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The effect of Public Health/Pediatric Obesity interventions on socioeconomic inequalities in childhood obesity: A scoping review

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Summary

Childhood obesity has a strong social gradient. This scoping review aims to synthesize the evidence on the impact on inequalities of non-targeted interventions to reduce the prevalence of childhood and adolescent obesity in high-income countries. We updated a review by Hillier-Brown, searching up to 31 December 2017 on MEDLINE, Embase, The Cochrane Library, CINAHL, and PsycINFO, with no limitations on study design. Fifty-eight studies describing 51 interventions were included: 31 randomized clinical trials and 27 non-randomized trials, with sample sizes from 67 to 2,700,880 subjects. The majority were implemented in the school setting at a community level; the others were in health services or general population setting and targeting individuals or the system. Twenty-nine interventions proved to be effective overall; seven others had an effect only in a subgroup, while 15 proved not to be effective. All types of included interventions can increase inequalities. Moreover, some interventions had opposite effects based on the socioeconomic characteristics. Any kind of intervention can reduce equity. Consequences are difficult to predict based on intervention construct. Complex interventions acting on multiple targets, settings, and risk factors are more effective and have a lower risk of increasing inequalities.

KEYWORDS

childhood obesity, equity, prevention, public health

Abbreviations: NPP, National Prevention Plan; CCM, National Centre for Disease Prevention and Control; RPP, Regional Prevention Plans; PICO(S), Population, Intervention, Comparator, Outcomes, Study design; RCTs, randomized clinical trials; BMI, body mass index; SES, socioeconomic status; KOPS, Kiel Obesity Prevention Study; HBSC, Health Behavior in School-aged Children

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1 | INTRODUCTION

1.1 | Inequalities in prevalence of childhood obesity

Childhood obesity is a highly prevalent condition, with an increasing trend worldwide. It is estimated that the number of children around the world under the age of 5 who are affected by overweight or obesity increased from 32 million in 1990 to 42 million in 2013.¹ The phenomenon is seen primarily in industrialized countries, with prevalence in 2013 of 23.8% in males and of 22.6% in females.¹⁻³ Moreover, childhood obesity has a strong social gradient, with a higher prevalence among children from families with low socioeconomic status (SES).³ For instance, in 2014, the prevalence of obesity in Italy was 2.9% among adolescents and 9.3% in childhood, ranging from 14% in children in more deprived families to 6% in children of parents with high education level and no perceived economic difficulty.⁴⁻⁶

1.2 | Risk factors for childhood obesity: Inequalities in exposure

The varying prevalence of obesity according to socioeconomic level is influenced by two main risk factors: insufficient physical activity and unhealthy diet.^{7,8} Additional factors include not eating breakfast,⁹ infant feeding with formula,^{10,11} and one or both parents being affected by overweight.^{6,12}

Given its epidemiological importance and impact on health, childhood and adolescent obesity is one of the main topics in prevention.¹³ Effects on health can be mitigated with interventions on diet and exercise^{14,15} or, indirectly, by promoting breastfeeding.¹⁰

1.3 | Evidence of effectiveness of prevention interventions and possible impact on inequalities

To reduce burden of disease, structured population-based strategies are needed that aim at prevention, alongside screening and treatment of those who are already affected by overweight or obesity.^{7,13,14}

A 2011 Cochrane systematic review summarized the evidence on the effectiveness of complex interventions directed towards children between the ages of 6 and 12.¹⁵ Among the most promising strategies were activities in the school setting (health promotion integrated into school curricula, increased number of exercise sessions in and outside of school, and training of teachers), environmental interventions, and promoting healthy diet and physical activity. The review underlined the need for quality evidence that takes into account the possible differences in impact of the interventions based on the socioeconomic characteristics of the recipients to reduce inequalities.^{15,16}

1.4 | Strategies and policies to tackle inequalities in childhood obesity

In the "Health 2020" strategy, the World Health Organization highlighted the urgency of reducing health inequalities and applied this

approach to obesity prevention, publishing "Obesity and inequities" in 2014. This policy guidance aims to support policy-makers in improving interventions and policies to promote equity in overweight and obesity.¹⁷ Equity in health care can be operationally defined as a fair distribution of resources among the population, providing equal services access, use, and quality to individuals with equal needs.¹⁸

The issue of how to reduce inequalities in childhood obesity has been the focus of at least five systematic reviews.^{16,19-22} While two systematic reviews reported weak evidence of a negative impact on equity of interventions primarily targeting individuals' skills,^{21,22} a third reported this kind of intervention as potentially effective in reducing inequalities.¹⁶ On the contrary, all the systematic reviews reported inconclusive results regarding community-based interventions.^{16,19-22} Different ways of classifying interventions, (ie, based on the setting, target, or mechanism of action), may explain the differences in results. All the classification criteria showed some limitations, particularly when applied to complex interventions in which several actions were put in place, often acting on different targets, in different settings, and with different underlying mechanisms to induce changes in behaviours.

Thanks to the debate in the scientific community and to the results of these reviews, most agencies^{15,17,23,24} recommend analyzing the impact of health promotion and public health interventions throughout the socioeconomic strata of the population, acknowledging that these interventions may have differential effectiveness and thus may generate further inequity. Therefore, it is possible that such analyses have been more systematically carried out in recent years. Furthermore, the previous reviews tried to classify complex interventions as a whole and did not try to classify the single actions included in each intervention.^{16,19-22} In this systematic review, we tried to update the previous reviews and to overcome their limits while generalizing their results.

2 | OBJECTIVE

The objective of the study is to provide a synthesis of the evidence on the impact on inequalities of interventions aiming to reduce the prevalence of childhood and adolescent obesity. This systematic review is part of the projects to support the implementation of the Italian 2014-2019 National Prevention Plan (NPP). Specifically, it was conducted within the "Equity audit in Regional Prevention Plans" project.

3 | METHODS

3.1 | Context: The "Equity audit in Regional Prevention Plan" project funded in 2014 by the National Centre for Disease Prevention and Control (CCM)

The purpose of the CCM "Equity audit in Regional Prevention Plan" project is to help frame the drafting of the Regional Prevention Plans

(RPP) prevention projects with a focus on equity, in line with the NPP objectives that are more sensitive to health inequalities.²⁵ The equity audit defines an audit of how an initiative functions, particularly in terms its organization and implementation, so as to detect any mechanisms generating inequalities in the process and in the results that can be monitored and corrected.²⁶

3.2 | Protocol of the systematic review (PROSPERO)

The protocol of this systematic review has been registered on the database PROSPERO with ID CRD42017080972.²⁷

3.2.1 | Search strategy and inclusion criteria of studies

The subject of the review is the effect on inequalities of public health interventions on the prevalence of overweight and obesity or of the risk factors associated with childhood and adolescent obesity. Taken into consideration was each family's SES, classified according to parental characteristics such as education level, income, employment status, or ethnicity, according to deprivation indexes of the area of residence or according to other composite indicators of SES. Only universal interventions were considered, ie, those targeting the entire population and not any intervention that targeted deprived children identified a priori.

The PICO(S) (Population, Intervention, Comparator, Outcomes, Study design) framework was used to frame the search strategy (Table 1).

3.2.2 | Search strategy, sources, and selection process

A search of the literature identified a systematic review that evaluated the impact on inequalities of interventions to reduce childhood and adolescent obesity, updated to October 2012.¹⁶ The strategy reported by the authors (Supporting Information), adapted to each database, was used to search for articles published in the following databases: MEDLINE (through PubMed, from October 2012), Embase, The Cochrane Library, CINAHL, and PsycINFO. To update the search of the previous systematic review, the search was limited to studies published from 2012 to 2017 (ie, the last search was performed in January 2018).¹⁶ Moreover, the reference list of the systematic reviews resulting from the search with objectives similar to those of the present review was used to retrieve other primary studies that fulfilled the eligibility criteria.

