

Interventions using behavioural insights to influence children's diet-related outcomes: A systematic review

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Summary

The global prevalence of children with overweight and obesity continues to rise. Obesity in childhood has dire long-term consequences on health, social and economic outcomes. Promising interventions using behavioural insights to address obesity in childhood have emerged. This systematic review examines the effectiveness and health equity implications of interventions using behavioural insights to improve children's diet-related outcomes. The search strategy included searches on six electronic databases, reference lists of previous systematic reviews and backward searching of all included studies. One-hundred and eight papers describing 137 interventions were included. Interventions using behavioural insights were effective at modifying children's diet-related outcomes in 74% of all included interventions. The most promising approaches involved using incentives, changing defaults and modifying the physical environment. Information provision alone was the least effective approach. Health equity implications were rarely analysed or discussed. There was limited evidence of the sustainability of interventions—both in relation to their overall effectiveness and cost-effectiveness. The limited evidence on health equity, long-term effectiveness and the cost-effectiveness of these interventions limit what can be inferred for policymakers. This review synthesises the use of behavioural insights to improve children's diet-related outcomes, which can be used to inform future interventions.

KEYWORDS

behavioural insights, nudge, obesity, children

1 | INTRODUCTION

The number of children aged five through 17 with obesity is projected to increase globally from 77.8 million in 2013 to 91.2 million by 2025 without substantial intervention.¹ Obesity in childhood has negative long-term consequences on health, social and economic outcomes.² The primary driver of obesity is energy imbalance, which is often caused by a poor diet consisting of an excess of energy-dense foods.² Many children live in obesogenic environments, in which the

consumption of energy-dense foods is encouraged through their increased availability, affordability and promotion.²

To address the obesogenic environment and reduce the global burden of obesity in childhood, multiple policy levers are required.² Policies informed by 'behavioural insights' (BIs) have demonstrated potential for improving children's diets. BIs is a broad term used to encapsulate the results of research on human behaviour undertaken in disciplines such as economics, psychology, sociology and neuroscience, providing an understanding of how human beings make choices

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(behave) given individual endowments, experiences and external influences.³ BIs draw on a range of theoretical frameworks from behavioural economics and psychology and other social sciences, including Kahneman's Dual Process Theory,⁴ Thaler's and Sunstein's Nudge Theory⁵ and Bandura's Social Cognitive Theory. By drawing on a wide range of concepts and findings, BIs provide a more comprehensive understanding of the factors that influence human behaviour than individual theories of disciplines.

Typically, interventions using BIs influence an individual's behaviour through subtle changes to the social and physical environment without actively restricting available options.⁶ These changes attempt to reduce the cognitive biases in the decision-making process that prevent individuals from adopting self-interested behaviours,⁷ such as healthy eating. Previous research has shown incentives, social norms and environmental cues are important drivers of children's dietary choices.⁸ Thus, children's reliance on social norms (adult or peer influence) environment cues (meal size/composition indicators) to dictate appropriate eating behaviour suggests that children may be particularly amenable to interventions using BIs. Interventions using BIs can also be implemented at a relatively low cost and preserve free choice, thus are often easier to implement than major mandatory regulatory changes—such as taxation.⁹

Previous systematic reviews on diet-related topics have focused on a single BIs precept. For example, many reviews have focused on nudge interventions,^{7,10–14} which centre on modifying the choice architecture without significantly changing financial incentives or restricting options.¹⁵ Other reviews have focused on singular behavioural economics precepts^{16–21} such as incentives or anchoring, which are derived from economic theory and social psychology.¹⁵ This review extends beyond previous reviews as we focus on a broader range of insights from the behavioural and social sciences, which are reflected in Table 1. This current review used the framework proposed by Bauer and Reisch,³ who classified interventions into one of five categories: (1) provision of information; (2) use of salience and social norms; (3) changes in the defaults; (4) changes to the physical environment; and (5) incentives and preplanning (Table 1).

