O at follow-up:** Odds ratio at 6 months (intervention: control) = 0.50; 95% CI, 0.26 to 0.96; p = 0.04 *(decrease in the intervention group)*. Odds ratio at 12 months = 0.81; 95% CI, 0.42 to 1.55; p = 0.52.	control) = 0.75; 95% CI, 0.52 to 1.09; p = 0.14. **Proportion of children consuming sugar-sweetened beverage per day at follow-up:** Odds ratio (intervention: control) = 0.56; 95% CI, 0.42 to 0.74; p < 0.0001 *(decrease in the intervention group)*.	
[a] Wang et al, China, 2018, published.[58]	**Intervention:** PA. **Total no. of clusters analysed**: 48 schools. **Total no. of participants analysed:** 9858	**BMI at follow-up:** Mean difference = −0.3; 95% CI, −0.5 to −0.1; p = 0.01 *(decrease in the intervention group)*. **BMI z-score at follow-up:** Mean difference = −0.1; 95% CI, −0.20 to −0.03 *(decrease in the intervention group)*. **BMI z-score at follow-up (non-OW at baseline and remained non-OW):** Mean difference = −0.08; 95% CI, −0.15 to −0.01; p = 0.02 *(decrease in the intervention group)*. **BMI z-score at follow-up (non-OW at baseline and became OW or O):** Mean difference = −0.26; 95% CI, −0.50 to −0.01; p = 0.04 *(decrease in the intervention group)*. **BMI z-score at follow-up (OW or O at baseline):** Mean difference = −0.08; 95% CI, −0.15 to −0.01; p = 0.03 *(decrease in the intervention group)*. **Prevalence of OW or O at follow-up:** Odds ratio (intervention: control) = 0.8; 95% CI, 0.7 to 1.0; p = 0.05 *(decrease in the intervention group)*. **Prevalence of O at follow-up:** Odds ratio (intervention: control) = 0.7; 95% CI, 0.6 to 0.9; p < 0.01 *(decrease in the intervention group)*.		**Mean value of weekly MVPA time at follow-up:** Mean difference = 37.6; 95% CI, −43.9 to 119.1; p = 0.36. **Percentage of students with increased MVPA time at follow-up:** Odds ratio (intervention: control) = 1.15; 95% CI, 1.06 to 1.25; p < 0.01 *(increase in the intervention group)*.
[a] Habib-Mourad et al, Lebanon, 2014, published.[75]	**Intervention:** Diet and PA. **Total no. of clusters analysed**: 8 schools.		**Proportion of children eating breakfast at follow-up:** Odds ratio (intervention: control) = 3.50; 95% CI,	**Proportion of children playing at recess at follow-up:** Odds ratio = 1.38; 95%

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TABLE 2 (Continued)

Study Reference	Study Details	Adiposity-Related Outcomes	Dietary Behaviour Outcomes	Physical Activity Behaviour Outcomes
	Total no. of participants analysed: 363		1.80 to 6.90; $p < 0.05$ *(increase in the intervention group).* **Proportion of children eating 3 or more snacks per day at follow-up:** Odds ratio (intervention: control) = 0.62; 95% CI, 0.34 to 1.15; $p > 0.05$. **Proportion of children eating in front of the TV at follow-up:** Odds ratio (intervention: control) = 0.44; 95% CI, 0.23 to 0.85; $p < 0.05$ *(decrease in the intervention group).* **Proportion of children eating out 3 or more times per week at follow-up:** Odds ratio (intervention: control) = 0.70; 95% CI, 0.35 to 1.38; $p > 0.05$. **Proportion of children consuming the following snacks between meals at follow-up:** ***Chips:*** Odds ratio (intervention: control) = 0.14; 95% CI, 0.11 to 0.19; $p < 0.05$ *(decrease in the intervention group).* ***Chocolate:*** Odds ratio = 0.54; 95% CI, 0.25 to 1.15; $p > 0.05$. ***Fruit:*** Odds ratio (intervention: control) = 1.65; 95% CI, 0.87 to 3.10; $p > 0.05$. ***Sandwiches:*** Odds ratio (intervention: control) = 1.50; 95% CI, 0.78 to 2.90; $p > 0.05$. ***Soft drinks:*** Odds ratio (intervention: control) = 0.31; 95% CI, 0.18 to 0.51; $p < 0.05$ *(decrease in the intervention group).* ***Sweetened drinks*** = Odds ratio (intervention: control) = 0.47; 95% CI, 0.16 to 1.40; $p > 0.05$. **Proportion of children purchasing snacks from the school shop at follow-up:** ***Chips:*** Odds ratio (intervention: control) = 0.16; 95% CI, 0.04 to 0.61; $p < 0.05$ *(decrease in the intervention group).*	CI, 1.10 to 1.80; $p < 0.05$ *(increase in the intervention group).* **Proportion of children participating in at least one after school PA per week at follow-up:** Odds ratio = 2.35; 95% CI, 0.97 to 5.65; $p > 0.05$. **Proportion of children playing at home after school at follow-up:** Odds ratio = 0.86; 95% CI, 0.49 to 1.52; $p > 0.05$.