The selection by title and abstract of articles to include for full-text evaluation was carried out by two pairs of four reviewers, independently (ie, each pair of reviewers independently assessed 50% of the search results). When opinions were discordant, a fifth reviewer was consulted. Moreover, after the screening of the first 200 titles and abstracts, the four reviewers and the supervisor collectively discussed all the choices to agree on how to apply inclusion and exclusion criteria. The selection of full-text articles was carried out by a single

TABLE 1 Research question reported according to the PICO framework

Research Question	
Population	Children and adolescents between the ages of 1 and 18.
Intervention	Overweight and obesity prevention interventions or interventions to reduce their prevalence in childhood and adolescence and targeting the entire population (universal).
Comparator	No intervention or standard care.
Outcomes	Outcomes related to anthropometric measurements (body mass index [BMI], weight-to-height ratio, plicometry, and body fat percentage) and behavioural outcomes (intake of fruits and vegetables, calorie intake, sugary beverage intake or intake of other unhealthy foods or beverages, eating breakfast, breastfeeding, amount of physical activity, time spent in front of the television, and/or videogames). Both measured and self-reported outcomes were considered.
Study design	Only studies that evaluated differences in intervention effectiveness by socioeconomic status or those that evaluated the interaction between socioeconomic variables were included. All study designs were included, given that public health interventions at the individual and community level can be evaluated by means of experimental studies while the impact of interventions at the regional or national level are more easily evaluated by means of observational studies or by modelling studies. No limit was set on the duration of an intervention or on the length of follow up. For greater transferability to the European context, only studies that evaluated interventions implemented in high-income countries, per the World Bank classification, ² were included. Only articles in English or in Italian were included.

reviewer, with a cross check by another reviewer on 20% of the full texts selected. Inconsistent results were discussed by the reviewers and the supervisor (P. G. R.). The selection process of the studies is described in the PRISMA flowchart in Figure 1.

3.2.3 | Data extraction of included studies

Data extraction from included full-text articles was performed by a single reviewer using a data extraction form developed by the working group. The data extraction form included the first author's name, year of publication, name of intervention, country, study design, characteristics of population included, duration of the study, description of the intervention, outcomes evaluated, and socioeconomic variables considered. The extracted data were used to categorize the intervention according to the classifications reported below. Each classification was done by the reviewer who extracted data and was then discussed by that reviewer and the supervisor (P. G. R.). In the event that relevant information was not clear, we would have contacted the study authors; in the end, however, there was no need to.

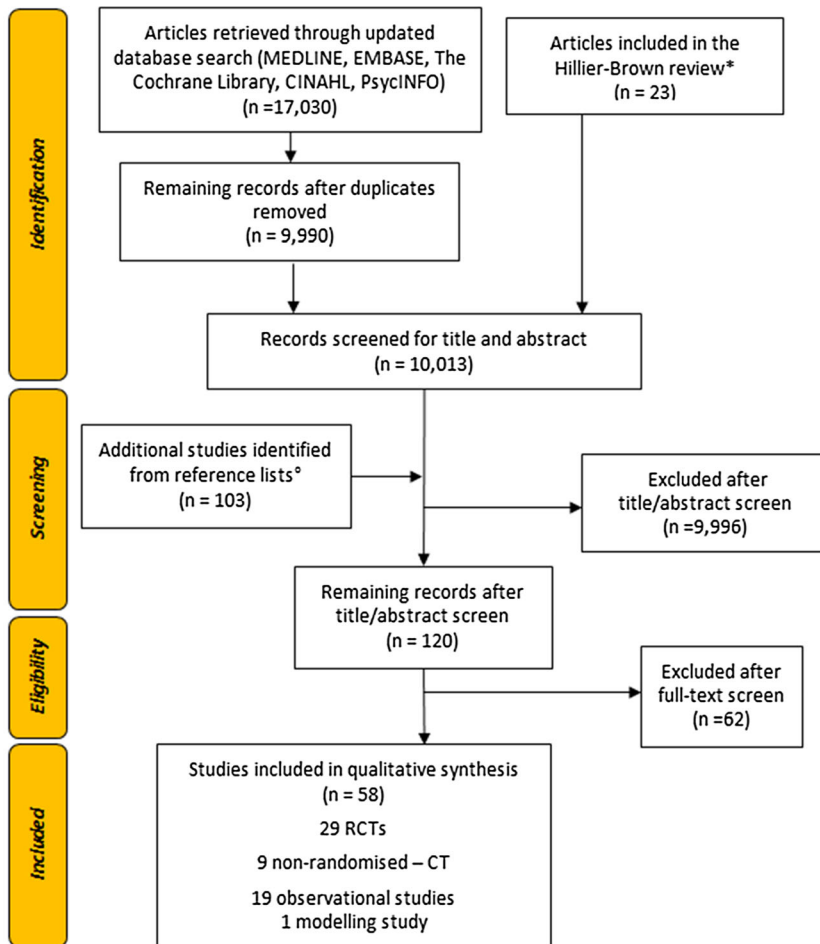


FIGURE 1 PRISMA flowchart describing the study selection process Notes: * studies included in review by Hillier-Brown et al.¹⁶ ° Studies retrieved from the reference lists of four reviews found in the updated literature search^{19–22} [Colour figure can be viewed at wileyonlinelibrary.com]

3.2.4 | Classification of interventions and actions

The unit of analysis is the intervention. Studies that evaluated the same intervention are described together.

The interventions included foresaw one or more actions. In the case of interventions with multiple actions, it was not possible to identify the contribution of each single action to the final result in terms of effectiveness and/or of impact on inequalities, except in one case.²⁸

Actions included in the interventions were classified according to different frameworks to be able to describe the characteristics in a more standardized manner. Given the heterogeneity of the childhood obesity prevention interventions, similar actions were grouped in macro categories to facilitate synthesis of results.

Target/Setting

An initial classification was carried out to identify the target of each action by using the targets proposed by the 2014–2018 NPP and by the authors of the systematic review currently being updated: individual, community, or system.^{13,16}

Along with the target, the setting where each intervention was implemented was identified per the current or planned settings in the 2014–2018 NPP: school, healthcare services, or general population.¹³

Those interventions that included actions aimed at more than one target and/or setting were defined complex interventions.

Mechanism of action

The framework proposed by Backholer et al²⁹ was used to describe and group the actions included in each intervention. This framework considers the degree of individual agency necessary to achieve the action's result. Those interventions where the mechanism of action is independent of the individual's will/action are defined as *structural*; examples include the elimination of added sugars in meals served at school or the elimination of snack cakes from school vending machines.

Interventions defined as *agentic* require individual agency to achieve the desired result. Examples of *agentic* interventions include all educational projects on healthy lifestyle and information campaigns. This mechanism can be influenced by the individual's characteristics and is therefore considered at greater risk of introducing health inequalities.^{30,31}

There is a third category of actions defined as *agentic-structural*; these actions have intermediate characteristics, with a mechanism of action based on environmental modifications that facilitate implementation of healthy behaviours by individuals, who nevertheless retain agency. Some examples are reducing the price of fruits and vegetables

by eliminating the tax on them or selling fruit in school vending machines.

Classification of intervention implementation levels

Each intervention was evaluated in terms of whether it was implemented in an experimental context (pilot), ie, with the elective participation of centres in the intervention or whether it was scaled up in the context of public health, with the “mandatory” participation of the centres involved.

3.2.5 | Evaluation of overall effectiveness and impact on inequalities

Each intervention was evaluated for overall effectiveness in preventing childhood obesity and for impact on inequalities. Given that there is no standard cutoff in the literature to evaluate the effectiveness of a childhood and/or adolescent obesity prevention intervention and given the broad heterogeneity of the study designs and interventions included in this review, evaluating the overall effectiveness of the interventions and their impact on inequalities as reported by the authors of each study was considered opportune. Exceptions were those cases in which there were appreciable inconsistencies between conclusions and presented results.

Each intervention, therefore, was given a score on overall effectiveness (+ effective, 0 not effective). Effective was defined as there being a reduction in anthropometric measurements and/or improvement in behavioural factors (eg, increased intake of fruits/vegetables, increase in physical activity, reduction in screen time, reduced intake of fats or carbonated/sugary beverages, and reduction in the percentage of children who skip breakfast). Not effective was defined as when not even one of the preceding outcomes occurred.

The impact of an intervention on inequalities, instead, was classified as “↓” or positive if the intervention reduced inequalities (ie, proved to be more effective in the more disadvantaged socioeconomic groups than in the more advantaged), “0” or neutral if the intervention did not modify inequalities (ie, was equally effective in all socioeconomic groups), or “↑” or negative if the intervention increased inequalities (ie, it was more effective in the more advantaged socioeconomic groups than in the more disadvantaged groups).