Interest in BIs has grown in many governments, which has led governments in countries such as the United Kingdom²² and the United States²³ to establish dedicated teams tasked with applying BIs to public policy. Additionally, the Organisation for Economic Co-operation and Development, World Bank and European Commission have produced policy reports on BIs in recent years,^{24–26} which cover the policy efficacy of BIs in areas including energy, health and finance.

Major health inequities are created via the unequal distribution of obesity burden by sociodemographic characteristics.² Health equity is a commitment to reduce, and ultimately eliminate, disparities in health.²⁷ In this review, we focus on 'health equity elements', which are the sociodemographic characteristics (e.g., sex, socioeconomic status and ethnicity) by which obesity is unfairly distributed, leading to major health inequities. The World Health Organization (WHO) has highlighted the centrality of equity in the design and implementation of obesity policies to protect against worsening inequities and actively

TABLE 1 Framework of interventions using behavioural insights developed by Bauer and Reisch³ with examples of food-related subcategories (added by authors)

Behavioural insights	Definition	Subcategories
Provision of information	Interventions that improve the communication of nutritional knowledge	Suggesting serving size on front-of-package labelling, calorie labelling, nutritional facts
Salience and social norms	Interventions that aim to make health a relevant consideration in the moment of decision making	Presenting visual or verbal cues, priming, social modelling
Changes in defaults	Making healthier options the default choices	Changing default meal and side options
Changes to the physical environment	Altering the location, presentation, and composition of food to foster healthier choices	Changing the portion or unit size of product, changing the presentation, accessibility, or serving style of foods
Incentives and preplanning	The use of incentives and precommitment to alter food choices	Tangible rewards, social rewards, preordering or precommitment devices

reduce them.²⁸ Evidence of the health equity potential of policies using BIs is unclear, with some evidenced of exacerbating^{3,29} and others reducing existing inequities.^{30,31}

To date, there appears to be only one review of systematic review that focused on and classified BIs interventions.³ Previous systematic reviews of diet-related interventions using BIs have focused on education,^{13,21,32} home⁷ and food retail¹⁴ settings but have not compared the effectiveness by setting. The populations within these reviews also vary, as some exclusively focus on adults,^{12,14,17,32} or children,^{7,19,21} or both.^{3,10,11,16,18,20,33,34} In addition, previous reviews have not prioritised health equity in their evaluations. We aim to assess the effectiveness and equity potential of interventions using BIs to improve children's diet-related outcomes in all settings.

2 | METHOD

This systematic review was prospectively registered in January 2019 with the International Prospective Register of Systematic Reviews (PROSPERO, CRD42019123065 http://www.crd.york.ac.uk/PROSPERO/display_record.php?ID=CRD42019123065).

2.1 | Search strategy

The Population, Intervention, Comparison and Outcome framework was used to formulate our search strategy (Table 2). The key exclusion criteria were children with severe comorbidities or only children with obesity, interventions that included a non-BIs component (e.g., school curriculum), interventions focusing on attitudes or hypothetical food choices and cross-sectional studies. We chose to exclude

TABLE 2 PICO inclusion and exclusion criteria for a systematic review on interventions using behavioural insights to influence children's diet-related outcomes

PICO feature	Included	Excluded
Population	Children <18 years of age	Children with critical illness or severe comorbidities (e.g., Diabetes). Children from special populations (e.g., blind, physically disabled). Studies with only children with obesity
Intervention (s)	Behaviour-changing interventions aimed at improving diet-related outcomes that used one or more BIs. No restriction on who delivered the interventions, for example, researchers, teachers, food retailers or governments. No limits on the length of the intervention or follow-up	Interventions including those treating obesity. Interventions with additional non-BI components, such as an education curriculum
Comparison (s)	Comparators include no intervention	N/A
Outcomes	Primary outcomes: changes in food or beverage selection or consumption Secondary outcomes: cost of intervention, cost for participation Health equity elements: changes in outcomes by key sociodemographic characteristics	Changes in awareness, knowledge or beliefs, hypothetical food choices
Study design	Randomised control trial (RCT), nonrandomised control trials, controlled before-and-after, interrupted time series and before-after studies	Cross-sectional studies

Abbreviation: PICO, Population, Intervention, Comparison and Outcome.

multicomponent studies because we could not isolate the effect of the BI components from the other intervention components. The search strategy was designed in consultation with a specialist health sciences librarian from Imperial College London and members of the British Cabinet Office's Behavioural Insights Team.