TABLE 2 (Continued)

Study Reference	Study Details	Adiposity-Related Outcomes	Dietary Behaviour Outcomes	Physical Activity Behaviour Outcomes
			Chocolates: Odds ratio (intervention: control) = 0.29; 95% CI, 0.12 to 0.66; $p < 0.05$ *(decrease in the intervention group).* ***Manoushe:*** Odds ratio (intervention: control) = 0.80; 95% CI, 0.40 to 1.50; $p > 0.05$. ***Croissants:*** Odds ratio (intervention: control) = 0.64; 95% CI, 0.34 to 1.12; $p > 0.05$. ***Soft drinks:*** Odds ratio (intervention: control) = 0.12; 95% CI, 0.04 to 0.29; $p < 0.05$ *(decrease in the intervention group).* ***Sweetened drinks*** = Odds ratio (intervention: control) = 0.40; 95% CI, 0.15 to 1.07; $p > 0.05$.	
[c] Bacardí-Gascón et al, Mexico, 2012, published.[65]	**Intervention:** Diet and PA. **Total no. of clusters analysed**: 4 schools. **Total no. of participants analysed:** 484	**BMI at follow-up:** Mean difference = −0.74; 95% CI, −1.12 to −0.36; $p = 0.001$; *(decrease in the intervention group).*		
[a] Levy et al, Mexico, 2012, published.[60]	**Intervention:** Diet and PA. **Total no. of clusters analysed**: 60 schools. **Total no. of participants analysed:** 997	**Incidence of O:** Odds ratio (intervention: control) = 0.68; 95% CI, 0.52 to 0.91; $p = 0.01$ *(decrease in the intervention group).*		
[a] Mo-suwan et al, Thailand, 1998, published.[67]	**Intervention:** PA. **Total no. of clusters analysed**: 10 classes (2 schools). **Total no. of participants analysed:** 292	**BMI among girls at follow-up:** Mean difference = −0.28; 95% CI, −0.65 to 0.09. **BMI among boys at follow-up:** Mean difference = 0.11; 95% CI, −0.06 to 0.27. **Triceps skinfold thickness at follow-up:** Mean difference = −0.17; 95% CI, −0.69 to 0.35. **WHCU among girls at follow-up (ratio of weight in kilograms divided by height cubed in metres):** Mean difference = −0.26; 95% CI, −0.64 to 0.11. **WHCU among boys at follow-up (ratio of weight in kilograms divided by height cubed in metres):** Mean		

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TABLE 2 (Continued)