3.2.6 | Data synthesis and presentation of results

The results of this review are reported by means of a narrative synthesis. Given the broad heterogeneity of the interventions, the actions in the studies were categorized in 25 types of actions to facilitate synthesis; the setting, target, and mechanism of action are described for each action. Tables 2–4 report the macro categories defined, describe each action included in each category, report the interventions that include that action, and summarize the overall effectiveness and impact on inequalities of each intervention. To provide an overview of interventions with multiple actions, Figure 2 reports their respective characteristics and included actions. Instead, interventions with only one action are listed in the Supporting Information.

4 | RESULTS

4.1 | Selection of studies

Updating the previous search by Hillier-Brown,¹⁶ 9,990 unique records were retrieved, including four systematic reviews on the topic.^{19–22} Thus, 10,013 titles and abstracts (ie, the 9,990 unique records plus the 23 papers from Hillier-Brown review) were screened.¹⁶ Moreover, a cross-check of the reference lists of the four systematic reviews was done to find other eligible studies.^{19–22} Overall, 58 studies were included, which reported results of 51 different interventions, one of which was evaluated in its pilot phase as well as in its implementation phase at the national level. Figure 1 shows the PRISMA flowchart of the study selection process, while characteristics of the included studies are reported in the Supporting Information (flowchart, Figure 1).

4.2 | Characteristics of included studies

4.2.1 | Study design, sample, and country

Of the 58 studies included, 29 were randomized controlled trials, 9 were non-randomized trials, 3 were cohort studies, 16 were cross-sectional studies, and 1 was based on models. Thirty-eight studies evaluated pilot interventions, while the remaining 20 evaluated interventions that were scaled up, with a resulting variability in sample sizes (from 67 to 2,700,880 subjects). Five interventions targeted children affected by overweight or obesity, after school-based or paediatrician/medical record screening,^{32–37} while the rest included children and adolescents at any weight. Most of the interventions evaluated were implemented in North America, followed by EU countries, Australia, and Asia. Twenty-four studies evaluated the impact only on anthropometric outcomes, 25 only on behavioural outcomes, and the remaining 9 on both. To define the socioeconomic level of families, 38 studies used only one parameter: 6 used area deprivation indexes, 9 used education level, 7 used ethnicity, 14 used income, 1 used type of parental employment, and 1 used the level of health literacy. Of the remaining 20 studies, 7 used a composite indicator of SES defined at individual level (SES) and 13 used a combination of various socioeconomic variables. Additional characteristics of the included studies are reported in the Supporting Information.

4.2.2 | Intervention setting and target

The studies evaluated community interventions more frequently, with a mechanism based on behavioural changes and implemented in the school setting.

System interventions are more equally distributed among the different mechanisms of action. In this case as well, the main setting was school, but interventions at the population level and in the healthcare setting were also common.

Interventions at the individual level all had a mechanism of action that foresaw behavioural changes.

Complexity	No of actions	Study	Target Setting Class of Action**	Individual										Community										System									
				School					HCS					School					HCS					School					HCS				
				1	2	3	4	5	6	7	8	9	10a	10b	11a	11b	12	13	14	15	16	17	18	19	20a	20b	21	22	23	24	25		
			Curricula tailored	Homework	Counselling	Family support	Screening, counselling	Money for screen time reduction	Informative material	Family involvement	Eyes subtitled with	Nutrition environment	Nutrition and PA	Environment	Extra-curricular PA	Environment and transports	Curricular PA	Curricula on nutrition and PA	Provision of FV	Informative material in clinics	Local Media	Events for families	Environment and transports	Curricula on diet and PA	Vending Machine	Canteen	Improvement of PA	Education and training	Mass media	Taxation / de-taxation	Collective food services laws		
C	8	Smigorski 2008				X	X		X	X			X	X									X								X		
C	4	Zoellner 2017	↑			X	X		X												X												
C	3	Jouret 2009	↑			X	X		X																								
C	3	Taveras 2011	↑			X	X		X											X													
NC	3	Dallogeville 2011	+ 0/↓/0																														
NC	2	Hobin 2014	0 ↓																														
C	7	Economos 2007	+ 0						X	X		X								X,X	X	X											
C	5	Chomitz 2010	+ 0					X				X							X		X												
C	4	Reynolds 2000	+ 0				X					X							X		X												
C	3	Perry 1998	+ 0				X					X							X		X												
C	2	Kalvalainen 2007	+ 0			X													X		X												
NC	2	Rosenkrantz 2010	+ 0			X				X									X		X												
NC	2	Simon 2008	+ 0			X			X										X		X												
NC	6	Rappaport 2013	+ 0			X			X										X		X					X	X	X					
C	5	Salanave 2009	0				X			X									X		X												
C	4	Christiansen 2013; Tofflager 2014	0				X			X									X		X												
C	4	Greening 2011	0				X			X									X		X												
C	4	Rush 2012	0				X			X			X						X		X												
C	3	Edmundson 1996; Lytle 1996	0				X			X			X						X		X												
C	3	Nyberg 2016	0				X			X			X						X		X												
NC	3	Bae 2012	0				X					X							X		X												
NC	3	Tak 2009; Tak 2010	0				X					X							X		X					X	X	X					
NC	2	Kim 2012	0									X							X		X												
C	5	Bürgi 2012 and Puder 2011	+ 0/↑									X	X,X						X		X												
C	2	Frenn 2003	+ 0/↑								X								X		X												
NC	2	Kim 2013	+ 0										X						X		X												
NC	2	Sanchez-Vaznaugh 2015	+ 0										X						X		X												
C	2	Davoli 2013; Broccoli 2016	0																X		X												
NC	2	Plachta-Danielczik 2007, 2011	0										X						X		X												
NC	2	Schaegen 2005	0											X					X		X												

FIGURE 2 Description of included studies describing interventions with two or more actions: overall effect, impact on inequalities and macro categories of actions included in each intervention. Notes: Complexity: C complex (which include multiple actions with different settings and/or targets); NC not complex (which include multiple actions but only one target and setting); * + positive effect (reduction in anthropometric values; improve behavioural factors like increased intake of FV, increased PA, reduction in intake of fats or carbonated/sugary beverages, reduction in % of children who skip breakfast); 0 (no effect); - negative effect (increase in anthropometric values; worsening of behavioural factors like reduction in intake of FV, reduction in PA, increase in screen time, increased intake of fats or carbonated/sugary beverages, increase in % of children who skip breakfast). Anthro: body mass index, waist circumference, plicometry, other anthropometric measures; Behaviour: intake of sugary beverages, intake of fruits and vegetables, physical activity, screen time, other unhealthy behaviours). **For details on the description of actions, see Tables 2-4. Classification of Actions. *** Impact on inequalities: ↓ reduction; 0 neutral; ↑ increase. PA: physical activity; FV: fruits and vegetables; TV Television. The classification per setting and target was based on previous studies.¹⁶ The colours relative to actions indicate the classification of mechanism of action: yellow = agentic; orange = agento-structural; red = structural²⁹ [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 2 Macro categories of actions included in interventions with individual as target evaluated in included studies and impact (overall +, 0 and on inequalities) of interventions