We searched for relevant articles published in peer-reviewed journals from January 1994 until January 2019 through keyword searches on EMBASE, MEDLINE, CENTRAL, PsycINFO SCOPUS and Global Health (Data S1). The search strategy was refined by conducting a sensitivity analysis in EMBASE with a test set of 20 key papers purposely selected from existing systematic reviews. Adjustments to the search strategy concluded once 90% of the key papers were identified. In addition to database searches, we included all references from 10 relevant systematic reviews^{3,7,10,13,14,18–20,33,34} and backward searched all the reference lists of included studies. We did not include grey literature given the large number of peer-reviewed studies on the topic.

2.2 | Data extraction and risk of bias assessment

Data extraction and risk of bias (RoB) assessment procedures were conducted by two independent reviewers. One reviewer conducted all procedures in full while a second reviewer conducting a cross-check of 10% of the studies at each stage of the data extraction and RoB assessment procedures.^{35–37}

Abstract and title screening were conducted using the reference managing software, *Rayyan*.³⁸ Full text screening was conducted in EndNote using the Population, Intervention, Comparison and Outcome inclusion and exclusion criteria. Information extracted on the characteristics and outcome data of eligible studies included title, setting, country, design, sample, participants, control group, duration, BIs and results, including by health equity elements. Each intervention was classified according to Bauer and Reisch's framework.³ When an intervention used multiple BIs, each unique BI concept was recorded and analysed as a separate category (multiple components). The Cochrane RoB criteria was used to assess RoB for each randomised control trial (RCT) study. Studies were graded low, unclear or high risk for each RoB category.³⁹ An adapted Newcastle–Ottawa RoB tool was used for nonrandomised studies.⁴⁰ We opted for the Newcastle–Ottawa RoB tool as our review contained a large amount of before–after studies that have not been validated using tools such as ROBINS-I. Our approach is consistent with recent reviews on obesity containing before–after studies and nonrandomised studies.

2.3 | Data analysis

The main analysis was conducted at the intervention level. Unique interventions were defined as different experimental conditions within an intervention or a separate intervention reported within the same article. Intervention effectiveness was defined as having one or more statistically significant findings ($p \leq 0.05$ level) that changed

children's selection or consumption of food or beverages. Outcomes were classified into four categories: (1) fruit and vegetables (F&V); (2) total energy intake (3) healthy meals, snacks, sides and beverages (MSSB); and (4) unhealthy MSSB. The nutrient profile of the foods was frequently unavailable so there is a level of subjectivity in the classification system. However, most foods were easily categorised because most unhealthy MSSB included candy, sugary beverages or fast food, whereas healthy MSSB included milk or a healthier meal option. Effectiveness was evaluated as a binary outcome, where 1 represented a significant finding, and 0 represented a nonsignificant finding. Comparisons of effectiveness were assessed according to the following characteristics: setting, study design, follow-up length and food outcome type. A detailed analysis of the effectiveness of interventions were stratified by BI type and health equity elements. Comparisons for differences were conducted using chi-squared and Fisher's exact tests ($p \leq 0.05$ significance level). A meta-analysis was not performed due to the heterogeneity of outcomes, their measurement and reporting across studies.

3 | RESULTS

3.1 | Search strategy

The review was conducted and reported in adherence to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses. Figure 1 shows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram outlining the study identification, screening and exclusion processes. The search strategy yielded 5671 unique titles. In total, 5394 were excluded after title and abstract screening, leaving 277 articles eligible for full-text screening. During full-text screening, 186 articles were excluded. An additional 17 articles were included from manual searching of the included articles ($n = 91$). The final analytic sample for the qualitative synthesis included 108 articles (see Data S2 for characteristics and full list of included studies). From these 108 articles, there were 137 unique interventions.