Study Reference	Study Details	Adiposity-Related Outcomes	Dietary Behaviour Outcomes	Physical Activity Behaviour Outcomes
		difference = 0.11; 95% CI, −0.05 to 0.28.		
[b] Akdemir et al, Turkey, 2017, published.[70]	**Intervention:** Diet and PA. **Total no. of clusters analysed**: 2 schools. **Total no. of participants analysed:** 1288	**Normal weight status maintenance:** Relative risk (intervention: control) = 1.04; 95% CI, 1.01 to 1.06; p = 0.0025 *(increase in the intervention group).* **Normal weight status maintenance among girls:** Relative risk (intervention: control) = 1.05; 95% CI, 1.01 to 1.10; p = 0.004 *(increase in the intervention group).* **Normal weight status maintenance among boys:** Relative risk (intervention: control) = 1.02; 95% CI, 0.99 to 1.05; p = 0.104. **Shift from OW/O to normal weight status:** Relative risk (intervention: control) = 1.88; 95% CI, 1.09 to 3.24; p = 0.0097 *(increase in the intervention group).* **Shift from OW/O to normal weight status among girls:** Relative risk (intervention: control) = 1.83; 95% CI, 0.81 to 4.14; p = 0.067 **Shift from OW/O to normal weight status among boys:** Relative risk (intervention: control) = 1.92; 95% CI, 0.93 to 3.98; p = 0.055.	**Daily no. of meals:** ***Maintenance of appropriate behaviour:*** Relative risk (intervention: control) = 1.03; 95% CI, 1.01 to 1.05 (increase in the intervention group). ***Improvement in inappropriate behaviour:*** Relative risk (intervention: control) = 3.47; 95% CI, 2.00 to 6.01 *(increase in the intervention group).* **Regular daily breakfast:** ***Maintenance of appropriate behaviour:*** Relative risk (intervention: control) = 1.05; 95% CI, 1.00 to 1.09 *(increase in the intervention group).* ***Improvement in inappropriate behaviour:*** Relative risk (intervention: control) = 2.07; 95% CI, 1.65 to 2.58 *(increase in the intervention group).* **Consumption of take-home pastry for breakfast:** ***Maintenance of appropriate behaviour:*** Relative risk (intervention: control) = 0.97; 95% CI, 0.89 to 1.05. ***Improvement in inappropriate behaviour:*** Relative risk (intervention: control) = 1.64; 95% CI, 1.30 to 2.07 *(increase in the intervention group).* **Sweet, candy and chocolate consumption:** ***Maintenance of appropriate behaviour:*** Relative risk (intervention: control) = 0.96; 95% CI, 0.86 to 1.06. ***Improvement in inappropriate behaviour:*** Relative risk (intervention: control) = 1.79; 95% CI, 1.41 to 2.26 *(increase in the intervention group).* **Daily consumption of fresh fruits:** ***Maintenance of appropriate behaviour:*** Relative risk (intervention: control) = 1.06; 95% CI, 1.03 to 1.08 *(increase in the intervention group).* ***Improvement in inappropriate behaviour:*** Relative risk (intervention:	**Walking exercise with family members:** ***Maintenance of appropriate behaviour:*** Relative risk = 1.59; 95% CI, 1.43 to 1.76 *(increase in the intervention group).* ***Improvement in inappropriate behaviour:*** Relative risk = 6.28; 95% CI, 4.10 to 9.61 *(increase in the intervention group).* **Inactivity during physical training lessons:** ***Maintenance of appropriate behaviour:*** Relative risk (intervention: control) = 1.01; 95% CI, 0.96 to 1.06. ***Improvement in inappropriate behaviour:*** Relative risk (intervention: control) = 1.56; 95% CI, 1.28 to 1.89 *(increase in the intervention group).* **Playing computer games/TV watching:** ***Maintenance of appropriate behaviour:*** Relative risk (intervention: control) = 1.12; 95% CI, 1.02 to 1.23 *(increase in the intervention group).* ***Improvement in inappropriate behaviour:*** Relative risk (intervention: control) = 1.52; 95% CI, 1.18 to 1.96 *(increase in the intervention group).*

TABLE 2 (Continued)

Study Reference	Study Details	Adiposity-Related Outcomes	Dietary Behaviour Outcomes	Physical Activity Behaviour Outcomes
			control) = 1.95; 95% CI, 1.41 to 2.70 (increase in the intervention group). **Daily consumption of fresh vegetables:** ***Maintenance of appropriate behaviour*:** Relative risk (intervention: control) = 1.10; 95% CI, 1.04 to 1.16 *(increase in the intervention group).* ***Improvement in inappropriate behaviour*:** Relative risk (intervention: control) = 2.56; 95% CI, 2.01 to 3.27 *(increase in the intervention group).* **Eating at a fast food restaurant:** ***Maintenance of appropriate behaviour*:** Relative risk (intervention: control) = 1.00; 95% CI, 0.96 to 1.05. ***Improvement in inappropriate behaviour*:** Relative risk (intervention: control) = 1.64; 95% CI, 1.26 to 2.13 *(increase in the intervention group).* **Consumption of fried food:** ***Maintenance of appropriate behaviour*:** Relative risk (intervention: control) = 1.07; 95% CI, 1.00 to 1.15 *(increase in the intervention group).* ***Improvement in inappropriate behaviour*:** Relative risk (intervention: control) = 1.92; 95% CI, 1.42 to 2.60 *(increase in the intervention group).* **Consumption of pastry at home:** ***Maintenance of appropriate behaviour*:** Relative risk (intervention: control) = 1.23; 95% CI, 1.12 to 1.35 *(increase in the intervention group).* ***Improvement in inappropriate behaviour*:** Relative risk (intervention: control) = 3.43; 95% CI, 2.24 to 4.86 *(increase in the intervention group).*	

Note. Study outcomes have only been included where a statistical comparison between the intervention and control group has been made. Three studies are not presented in the table because they did not make any statistical comparisons between outcomes in the intervention and control group.

Abbreviations: WC, waist circumference; %BF, body fat percentage; O, obesity; OW, overweight.

[a]Adjustment for clustering has been carried out in the statistical analysis.