Macro Category (and Mechanism of Action)	↓	0	↑
Overall Impact on Childhood Obesity Prevalence (+, 0) and Inequalities (↓, 0, ↑)			
Target: Individual Setting: School			
1. School-based curricula intervention with tailored sessions for groups or individual (A) School-based curricula on nutrition only or with PA based on trans-theoretical model (four session classroom format and four session internet/video format on healthy eating and PA) (Frenn, 2003) ⁴⁹ (Frenn, 2005). ⁷⁵ Once per class: 50-min theory-based computer-tailored dietary fat intake intervention on healthy eating with tailored message (Haerens, 2007). ⁷¹	+	Frenn, 2003; Frenn, 2005	Frenn, 2003; Frenn, 2005
2. Homework (with or without incentive) with tailored exercises (A) The "home team" approach consisting of five information/activity packets brought home by the students to be done with parents or of 4 snack packs prepared by the school food service and containing food items for students to prepare as a snack for their families at home; in both activities a card signed by the parent at task completion was used for a classroom drawing. (Perry, 1998). ³⁸ Complete Homework lesson using a signed voucher to indicate the lesson completion was returned to class for prize drawings (Reynolds, 2000). ⁵⁶	+	Perry, 1998; Reynolds, 2000	Perry, 1998; Reynolds, 2000
3. Individual counselling for children affected by obesity from school nurses (A) Consultations on diet and PA for children affected by obesity with school nurses (Kalavainen, 2007). ³⁷	+	Kalavainen, 2007	Kalavainen, 2007
4. Involvement of families with education and support (A) Family support and education program using set of 10 Parent tips sheets (Sanigorski, 2008). ⁵¹ Use of parent and child workbooks developed in 6 chapters on nutrition, PA, and behavioural strategies and including module objectives, educational content, a class activity, and homework combined with newsletters mailed weekly (Zoellner, 2017). ³⁶ Focus group with community residents on healthy eating and PA (Greening, 2011). ⁴³ Home-based education activities on diet and PA (Edmunson, 1996; Lytle, 1996). ^{44,45} Two sessions of 45-min motivational interviewing with parents without children, to support healthy eating, PA, parental care, and control and stimulate willingness to change (Nyberg, 2016). ⁴⁶	+	Sanigorski, 2008; Zoellner, 2017	Greening, 2011; Edmunson, 1996; Lytle, 1996; Nyberg, 2016
Target: Individual Setting: Health Care System			
5. Screening children affected by obesity and counselling/individual management (A) Recruitment after review of medical records for children affected by overweight/obesity with invitation letter. One week following each class, the parents received a telephone support call delivered by a research or community staff member. Goal setting occurred during the small group classes and was reinforced during the telephone calls. Self-monitoring activities were incorporated (Zoellner, 2017). ³⁶ Screening and consultations on diet and PA for children affected by obesity with follow up from healthcare professionals where indicated (EPIPOI-1 and 2) (Jouret, 2009). ⁵² Consultations on diet and PA for children affected by obesity with healthcare physicians partially offered by local insurances (Taveras, 2011) ⁵³ or offered to families (Chomitz, 2010). ⁵⁵ Screening for obesity and oriented medical care by healthcare professional (Salanave, 2009). ⁴⁰ Screening for obesity and paediatrician-led motivational interview consisting in 5 appointments in 12 months (Davoli, 2013; Broccoli, 2016). ^{32,33} Screening and consultations on diet and PA for children affected by obesity and mildly overweight consisting in 4 standard consultations over 12 weeks (Wake, 2009). ³⁵ Screening and consultations on diet and PA for children affected by obesity consisting in 5 units of 90 minutes tailored counselling performed by a dietitian at family's home with parents and children (Langnase, 2004). ³⁴	+	Zoellner, 2017; Jouret, 2009; Taveras, 2011	Chomitz, 2010 Langnase, 2004 Wake, 2009; Salanave, 2009 Davoli, 2013; Broccoli, 2016
6. Economic incentives for those who watch less television (A) TV monitoring devices were installed to promote screen time reduction; for each family a target of minutes of screen time were set up each week and the family earned money proportionally to reaching target or doing better (Epstein, 2008). ⁷⁷	+	Epstein, 2008	Epstein, 2008

Note. The impact refers to the whole intervention cited. Instead, impact corresponds to the impact of the single action in interventions with only one action. Non-complex interventions are reported in bold, while complex interventions (ie, including actions with multiple target and/or setting) in bold italic.

TABLE 3 Macro categories of actions included in interventions with community as target evaluated in included studies and impact (overall +, 0 and on inequalities) of interventions

Macro Category (and mechanism of action)	Overall Impact on Childhood Obesity Prevalence (+, 0) and Inequalities (↓, 0, ↑)		
	↓	0	↑
Target: Community Setting: School			
7. Distribution of information material to parents and educators (A) Curriculum-based information material to teachers and educators, and "healthy nuggets" short information delivered weekly by school newsletter (<i>Rush, 2012</i>). ⁵⁰ Informative material and social marketing to increase PA, healthy diet and reduce screen time (<i>Sanigorski, 2008</i>). ⁵¹ Distribution of information material for both parents and teachers through poster and leaflet dissemination with information on obesity-related issues and within session held by dieticians for teachers (EPIPOI-1 and 2) (<i>Jouret, 2009</i>). ⁵² Distribution of information booklets for families (<i>Kalavainen, 2007</i>). ³⁷	+	0	<i>Kalavainen, 2007</i> <i>Rush, 2012</i>
8. Involvement of families with group meetings and events (A) Regular meeting with parents and educators to encourage the support of PA for children (<i>Simon, 2008</i>). ⁵⁷ Workshop and events with trained health promoters in collaboration with the teachers to increase awareness in parents of healthy lifestyles (<i>Rush, 2012</i>). ⁵⁰ "Happy healthy families" program groups for 6 weeks (<i>Sanigorski, 2008</i>). ⁵¹ Nutrition educators reached family members through home and school association meetings, report card nights, parent education meetings, and weekly nutrition workshops (<i>Rappaport, 2013</i>). ³⁹ Monthly events and contests about nutrition and PA with healthy prizes (<i>Greening, 2011</i>). ⁴³	+	0	<i>Simon, 2008</i> <i>Rush, 2012</i> ; <i>Rappaport, 2013</i> ; <i>Greening, 2011</i>
9. Replacement fryers with ovens in school canteens (S) Improvement in nutritional environment replacing deep frying equipment with ovens in school canteen (<i>Greening, 2011</i>). ⁴³	+	0	<i>Greening, 2011</i>
10a. Interventions on the environment to promote healthy diet: fruit in vending machine and canteens (AS) Improvement in nutritional school environment by increasing availability, accessibility, and exposure to FV (<i>Tak, 2009 & 2010</i>). ^{66,67} Changes in canteen menu including healthy foods; lunch pack with healthy combos in designed packaging (<i>Sanigorski, 2008</i>). ⁵¹ Increasing availability of healthy food before, during, and after school (<i>Economos, 2007</i>). ⁵⁴ A half-day of training for food service managers and workers on purchasing, preparing, and promoting fruits and vegetables that meet High 5 guidelines, supported by nutritionists (<i>Reynolds, 2000</i>). ⁵⁶ Improvement in nutritional school environment (to encourage consumption of FV) (<i>Perry, 1998</i>). ³⁸ Social marketing techniques to increase meal participation and consumption of healthy snack and beverage items; students who purchased or brought healthy snacks and beverages received raffle tickets to win prizes for healthy eating (<i>Rappaport, 2013</i>). ³⁹ Increased social responsibility of all stakeholders and making healthy choices the easiest, in particular modifying the vending machines in school settings and the nutritional quality of school meals (<i>Salanave, 2009</i>). ⁴⁰ Modification in nutritional school environment designed to help children exercise more control over their choices for diet and physical activity behavior (<i>Edmundson, 1996</i> ; <i>Lytle, 1996</i>). ^{44,45}	+	0	<i>Sanigorski, 2008</i> <i>Economos, 2007</i> ; <i>Reynolds, 2000</i> ; <i>Perry, 1998</i> <i>Tak, 2009 & 2010</i> ; <i>Rappaport, 2013</i> ; <i>Salanave, 2009</i> ; <i>Edmundson, 1996</i> ; <i>Lytle, 1996</i>

(Continues)

TABLE 3 (Continued)