3.2 | Characteristics and effectiveness of interventions using behavioural insights

3.2.1 | Overall effectiveness

The characteristics and effectiveness of the 137 unique BIs interventions are displayed in Table 3. In total, 102 (74%) of interventions had a statistically significant and positive effect on the targeted diet-related outcome.

3.2.2 | Study design

Over half of the interventions were RCTs ($n = 79$, 58%), followed by before–after studies ($n = 29$, 21%) and controlled before–after studies

(CBA) ($n = 18$, 13%). Before–after studies produced statistically significant results 97% of the time, compared with CBA studies and non-RCT studies that had statistically significant results only 50% and 55% of the time, respectively ($p = 0.001$).

3.2.3 | Settings

Education settings were the most common setting for interventions, covering 78% ($n = 107$) of all included interventions. The remaining studies were equally conducted in different settings. In terms of effectiveness within settings, lab-based interventions (100%, $n = 7$) and primary schools (80%, $n = 80$) showed the most consistent effectiveness compared with the food retail (25%, $n = 8$) and home settings (57%, $n = 7$) ($p = 0.018$).

3.2.4 | Follow-up

Follow up refers to the time between the outcome measurement at the end of the intervention and any subsequent outcome measurements. Evidence of sustained effectiveness was limited; only 21 (15%) interventions had long-term follow-ups (greater than 1 month) and 16 (12%) interventions had short-term follow-ups (less than 1 month). Evidence suggests intervention effects are time sensitive as only 56% and 52% interventions showed sustained effectiveness in the short term and long term, respectively. Of the 10 long-term follow-ups without sustained effectiveness, three had initially showed effectiveness post intervention but not at follow-up. Likewise, for interventions with short-term follow-ups, five of the seven interventions evidenced effectiveness post intervention, but it was not sustained at follow-up.