[b]No adjustment for clustering has been carried out in the statistical analysis.

[c]Unclear whether adjustment for clustering has been carried out in the statistical analysis.

outcome.[44–47,53,55,58,60,65,68,70,71,73,77] Five of the studies reporting positive effects were assessed as 'low risk of bias' for at least five domains; three of these have been reported on in the last 2 years.[46,47,58,68,77] Ten of the studies reporting significant intervention effects targeted populations in which the mean age of participants was between 9 and 12 years, which broadly reflects the proportion of studies focusing on this age group across all 21 included studies.[45,46,55,58,60,68,70,71,77] Meta-analyses for the outcomes of BMI, prevalence of obesity and prevalence of overweight showed a decrease in the outcome measure in the intervention group compared with the control group, but this was only significant for prevalence of obesity (odds ratio = 0.77; 95% CI, 0.63 to 0.94; p = 0.009). High study heterogeneity was observed among all meta-analyses.

Regarding the effectiveness of specific intervention components, our narrative synthesis suggests that school-based interventions comprising diet and PA components with an element of parental involvement are likely to be effective in preventing childhood obesity. These findings are consistent with previous research conducted in HICs.[20,25,31] Our findings further indicate that multicomponent interventions delivered by school teachers are likely to be effective, whereas more mixed results were obtained for interventions delivered externally by researchers or health professionals. These intervention components have previously been highlighted as potentially effective in low- and middle-income countries.[32–34] However, in this review, we have identified additional intervention characteristics that are common across studies reporting positive effects on obesity-related outcomes in MICs: an intervention duration of at least 8 months (one academic school year), modifications to provision of school food and inclusion of education sessions.

Interpretation of the validity of the results of this review would be made easier by better reporting of methods by trial authors, allowing proper assessment of the risks of bias in the trials. The majority of trials had at least one source of bias in their methods, and this reduces confidence in the results of the individual trials and in turn the meta-analyses to which they contribute.

4.2 | Strengths and limitations

This is the first systematic review of school-based interventions to prevent childhood obesity that focuses specifically on MICs. The unique situation of these countries in terms of their rapid nutrition transition and consequent steep rise in childhood obesity prevalence highlights the importance of achieving an understanding of the types of interventions that are likely to work in these settings. A comprehensive search strategy was developed and included approaches for identifying unpublished studies. In addition, studies were not excluded based on publication language, which was a common methodological limitation of previous reviews.[31,32,34] Eight of the 21 studies had not previously been included in a systematic review, and two included studies had not been published at the time the review was undertaken.[46,47,58,69–73] The quality of the reporting and risk of bias was improved in two trials published more recently and included in this review (Figure 2).[47,58] The low quality of evidence has been a common limitation in previous reviews.[31,32] A further strength is that additional obesity-related outcomes such as body fat percentage and waist circumference were evaluated in addition to BMI, providing a more comprehensive picture of intervention effectiveness.

There are also some limitations. The search strategy was restricted to international electronic databases, which may not have identified studies published in local or national journals. Nevertheless, our search strategy included a comprehensive approach to identifying international literature and also utilized the knowledge of experts in the field. Abstract and title screening of articles was only carried out in duplicate for a 5% random sample; however, there was a high level of agreement between reviewers for this sample. Despite our attempts, we were unable to contact some study authors to gain further information and so were unable to include two potentially eligible studies.[78,79] Due to the design and reporting of many studies, we were unable to include them in our meta-analyses. In addition, the high heterogeneity observed in the three meta-analyses undertaken needs to be considered when interpreting the findings. Consistent with the limitations described in previous reviews, outcome measurements for some studies were restricted to BMI, which can result in misleading results because BMI may be insensitive to changes in adiposity for children and is an age- and sex-dependent variable.[26,62,80] Also, many studies used self-report measures for PA and dietary behaviour, which may have low validity.

4.3 | Implications of findings

The findings of this review suggest that school-based interventions can be effective in preventing childhood obesity in MICs and should be implemented alongside other targeted measures of action. We have identified several characteristics that are common across childhood obesity intervention approaches which have resulted in positive effects on adiposity outcomes. Intervention characteristics associated with greater effectiveness include the following: combined diet and PA interventions, duration of at least 8 months (one academic year), parental involvement, inclusion of education sessions, modifications to school food provision and intervention delivery by school teachers. This provides valuable information for policy-makers, educators and health promotion personnel. An important consideration in these settings is ensuring that intervention approaches are contextually appropriate.[46] For example, the nutritional environment in schools in MICs poses a challenge as often street-food vendors will intermingle with privately owned school food shops.[53,62,63] A further example is the strong emphasis on academic performance found in some settings such China. Obesity prevention efforts need to complement and synergize with this academic focus.[50,51] Intervention programmes must be tailored to take account of these different social, environmental and educational contexts.