Overall Impact on Childhood Obesity Prevalence (+, 0) and Inequalities (↓, 0, ↑)	
Macro Category (and mechanism of action)	
<p>10b. Interventions on the environment to promote healthy diet: diet and physical activity (AS) Promotion of movement skills training classroom and programs, active transports, lunchtime exercises, and changes in canteen menus supported by a team of experts (Rush, 2012).⁵⁰ Scout troop meeting policies with ban on unhealthy food and TV watching, and promotion of PA and FV consumption, including reward for healthy tasks completion (Rosenkranz, 2010).⁸⁸ Wellness policy; nutrition and vending machine guidelines; food purchasing system established with local farmers; School nutritionist and consultant chef introduced 15 new recipes emphasizing fresh, local ingredients; 110 "taste-tests" in 12 schools, including staff coaching to prepare recipe; farm-to-school activities; "New PA" including nontraditional activities (i.e., yoga, ballroom dance, "Project Adventure"); before- and after-school programming expanded (Chomitz, 2010).⁵⁵ Schools assessed their environments by using the CDC School Health Index. After completing ratings on healthy eating and physical activity, schools developed an action plan for change including various strategies, such as limiting the use of food as reward, promoting active recess, and serving breakfast in classrooms (Rappaport, 2013).³⁹</p>	<p>+</p> <p>Rosenkranz, 2010; Chomitz, 2010 Rush, 2012; Rappaport, 2013</p> <p>↑</p>
<p>11a. Interventions on the environment to promote physical activity: proposal for extracurricular activities (A) Planning of running games and other PA activities (Plachta-Danielzik 2007, 2011).^{78,79} Afterschool activities program; Sport club coach training; Be active Arts program (Sanigorski, 2008).⁵¹ Twenty-four physical activity classes (2 per week) scheduled for 1 hour to engage children in moderate to vigorous PA (Zoellner, 2017).³⁶ Afterschool fitness, mandatory outdoor recess; free access to school gym, walking-and-cycling-to-school promoting activities (Christiansen, 2013; Toftager, 2014).^{41,42} Workshop, lessons, home activities, offers of culturally tailored extracurricular activities on healthy nutrition, PA, and media use (Puder, 2011; Bürgi, 2012).^{47,48}</p>	<p>+</p> <p>Sanigorski, 2008; Zoellner, 2017</p> <p>0</p> <p>Christiansen, 2013; Toftager, 2014</p> <p>Puder, 2011; Bürgi, 2012 Plachta-Danielzik 2007 & 2011</p>
<p>11b. Interventions on the environment to promote physical activity: school hours and transport (AS) "Walking school buses"; Walk to school days; Two class sets of pedometers for rotation between schools (Sanigorski, 2008).⁵¹ Increasing physical activity options before or during school: "walking to school bus"; PA contests (Economos, 2007).⁵⁴ Thematic PA lessons of 45 min. weekly and additional sessions with regular before-school teachers; fixed and mobile equipment for PA in gym and around the school to promote unstructured PA during recess (Puder, 2011; Bürgi, 2012).^{47,48}</p>	<p>+</p> <p>Sanigorski, 2008</p> <p>0</p> <p>Economos, 2007</p> <p>Puder, 2011; Bürgi, 2012</p>
<p>12. Curricular physical exercises and theoretical lessons (AS) Policy to make mandatory a minimum of PA practical exercises classes for students (Hobin, 2014).⁸⁶ School-based curricula on healthy eating and PA and exercise programs using American Heart Association (AHA) school-site kits (Bingham, 2002).⁶⁰ Peer-led gym labs with a focus on activities that could be accessible and performed safely outside, increasing self-awareness of lifelong opportunities for PA (Frenn, 2003).⁴⁶</p>	<p>+</p> <p>Frenn, 2003</p> <p>0</p> <p>Hobin, 2014</p> <p>Bingham, 2002</p> <p>Frenn, 2003</p>
<p>13. Curricula on diet and physical activity with indications on how to do physical activity at home or outside (A) School-based curricula on healthy eating and PA including sessions focusing on decreasing television viewing, decreasing consumption of high-fat foods, increasing fruit and vegetable intake, and increasing moderate and vigorous physical activity (Gortmaker, 1999).⁸³ Policy to make mandatory PA credits in schools earned attending class on healthy lifestyle and PA (Hobin, 2014).⁸⁶ Interactive educational curriculum on PA and healthy eating delivered by Scout troop leaders (Rosenkranz, 2010).⁸⁸ School-based curricula on healthy diet and PA and exercise included in routine school curriculum (Simon, 2008).⁵⁷ 20 sessions in classroom including diet</p>	<p>+</p> <p>Gortmaker, 1999; Jouret, 2009</p> <p>0</p> <p>Hobin, 2014; Rosenkranz, 2010; Simon, 2008; Friel, 1999; Robinson, 1999; Economos, 2007; Chomitz, 2010; Reynolds, 2000; Perry, 1998</p> <p>0</p> <p>Hobin, 2014; Tak, 2009 & 2010; Salanave, 2009; Christiansen, 2013; Toftager, 2014; Greening, 2011;</p> <p>Plachta-Danielzik 2007 & 2011;</p>

(Continues)

TABLE 3 (Continued)

Macro Category (and mechanism of action)	Overall Impact on Childhood Obesity Prevalence (+, 0) and Inequalities (↓, 0, ↑)		
	↓	0	↑
<p>and PA recommendations (Friel, 1999).⁶² 18 lessons of 30-50 minutes each in standard curriculum taught by trained classroom teachers focusing on self-monitoring and self-reporting of screen time, including reducing screen time challenges and how to become "intelligent viewers" (Robinson, 1999).⁶⁴ Optional school-based curricula on healthy eating developed by the Netherlands Nutrition Centre Foundation (Tak, 2009 & 2010)^{66,67} or by the French National Nutrition Programme (Salamave, 2009).⁴⁰ 6 nutrition classroom units during 2-3 weeks on PA and healthy diet after teacher training (Plachta-Danielzik, 2007 & 2011).^{78,79} School-based curricula on nutrition taught by peer leaders to younger students (Formeris, 2010).⁸¹ Ten 20-min sessions, five sessions per year, in the classroom conducted by dietitians focusing on promoting healthy nutrition habits and physical activity and reducing television watching (EIPOI-2 only) (Jouret, 2009).⁵² SUS classroom curriculum including 10-minute daily "Cool Moves"; 30-minute nutrition and physical activity lesson (1 week); Fun and healthy giveaways; SUS afterschool curriculum including cooking classes, promotion of healthy snacks, and physical activity (Economos, 2007).⁵⁴ School-based curricula on nutrition with cooking courses and other classes on nutrition (Chomitz, 2010).⁵⁵ 14-lesson curriculum taught by coordinators using learning methods including modelling, self-monitoring, problem-solving, reinforcement, taste testing, and other methods (Reynolds, 2000).⁵⁶ Sixteen 40- to 45-minute classroom sessions implemented twice a week for 8 weeks including skill-building and problem-solving activities, snack preparation, and taste testing and introducing new role models in the form of comic books and an adventure story (Perry, 1998).³⁸ Theme week, teachers educated as kickstarters, school play patrol for older students (Christensen, 2013; Toftager, 2014).^{41,42} 45-min nutritional information session presented by a nutritionist once during the school year; 45-min PA education class twice a week, teachers incorporated health information in weekly classes (Greening, 2011).⁴³ CATCH curricula designed to influence self-efficacy and selected efficacy-activated processes during PA skill acquisition (Edmundson, 1996; Lytle, 1996).^{44,45} Ten 30-min teacher-led classroom sessions with homework to increase children's knowledge, attitudes, and preferences, with culturally appropriate contents (Nyberg, 2016).⁴⁶</p>		<p>2011; Edmundson, 1996; Lytle, 1996; Nyberg 2016</p>	<p>Formeris, 2010</p>
<p>14. Distribution of fruits, vegetables, or breakfast at school (AS) Provision of a free piece of fruit at school daily (Hughes, 2012)⁸⁴ (Fogarty, 2007).⁶⁹ Provision of a piece of fruit for free or paid for at school (Bere, 2005 & 2010).^{38,59} Provision of free school breakfast (Moore, 2014).⁶³ Provision of a free piece of fruit at school twice a week and FV-adapted lunchbox (Tak, 2009 & 2010).^{66,67}</p>	+	<p>Hughes, 2012; Moore, 2014</p>	<p>Bere, 2005 & 2010 Tak, 2009 & 2010; Fogarty, 2007</p>
<p>Target: Community Setting: Health Care System</p>			
<p>15. Poster and information material in the clinics (A) Distribution of information and health promotion-supporting poster in medical offices and waiting rooms, booklets to support nurse counselling (Taveras, 2011).⁵³ Distribution of information and health promotion-supporting booklets to support counselling (Davoli, 2013; Broccoli, 2016).^{32,33}</p>	+	<p>Taveras, 2011</p>	<p>Davoli, 2013; Broccoli, 2016</p>
<p>Target: Community Setting: General Population</p>			
<p>16. Local information and media campaigns (leaflets, posters, newsletters) (A) Distribution of information booklets for families and community on PA recommendations and initiatives list; yearly awareness campaigns to support spread of initiatives (Economos, 2007). Distribution of informative posters around the city and newsletter (Chomitz 2010). Publication of nutritional guidelines for population groups with practical advice (Salamave 2009). Home</p>	+	<p>Economos, 2007; Chomitz, 2010</p>	<p>Puder, 2011; Bürgi, 2012</p>
	0	<p>Salamave, 2009; Nyberg, 2016</p>	

(Continues)

TABLE 3 (Continued)