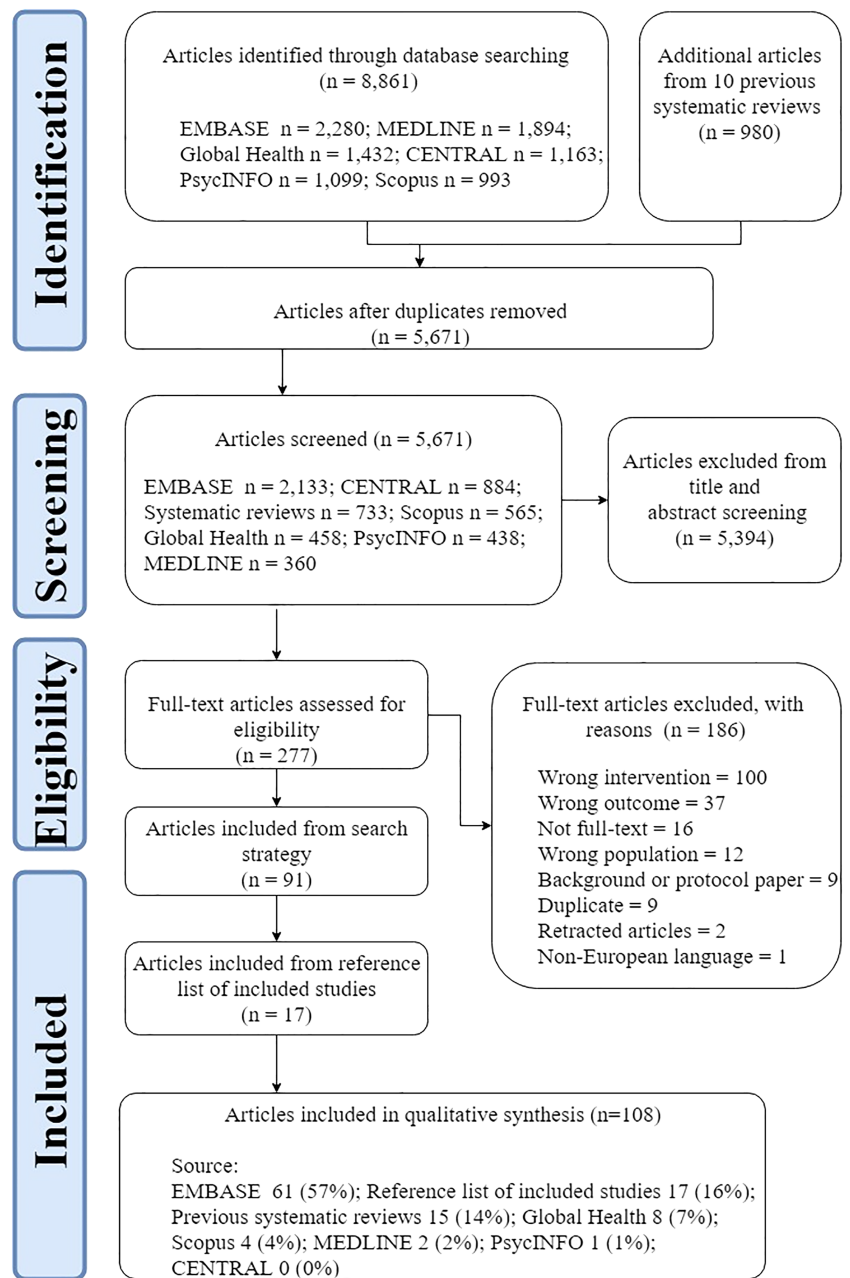
3.2.5 | Food type

The most commonly reported intervention outcome was F&V consumption ($n = 99$, 72%). The other intervention outcomes included total energy intake ($n = 22$, 16%), unhealthy MSSB ($n = 23$, 17%) and healthy MSSB ($n = 25$, 18%). There were no statistically significant differences in effectiveness by food type, despite interventions targeting healthier foods showing more consistent effectiveness (between 74% and 84% effectiveness across outcomes) compared with unhealthy foods (57% effectiveness). This finding was reinforced when the effectiveness of interventions for healthy foods (F&V and healthy MSSB combined) are directly compared with unhealthy MSSB (76% vs 57% effectiveness, $p = 0.056$).

3.3 | Behavioural insights type

Panel A of Table 4 shows the effectiveness of interventions and the number of interventions that evaluated health equity elements. We

FIGURE 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow chart for systematic review on interventions using behavioural insights



categorised these interventions by BIs, including a category for multiple BIs. Implementing changes to the physical environment was the most common intervention category ($n = 41$, 30%) followed by salience ($n = 26$, 19%) and incentives ($n = 20$, 14%). Overall, there were no statistically significant differences in effectiveness between intervention BIs categories when the multiple category was included in the analysis ($p = 0.119$). However, the poor effectiveness of information provision ($n = 7$, 29%), when used in isolation, suggested this was not an effective approach.

Just under half ($n = 64$, 47%) the interventions tested for differential effects by one or more sociodemographic characteristics; 44 interventions investigated differences by sex, 41 by age, 32 by BMI, 10 by SES and eight by ethnicity. There were 23 examples of differential

effects, with the most evidence showing slight differences by age ($n = 11$), sex ($n = 5$), SES ($n = 4$), ethnicity ($n = 2$) and BMI ($n = 1$). Whereas there were no statistically significant differences between BIs intervention categories in relation to their health equity implications ($p = 0.065$), interventions using incentives, which tested for differential effects, reported statistically significant differences 58% of the time compared with only 14% for salience and 20% for changes to the physical environment.

Panel B of Table 4 removes the category for multiple BIs, meaning that interventions that used multiple BIs can be represented multiple times in Panel B. This analysis shows that salience was the most used BIs category overall ($n = 62$, 45% of all interventions), followed by changes to the physical environment ($n = 51$, 38%) and incentives

TABLE 3 Study characteristics and effectiveness of interventions using behavioural insights to influence children's diet-related outcomes