TABLE 3 Summary of results of individual studies grouped by intervention characteristics

Combined Interventions											
Study Reference	Education Sessions	Daily PA Sessions	Changes to the School Food	Physical Changes to the School Environment	Delivery by School Teachers	Delivery by Researchers or Health Professionals	Parental Involvement	Secondary Home Setting	Intervention Duration ≥8 months	Secondary Outcomes with Positive Effects	Adiposity-Related Outcomes with Positive Effects
Sgambato et al, Brazil, protocol (2016).[69]	✓	X	X	X	✓	X	✓	✓	X	✓PA	None.
Friedrich et al, Brazil, 2015.[73]	X	X	✓	X	✓	✓	✓	X	X	N/A	BMI, BMI z-score, WC, prevalence of O, prevalence of OW, incidence of O, remission of O, incidence of OW, and remission of OW.
Li et al, China, protocol (2017).[47]	✓	✓	✓	X	X	✓	✓	✓	✓	✓ Diet	BMI z-score.
Xu et al, China, 2015.[50]	✓	X	X	✓	✓	X	✓	✓	X	✓ Diet and PA	None.
Jiang et al, China, 2006.[44]	✓	X	X	X	✓	X	✓	X	✓	N/A	BMI, prevalence of O, prevalence of OW, incidence of O, and remission of O.
Li et al, China, 2017.[55]	✓	✓	✓	X	✓	X	✓	X	✓	N/A	BMI, BMI z-score, % BF and WC.
Cao et al, China, 2015.[53]	✓	✓	✓	X	✓	X	✓	✓	✓	N/A	BMI z-score (OW at baseline), BMI z-score (O at baseline), prevalence of O, and prevalence of O or OW.
Liu et al, China, 2019.[46]	✓	X	✓	X	✓	X	X	X	✓	✓ Diet and PA	Prevalence of O (at 6 months).
Habib-Mourad et al, Lebanon, 2014.[75]	✓	X	✓	✓	X	✓	✓	X	X	✓ Diet and PA	None.

(Continues)

TABLE 3 (Continued)

Combined Interventions											
Study Reference	**Education Sessions**	**Daily PA Sessions**	**Changes to the School Food**	**Physical Changes to the School Environment**	**Delivery by School Teachers**	**Delivery by Researchers or Health Professionals**	**Parental Involvement**	**Secondary Home Setting**	**Intervention Duration ≥8 months**	**Secondary Outcomes with Positive Effects**	**Adiposity-Related Outcomes with Positive Effects**
Bacardí-Gascón et al, Mexico, 2012.[65]	✓	X	X	X	X	✓	✓	X	X	N/A	BMI.
Safdie et al, Mexico, 2013.[62]	X	X	✓	X	✓	X	X	X	✓	N/A	None.
Levy et al, Mexico, 2012.[60]	✓	✓	✓	X	✓	X	✓	X	X	N/A	Incidence of O.
Alvirde-García et al, Mexico, 2013.[71]	✓	X	✓	X	✓	X	X	X	✓	✓Diet	Change in BMI.
Akdemir et al, Turkey, 2017.[70]	✓	X	✓	X	X	✓	✓	X	✓	✓Diet and PA	Normal weight status maintenance, and shift from OW/O to normal weight status.
Diet-Only Interventions											
Study Reference	**Education Sessions**	**Daily PA Sessions**	**Changes to the School Food**	**Physical Changes to the School Environment**	**Delivery by School Teachers**	**Delivery by Researchers or Health Professionals**	**Parental Involvement**	**Secondary Home Setting**	**Intervention Duration ≥ 8 months**	**Secondary Outcomes with Positive Effects**	**Adiposity- Related Outcomes with Positive Effects**
Cunha et al, Brazil, 2013.[68]	✓	X	X	X	X	✓	✓	X	✓	✓Diet	Change in BMI.
Sichieri et al, Brazil, 2008.[77]	✓	X	X	✓	✓	✓	✓	X	X	✓ Diet	BMI (OW girls at baseline only).
Li et al, China, 2017.[55]	✓	X	✓	X	✓	X	✓	X	✓	N/A	WC.
Keshani et al, Iran, 2016.[72]	✓	X	✓	✓	X	X	✓	X	✓	✓Diet	None.