Macro Category (and mechanism of action)	↓	0	↑
	Overall Impact on Childhood Obesity Prevalence (+, 0) and Inequalities (↓, 0, ↑)		
delivery of a brochure, co-created and translated into Somali and Arabic, with facts and advice on parental feeding practices; healthy food and family mealtimes; physical activity; screen time, and sleep (Nyberg 2016). Distribution of brochures on PA, nutrition activity cards, worksheets and leaflets at home provided in 10 different languages (Puder, 2011; Bürgi, 2012).			
17. Involvement of families in groups and events (A) Six small group classes of 2 h each with 8-12 families per class, including an interactive, didactic nutrition component and a PA component that engaged families in physical activity for 20 minutes (Zoellner, 2017). ⁵⁶ Newsletter and parent nutrition forums, "Health Report Chart" (Economos, 2007). ⁵⁴ Project Kick off night, parents asked to encourage and support behavior change in their children, do homework together, also using skill-building materials such as recipes or refrigerator magnets (Reynolds, 2000). ⁵⁶ Workshop and events with families taught by trained health promoters in collaboration with teachers (Puder, 2011; Bürgi, 2012). ^{47,48} Professional development and evenings with a dietitian to raise parents' awareness of healthier food choices; events such as gala open days and edible gardens. (Rush, 2012) ⁵⁰	+	Zoellner, 2017 Economos, 2007; Reynolds, 2000 Rush, 2012	Puder, 2011 - Bürgi, 2012
18. Interventions on the extracurricular environment to promote physical activity: school hours and transport (A5) Improvement in sport club equipment, "walking to school bus," community garden (Sanigorski, 2008). ⁵¹ Increasing physical activity options before and during school, "walking to school bus," contests (Economos, 2007). ⁵⁴	+	Sanigorski, 2008 Economos, 2007	

Note. The impact refers to the whole intervention cited. Instead, impact corresponds to the impact of the single action in interventions with only one action. Non-complex interventions are reported in bold, while complex interventions (ie, including actions with multiple target and/or setting) in bold italic.

TABLE 4 Macro categories of actions included in interventions with system as target evaluated in included studies and impact (overall +,0 and on inequalities) of interventions

Macro Category (and Mechanism of Action)	Overall Impact on Childhood Obesity Prevalence (+, 0) and Inequalities (↓, 0, ↑)		
	↓	0	↑
Target: System Setting: School			
19. Policies on school curricula (diet, physical activity, healthy lifestyles) (A) Modification of school-based curricula on healthy eating through dissemination of standardized obesity prevention programs (Bae, 2012) ⁶⁵ (Kim, 2013), ⁷³ School-based curricula on PA (based on national recommendations standard) (Kim, 2012), ⁶⁸ Three levels of school involvement with curricula on personal, social, and health education about sex, relationships, drugs, smoking, nutrition, PA, and bullying (Schagen, 2005), ⁸⁰ 50 hours of food and nutrition education per student per school year lead by 10-hour trained teachers; Nutrition integrated into various classroom subjects (Rappaport, 2013). ³⁹	+	Bae, 2012; Kim, 2012; Rappaport, 2013	Kim, 2013 Schagen, 2005
20a. Policies on food regulation in schools: vending machines (AS) Ban on the sale of carbonated beverages and training facilities, nutritional labelling at school, safe eating habit management laws, School Meal Act (Bae, 2012) ⁶⁵ (Kim, 2013), ⁷³ Ban of sale of sugary beverages at school (Sanchez-Vaznaugh, 2015). Foods sold and served at school changed to meet the nutritional standards. Beverages limited to 100% juice, water, and low-fat milk and respecting the allowed snack standards in vending machines (Rappaport, 2013). ³⁹	+	Bae, 2012; Rappaport, 2013	Kim, 2013; Sanchez-Vaznaugh, 2015
20b. Food regulation in schools: canteens (AS) New standards for healthy ingredients and quality of food of school lunches, stricter than those recommended by the government (Taber, 2013), ⁸⁵ Rules on vending machines and canteen menus, with restrictions on unhealthy food and beverages (Cullen, 2009). ⁶¹ Labelling on school meals, ban of unhealthy beverages in school meals (Bae, 2012), ⁶⁵ National program that rewards with cash subsidies and reimbursement the schools that serve nutritionally balanced meals according to the federal requirements, at low cost or free to eligible children (Gleason, 2009). ⁷⁰ Policy on modification in canteen food ingredients (Sanchez-Vaznaugh, 2015). ⁷⁴ Rules on vending machines and canteen menus, with restrictions on unhealthy foods and beverages (Mendoza, 2010). ⁷⁶ Policy on modification in canteen availability of healthy food, with 3 levels of school involvement (Schagen, 2005), ⁸⁰ Foods sold and served at school changed to meet nutritional standards. Beverages limited to 100% juice, water, and low-fat milk and respecting the allowed snack standards in vending machines (Rappaport, 2013). ³⁹	+	Taber, 2013 Cullen, 2009 Bae, 2012; Gleason, 2009; Rappaport, 2013	Sanchez-Vaznaugh, 2015; Mendoza, 2010 Schagen, 2005
21. Enhancing physical activity in schools: policies and/or structures (S) Improvement in PA school environment improving staffing requirements, recess time, health-related fitness programs (Kim, 2012). ⁶⁸ Improvement in PA school environment upgrading existing and creating new sports equipment, improving safety for active transport (Christiansen, 2013; Toftager, 2014). ^{41,42}	+	Kim, 2012; Christiansen, 2013; Toftager 2014	
Target: System Setting: Health Care System			
22. Training of health care personnel (AS) Improvement in healthcare practices, including training of paediatricians, paediatric nurses, and dieticians, improvement in electronic databases (Taveras, 2011). ⁵³	+	Taveras, 2011	
Target: System Setting: General Population			
23. Media campaigns and communication events (A) Yearly mass media campaigns to promote FV consumption, with a budget of 10M€ (Dallongeville, 2011). ²⁸ Yearly mass media campaigns to support guidelines spread (Salanave, 2009). ⁴⁰ Policies for PA and healthy food promotion within city environment, outreach events rewards (Chomitz, 2010). ⁵⁵	+	Dallongeville, 2011; Chomitz, 2010 Salanave, 2009	

(Continues)

TABLE 4 (Continued)

Macro Category (and Mechanism of Action)	Overall Impact on Childhood Obesity Prevalence (+, 0) and Inequalities (↓, 0, ↑)		
	↓	0	↑
<p>24. Taxation or tax relief (AS) Tax reduction on healthy foods, from 5.5% to 2.1% on fruits and vegetables; food stamp program with money for FV purchasing for low income families (targeted) (Dallongeville, 2011).²⁸ Small taxes on soda or sweetened beverages (Sturm, 2010).⁸⁷ Tax on sugary drinks both at grocery store and vending machines (Powell, 2009).⁷² Tax credit for PA promotion: Children's Fitness Tax Credit non-refundable tax credit of up to \$500 to register a child in a PA program offered for a minimum of 8 consecutive weeks or 5 consecutive days; depending on the net taxable income of a household, this would amount to a maximum tax saving of \$75 per child (Spence, 2010).⁸²</p>			
<p>25. Rules for collective food service (S) Policy implementation on quality of food in fast food restaurants (Sanigorski, 2008).⁵¹</p>			
	+ Dallongeville, 2011	0 Sturm, 2010	↑ Powell, 2009
	+ Sanigorski, 2008	0	Spence, 2010

Note. The impact refers to the whole intervention cited. Instead, impact corresponds to the impact of the single action in interventions with only one action. Non-complex interventions are reported in bold, while complex interventions (i.e. including actions with multiple target and/or setting) in bold italic.

4.3 | Classification of interventions and actions

Overall, 19 interventions were classified as complex and foresaw a number of actions that could have different targets, mechanisms of action, and, more rarely, different settings.^{32,33,36-56}

The other 32 interventions were classified as not complex and included one or more actions with the same target and setting.^{28,34,35,57-88}

Tables 2-4 report the 25 macro categories of action included in the interventions evaluated; for each intervention, the overall impact and the effect on inequalities are also reported. A summary graph of the actions included in each intervention with more than one action is reported in Figure 2.

4.4 | Overall effectiveness of the interventions

Of the 51 interventions described in the 58 studies included, 29 proved to be effective overall, reducing body mass index (BMI),^{34,36,37,51,52,54,55,57,64,74,77,85} waist circumference,^{47,48,51} or body-fat percentage (through plicometry)^{60,64} and/or improving behavioural factors like intake of fruits and vegetables,^{28,38,56,58,59,61,76,83,84} physical activity,^{47-49,62,73,75,88} number of hours of television/video,^{53,77} or other (eg, intake of fats, intake of carbonated beverages, and eating a healthy breakfast).^{36,63,75,83} Seven of the remaining studies had an effect only in a subgroup of the population,^{32,33,78-82,86,87} while 15 proved not to be effective.^{35,39-46,50,65-72} Of the 15 showing no effect, 7 were "complex" interventions, and 8 had a single target and setting. Three interventions, two effective and one ineffective overall, had positive results in some groups and harmful impact in others (Figure 2).^{32,33,49,75}

4.5 | Impact of interventions on inequalities

4.5.1 | Complex interventions

The 19 complex interventions evaluated are extremely heterogenous. Some are multisetting, involving both school and afterschool settings, others focus on schools alone but at various levels: national or regional regulations, with actions implemented at the single schools, and in some cases, at the individual level, directed at children identified as affected by obesity or at risk of obesity.

Most of the interventions evaluated were neutral in terms of the impact on inequalities.^{28,37-41,43,44,46,50,54-56} Exceptions were three interventions evaluated in five studies, which showed an increase in inequalities.^{32,33,47-49} In other words, a positive effect of the intervention on BMI and on aerobic fitness was found only among those children whose mothers had high levels of education, while no effect was found in children of mothers with a low level of education.^{32,33,47,48} Further, the effect of an intervention on lifestyle behaviours differed by race, with desirable changes in physical activity seen mainly in Hispanic and White children, while no changes were seen among African Americans and slightly negative changes among Native Americans.⁴⁹ Four interventions, instead, show an effect of reducing inequalities: Epipoi, in

versions 1 and 2,⁵² Be active eat well,⁵¹ iChoose,³⁶ and High Five for Kids.⁵³

No included study evaluated *structural* interventions to increase physical activity at the community or system level (ie, expanding/improving the usability of playgrounds, traffic calming zones, bicycle paths, and pedestrian routes for students) if not as part of complex interventions.^{47,48,51,54}

The setting of these interventions was primarily the school, but they did foresee an interaction with local agencies to facilitate afterschool physical activity. The impact on inequalities was positive in one case,⁵¹ negative in another,^{47,48} and neutral in a third.⁵⁴ However, it is not possible to ascribe these effects to any single component of the entire intervention.

4.5.2 | Interventions with a single target and setting

Of those interventions with a single target and setting, 13 involved system actions,^{28,61,65,68,70,72-74,76,80,85,87} 14 included actions carried out at the community level,^{57-60,62-64,66,67,69,78,79,81,83,84,86,88} and 5 targeted the individual.^{34,35,71,75,77}

System interventions

Nine system interventions were policies implemented in the school setting, aiming in particular at modifying food distribution, for example, vending machines, school canteens, increasing physical activity, and including healthy lifestyle in school curricula. Of these, four showed a negative impact on inequalities.^{73,74,76,80} In particular, groups with higher socioeconomic position or from schools with moderate or high SES showed greater desirable changes in dietary behaviours after the implementation of nutritional policies compared with the low socioeconomic position group,^{73,76,80} or these desirable changes occurred only in the socioeconomically advantaged neighbourhoods, while no effect was reported in the more deprived ones.⁷⁴ Instead, four others showed no difference in impact at the socioeconomic level.^{61,65,68,70} In addition, policies implemented in the United States to modify school canteen menus showed differing impact: in two studies a substantial neutrality emerged regarding inequalities measured at the area level,^{61,70} while a third study found a reduction in inequalities measured at the individual level.⁸⁵ Moreover, another study with a similar intervention, whose effect was evaluated in terms of calorie intake, showed a potential increase in inequalities.⁷⁶

Further, four system interventions foresaw actions involving taxing unhealthy food and beverages and untaxing healthy foods^{28,72,82,87}; two showed a reduction in inequalities.^{28,87} A negative effect was observed in only one study that evaluated untaxing fruit and vegetables through reimbursement requiring active request procedures, which was more frequently applied for by families with high SES.⁸²

Community interventions

The 14 interventions with a community target were all carried out in the school setting.

Most (ten interventions) involved including principles of healthy diet and physical activity in the school curriculum. Six had no meaningful impact on inequalities.^{57,60,62,64,66,67,88} Two interventions, instead, show a greater effect in more disadvantaged subjects,^{84,86} 1 of which included an increase in physical activity in the school curriculum.⁸⁶ The remaining two interventions showed a negative effect on inequalities.^{78,79,81} The first showed no gain in terms of fruit and vegetable consumption for African-American children compared with a slight increase for Caucasian children.⁸¹ The latter intervention, which included increased afterschool physical activity, had a positive effect on BMI changes in children from families with high SES only, with no or slightly negative impact on children with middle and low SES.^{78,79} The increase in physical activity at the curricular level was seen as a single intervention in another study, which showed no substantial effect on inequalities.⁶⁰

Those interventions that foresaw modifications in the school environment to support healthy diet and physical activity showed no effect on inequalities^{50,66,67,88} nor did the one that involved family members, including promoting healthy lifestyle in school curricula.⁵⁷

The direct distribution of healthy food at school was evaluated in many studies, whether as the principle intervention^{58,59,63,69,84} or as part of an intervention made up of a number of actions.^{66,67} These interventions did not have any impact on inequalities, with the exception of two interventions of free distribution of healthy food, the “5 a day”⁸⁴ project and the “Primary School Free Breakfast Initiative”⁶³ in the United Kingdom, which found a greater increase of healthy eating behaviours in the more deprived.

Interventions targeting the individual

Five interventions foresaw a single action directed towards the individual, two of which in the school setting,^{71,75} and three in healthcare facilities.^{34,35,77}

Tailored curricular interventions were evaluated in two studies,^{71,75} with contrasting results: one was neutral in terms of inequalities,⁷¹ while the other showed reductions or increases in inequalities, depending on the disadvantaged ethnic group examined: the positive impact on physical activity was higher among White children than among Hispanic and Black children.⁷⁵ This was also observed in an analogous complex intervention.⁴⁹

One intervention that gave financial incentives to families to reduce the number of hours watching television proved to be effective only in families with lower SES.⁷⁷

Finally, those interventions of screening and individual counselling for families with children affected by overweight or obesity produced contrasting results.^{34,35} Considering those complex interventions that included counselling as well, Broccoli^{32,33} and Kiel Obesity Prevention Study (KOPS)³⁴ showed a negative impact and Taveras⁵³ a tendentially positive impact, while the others had no effect on inequalities.^{35,37,40,55} Both Taveras and Broccoli included the distribution of information material; the former was limited to only a few doctors' clinics,⁵³ while Broccoli^{32,33} involved the entire province with a population-based approach. Noteworthy is that the

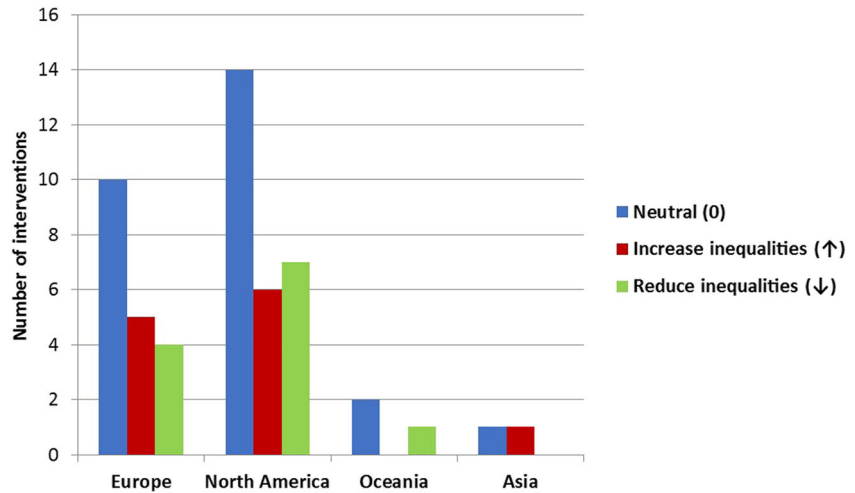


FIGURE 3 Geographic distribution of interventions evaluated in the included studies and impact on inequalities. Impact on inequalities: 0 neutral; ↑ increase, ↓ reduction [Colour figure can be viewed at wileyonlinelibrary.com]

Taveras intervention⁵³ was not effective on BMI total, while the Broccoli intervention³³ was, at 1 year, although the effect was not maintained over time for either group.