TABLE 3 (Continued)

Physical Activity-Only Interventions											
Study Reference	Education Sessions	Daily PA Sessions	Changes to the School Food	Physical Changes to the School Environment	Delivery by School Teachers	Delivery by Researchers or Health Professionals	Parental Involvement	Secondary Home Setting	Intervention Duration ≥ 8 months	Secondary Outcomes with Positive Effects	Adiposity- Related Outcomes with Positive Effects
Li et al, China, 2010.[45]	X	✓	X	X	✓	X	X	X	✓	N/A	Change in BMI, change in BMI z-score, change in %BF, and change in fat mass.
Li et al, China, 2017.[55]	X	✓	X	X	✓	X	✓	X	✓	N/A	None.
Wang et al, China, 2018.[58]	✓	X	X	✓	✓	X	✓	✓	✓	✓PA	BMI, BMI z-score, prevalence of O, and prevalence of OW or O.
Mo-suwan et al, Thailand, 1998.[67]	X	X	X	X	X	✓	X	X	X	N/A	None.

Note. 'Physical changes to the school environment' refers to posters and banners hung up around the school to promote PA and/or healthy eating and/or water consumption.
Abbreviations: WC, waist circumference; %BF, body fat percentage; O, obesity; OW, overweight.

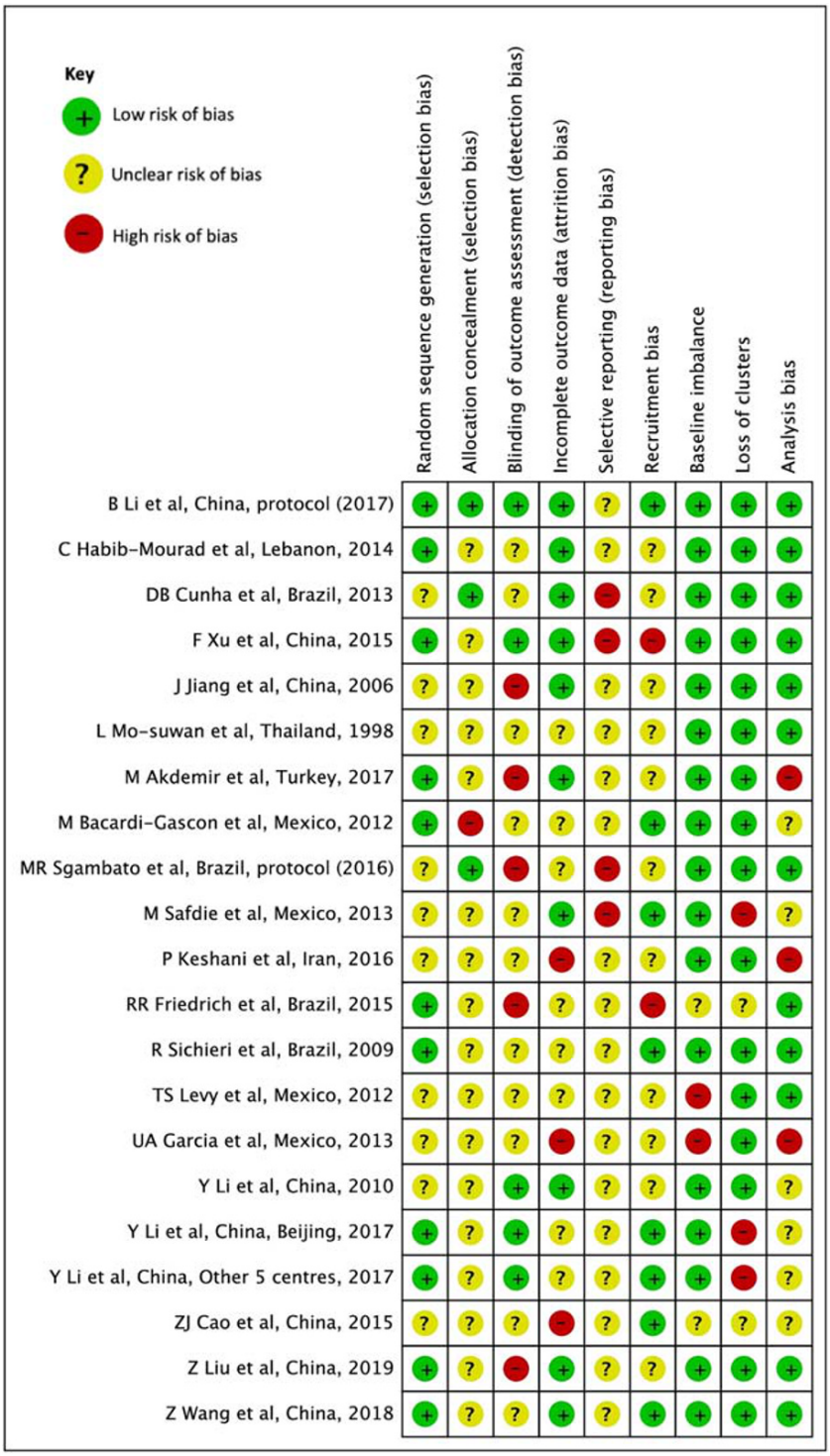

FIGURE 2 Summary of review authors' judgements about risk of bias across all domains and studies

4.4 | Recommendations for future research

In this review, we have acknowledged that few of the included studies reported adverse outcomes, including the prevalence of children with underweight, at follow-up. In MICs, undernutrition commonly coexists alongside obesity. Therefore, there is a potential for harm from obesity prevention programmes if they cause weight loss in children who are already living with underweight.[3,81] Consequently, future studies should ensure that underweight and other potential adverse outcomes, such as bullying or effect on quality of life (only assessed in one included study), are evaluated.[47] Although, some of the more recent studies had higher methodological quality and more comprehensive reporting, there is still a large variation across all the included studies. Thus, a further recommendation is for more rigorous

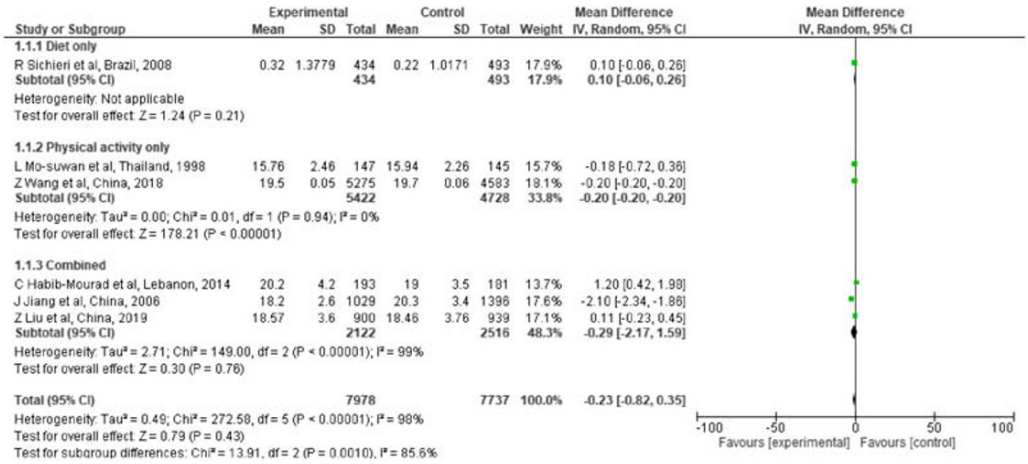

FIGURE 3 A forest plot presenting data on the effects of school-based obesity prevention interventions on BMI with 95% confidence intervals of individual studies, grouped by intervention type. The pooled estimates with 95% confidence intervals were calculated using a random effects model and inverse variance methods. The unit of measurement on the horizontal axis is weight (kg)/height (cm)^2. Studies have only been included where data were adjusted for clustering and reported in the appropriate format. SD, standard deviation; IV, inverse variance; CI, confidence interval