4.6 | Impact on inequalities and characteristics of included studies

Evaluating the characteristics of the included studies in relation to the impact on inequalities of the interventions they describe, no clear pattern or association emerged, except for nationality. Almost all the interventions that showed any ability to reduce inequalities were implemented in the United States (Figure 3).

5 | DISCUSSION

5.1 | Overview of impact on inequalities

We found 51 interventions for which the impact on inequalities was assessed. This number may seem large, but it must be compared with the vast literature on such a wide range of interventions^{15,89-93}; only a small proportion of the studies published data on effectiveness analysis throughout the socioeconomic strata of the population. From the review of the literature what emerges is that all types of interventions evaluated in the included studies can have a negative impact on inequalities, thereby widening the existing gap in the prevalence of obesity and/or exposure to risk factors, to the disbenefit of the more disadvantaged groups.^{33,34,73,74,76,79-82} Further, some interventions proved to have opposite effects based on the socioeconomic characteristics (especially education level) of the parents of children who were the target of the intervention.^{32,33} This means that not only all types of interventions can generate health inequalities but even those interventions that proved to be neutral or effective in the general population can in fact have negative effects on a subgroup.^{34,47-49,73-76,78,79} Thus, inappropriateness is de facto introduced, reducing the technical and allocative value at the population level as well as any personal value of prevention

interventions for the individual. Results of overall efficacy should always be evaluated together with the results of the impact on inequalities.

This evidence suggests that the local impact of prevention programs needs to be evaluated, regardless of the type of intervention adopted; indicators must be included to evaluate the impact by socioeconomic level or in population subgroups that may be more vulnerable. This issue was pointed out by many previous reviews, highlighting a lack of systematic reporting of efficacy of interventions throughout the socioeconomic strata of the population and the need to include this assessment in routine preventive practice.^{15,16,19-21} To this end, population surveillance is invaluable, especially in the prevention of behavioural risk factors. For example, the “Okkio alla Salute” surveillance, which collects information on children aged 7-9, and the Health Behavior in School-aged Children (HBSC) Italia study, which collects information on adolescents aged 11-13-15, make it possible to stratify information on body weight and lifestyle of children/adolescents by education level of the mother or by composite socioeconomic indicator, respectively.^{94,95}

5.2 | Complex interventions and risk reduction

Complex interventions, ie, those that foresee the involvement of multiple targets (system, community, and individual) and multiple settings (school, healthcare services, and general population), aside from being indicated by preceding systematic reviews as more effective,¹⁵ also seem to have a lower risk of introducing inequalities.^{36,51-53} Consistent results were found in two previous systematic reviews, which also reported the lack of studies on the equity impact of multilevel interventions and the challenging assessment due to their complex construct.^{16,21}

5.3 | Mechanism of action

It was plausible to expect a lesser impact on inequalities of *structural* interventions, ie, those that do not call into play the active

involvement of the individual; these interventions would thus likely be less influenced by personal characteristics, including socioeconomic characteristics.²⁹ Instead, what emerged from the review of the literature was that *structural*,^{82,87} *agentic*, ie, those that work only through the individual's participation,^{78,79,81} and *agentic-structural*^{74,76} interventions can all have negative effects on inequalities. In a previous systematic review on policies, Olstad and colleagues depict a similar scenario, identifying a negative impact on equity of both agentic and structural interventions, with a smaller proportion among agentic-structural interventions.²²

5.4 | Comments about types of intervention

Although it is not possible to identify types of interventions that have a lower risk of introducing inequity, some comments can be made regarding some specific actions. Counselling interventions proved to be at high risk of being ineffective or harmful to children of families with a lower education level³²⁻³⁴; this risk appears to decrease if the interventions are accompanied by contextual actions directed towards the general population.^{36,52,53}

Our review brought to light the fact that the vast majority of actions were implemented in the school setting (Figure 2). Although it is not surprising that interventions targeting children and adolescents are mostly implemented in a school setting, that this choice may exclude the most deprived and marginalized groups not attending any school, especially among adolescents, must be taken into account. Instead, interventions of taxing unhealthy foods or of reducing the price of healthy foods showed positive effects on reducing inequalities.^{28,87} Similar results were reported in previous systematic reviews, suggesting a combination of taxes and subsidies as a potential strategy to improve healthy eating among the deprived strata of the population.^{19,22} If, however, untaxing or reimbursement procedures are complex, these types of intervention may favour access of families with greater means, thereby producing a negative effect on inequalities.⁸²

5.4.1 | Scale up and pilot interventions

Although no clear pattern emerged between the results of the interventions evaluated and the level of implementation, ie, whether still in the experimental phase or already implemented on a large scale, some conclusions can be drawn. Specifically, it can be seen that pilot interventions implemented at the local level that do not appear to generate inequalities can have a negative impact once implemented at the regional or national level (scale up). For example, interventions that foresee modifying the school environment to support healthy eating habits primarily through the modification of the school canteen menu and/or control over vending machines at the community level almost never show negative effects on inequalities,^{38,40,44,45,50,51,54-56,66,67,88} unlike what is seen for similar interventions implemented at the system level.^{73,74,80} Generally speaking, pilot interventions arise and are implemented in contexts open to testing that are already sensitive to the problem of obesity and of healthy lifestyle. Instead, the subsequent extension of the same interventions to a macrolevel can

be perceived and implemented differently by various centres with differing competences and levels of motivation/collaboration. This may lead to obtaining results that differ for the same type of intervention, generally less favourable in contexts that are already disadvantaged, with a resulting increase in inequalities.

5.4.2 | Universal interventions, type of healthcare system, and implementation

The differences generated by the quality and level of implementation in the various geographical areas are particularly notable when one considers universal interventions like those in this review. This choice was made in accordance with the principles of the Italian National Health Service to achieve greater transferability of results to the Italian setting. In our country, the National Health Service proposes prevention interventions directed towards the whole population that include, when necessary, adaptations to support access of the more disadvantaged subgroups to existing services (universal interventions with tailored components). Making sure that universal interventions reach the entire target population is thus opportune given that otherwise, there is the risk of generating inequalities due to differing levels of exposure to the intervention, which cannot be measured by an internal evaluation of the intervention.

From this viewpoint, it is worth noting that almost all the interventions showing an effect on reducing inequalities were carried out in North America, and especially in the United States.^{36,53,77,83,85,87} This may be due to the fact that universal interventions in non-universal healthcare systems can partially reduce existing inequalities in access, especially in public health.

It is thus important to evaluate these interventions with a population-based approach so as to detect any inequalities in access or adherence that will inevitably translate into not only an increase in inequalities but also a reduction in the overall value of the interventions themselves in terms of impact of public health and the cost-benefit ratio.

5.5 | Limitations

Given the heterogeneity of included studies, the effectiveness and impact on inequalities of interventions were assessed according to the results and conclusions reported by the studies' authors rather than by extracting and analyzing raw data. Only in one case was there an appreciable inconsistency between conclusions and results, leading us to change the authors' conclusions from a possible negative effect on inequalities to a neutral one.⁵⁵ Although it may be imprecise, this method proves to be appropriate in a scoping review and guarantees a uniform method of assessment.

The classification of actions and interventions was done by only one reviewer; the classification could thus be influenced by subjectivity. This limitation was partially mitigated by a non-blind discussion with the supervisor.

Finally, as the assessment and reporting of the impact on inequalities was sporadic in the literature, a biased picture of the overall impact

on equity emerged, making quantitative interpretation rather difficult. It is possible that a negative impact on equity is more likely to be reported if it occurs in an intervention that was aimed at reducing differences, while when impact was not assessed in an intervention not focused on equity, it was not included in this systematic review.

6 | CONCLUSIONS

All the types of interventions included in our review, regardless of the setting, target, and/or mechanism of action, proved to be at risk of generating inequalities.

There is the need to evaluate by stratifying by socioeconomic level the local impact of prevention programs. More systematic reporting of the impact on equity will make it possible both to monitor effects, which our results showed to be unpredictable just on the basis of the intervention construct and to accumulate evidence on which intervention are more likely to increase or to reduce equity that would be generalizable.

The evidence shows that complex interventions acting on multiple targets, settings, and risk factors appear both to be more effective and to have a lower risk of increasing inequalities.

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SUPPORTING INFORMATION

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

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