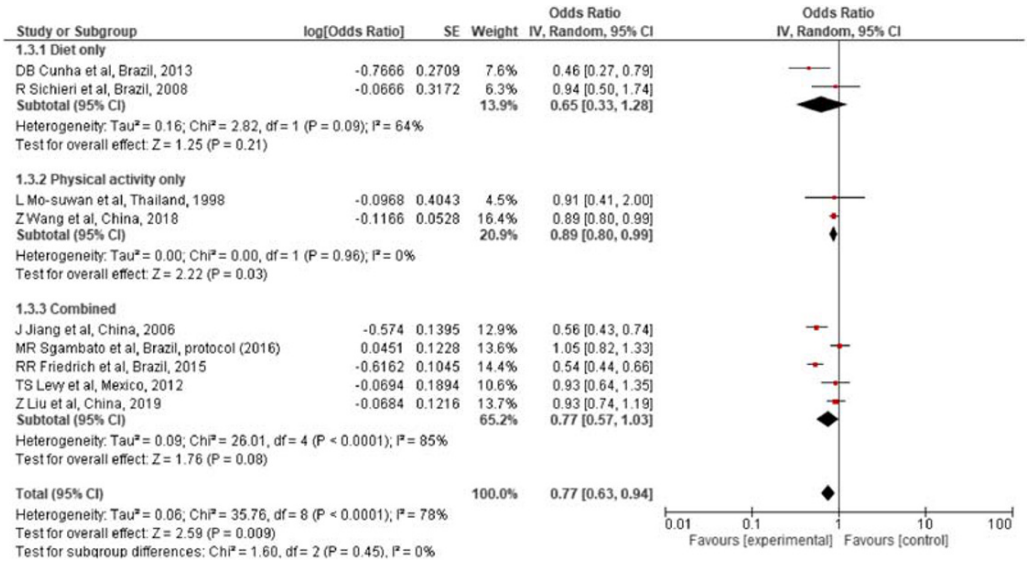

FIGURE 4 A forest plot presenting data on the effects of school-based obesity prevention interventions on the prevalence of obesity with 95% confidence intervals of individual studies, grouped by intervention type. Studies have used different definitions of obesity, either using the WHO or International Task Force classifications. The pooled estimates with 95% confidence intervals were calculated using a random effects model and inverse variance methods. Studies have only been included where data were adjusted for clustering and reported in the appropriate format. SD, standard deviation; IV, inverse variance

methodological design and reporting of RCTs evaluating school-based obesity prevention interventions in MICs. Additionally, long-term follow-up data are lacking in existing RCTs and should be included as an integral aspect of future study designs to enable evaluation of the sustainability of intervention effects. Some of the included studies have suggested that girls may respond differently to obesity prevention strategies than boys; thus, future studies should explore the interactions between intervention and gender.[45,53,60] Most intervention studies did not include evaluations of cost-effectiveness; this would be particularly useful to policy-makers in MICs given the limited availability of resources and should therefore be included in future research.

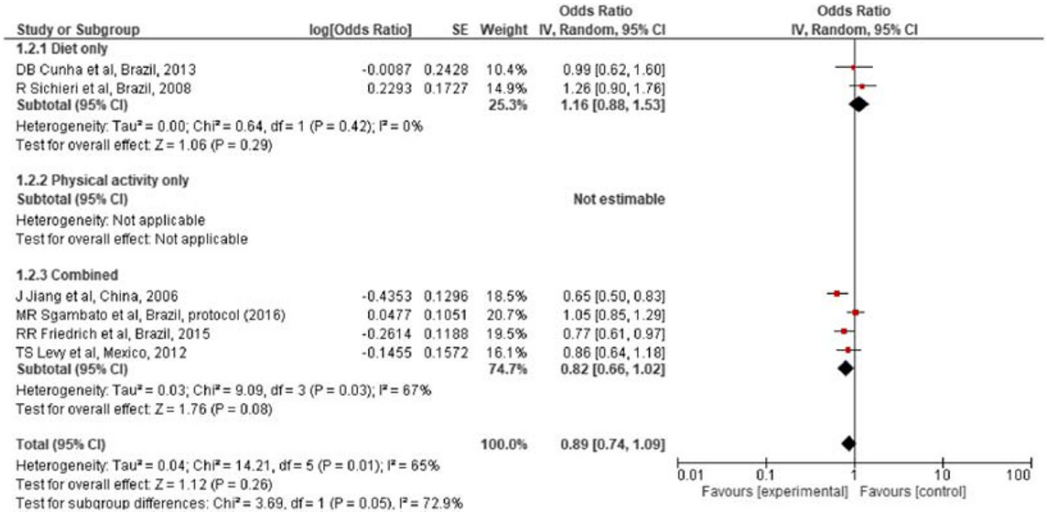

FIGURE 5 A forest plot presenting data on the effects of school-based obesity prevention interventions on the prevalence of overweight with 95% confidence intervals of individual studies, grouped by intervention type. Studies have used different definitions of overweight, either using the WHO and or International Task Force classifications. The pooled estimates with 95% confidence intervals were calculated using a random effects model and inverse variance methods. Studies have only been included where data were adjusted for clustering and reported in the appropriate format. SD, standard deviation; IV, inverse variance; CI, confidence interval

5 | CONCLUSION

This review presents some evidence to support the effectiveness of school-based interventions in preventing childhood obesity in MICs. Fifteen of the 21 (71%) included studies reported positive effects on at least one obesity-related outcome. The pooled estimates from the meta-analyses suggested a significant decrease in the prevalence of obesity in intervention groups compared with controls, but no significant effects on BMI and prevalence of overweight. Intervention characteristics that were commonly observed in studies reporting positive effects on obesity-related outcomes include the following: combined diet and PA interventions, delivery by school teachers, an intervention duration of at least 8 months, parental involvement, inclusion of education sessions and modifications to the school food provision. The review findings need to be interpreted with a degree of caution due to the variation in methodological quality and reporting and significant heterogeneity among studies.

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CONFLICTS OF INTEREST

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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