Study characteristics		N (%)		Significant findings/total (%) ^a		p value ^b	
Total		137	(100)	102/137	(74)		
Study design	RCT	79	(58)	59/79	(75)		
	Before-after	29	(21)	28/29	(97)		
	CBA	18	(13)	9/18	(50)		
	Non-RCT	11	(8)	6/11	(55)	0.001	
Setting	Primary school	80	(58)	64/80	(80)		
	Early childhood	18	(13)	13/18	(72)		
	Secondary school	9	(7)	6/9	(67)		
	Food retail	8	(6)	2/8	(25)		
	Community venue	8	(6)	6/8	(75)		
	Lab	7	(5)	7/7	(100)		
	Home	7	(5)	4/7	(57)	0.018	
Follow-up	Long (>1 month)	21	(15)	11/21	(52)		
	Short (<1 month)	16	(12)	9/16	(56)	0.815	
Food type ^c	F&V	99	(72)	73/99	(74)		
	Healthy MSSB ^d	25	(18)	21/25	(84)		
	Unhealthy MSSB ^d	23	(17)	13/23	(57)		
	Total energy intake	22	(16)	16/22	(73)	0.206	
Food type collapsed	Healthy	124	(91)	94/124	(76)		
	Unhealthy	23	(17)	13/23	(57)	0.056	

Abbreviations: CBA, controlled before-after study; RCT, randomised control trial.

^aDefined as a significant difference at $p \leq 0.05$ level.

^bp value for significant differences calculated using chi-squared or Fisher's exact tests.

^cPercentages add up to more than 100% because interventions could analyse one or more of the categories.

^dMSSB = meals, snacks, sides and beverages (not including fruits or vegetables).

TABLE 4 Effectiveness of interventions using behavioural insights to influence children's diet-related outcomes stratified by behavioural insight, including a category for multiple behavioural insights (Panel A), and with multiple behavioural insights category removed (Panel B)

Panel A: BIs, multiple category	n (%)		n = significant/total (%)		n with any equity element/total (%)		n = significant/total (%)	
Total	137	(100)	102/137	(74)	64/137	(47)	19/64	(30)
Multiple	38	(28)	31/38	(82)	16/38	(42)	6/16	(38)
Information provision	7	(5)	2/7	(29)	4/7	(57)	0/4	(0)
Saliency	26	(19)	18/26	(69)	7/26	(27)	1/7	(14)
Defaults	5	(4)	4/5	(80)	0/5	(0)	0/5	(0)
Physical environment	41	(30)	32/41	(78)	25/41	(61)	5/25	(20)
Incentives	20	(14)	15/20	(75)	12/20	(60)	7/12	(58)
Panel B: BIs, no multiple category ^a	n (%)		n = significant/total (%)		n with any equity element/total (%)		n = significant/total (%)	
Total	137	(100)	102/137	(74)	64/137	(47)	19/64	(30)
Information provision	16	(12)	9/16	(56)	10/16	(63)	2/16	(13)
Saliency	62	(45)	47/62	(76)	23/62	(37)	7/23	(30)
Defaults	7	(5)	5/7	(71)	0/7	(0)	0/0	(0)
Physical environment	51	(38)	41/51	(80)	29/51	(57)	5/29	(17)
Incentives	46	(34)	36/46	(78)	21/46	(46)	10/21	(48)

^aNote the percentage of studies will cumulatively be higher than 100% because each study could utilise multiple behavioural insights.

($n = 46$, 34%). However, as in Panel A, there were no statistically significant differences detected in the effectiveness between BIs categories ($p = 0.386$) or in health equity implications ($p = 0.051$). Further, as

in Panel A, interventions using incentives, which investigated differential effects, found statistically significant effects 48% of the time compared with interventions using information provision ($n = 2$, 13%),

salience ($n = 7$, 30%) and physical environment ($n = 5$, 17%). To investigate which characteristics of these interventions were most effective, results are presented by BIs category using information from both Panels A and B of Table 4.

3.3.1 | Information provision

In total, 16 interventions utilised information provision ($n = 16$, 56% effective); seven of these interventions focused on information provision exclusively ($n = 7$, 29% effective), and nine used it as part of a multiple BIs intervention ($n = 9$, 78% effective). The most common type of intervention included the provision of nutritional facts such as “carrots contain vitamin C” ($n = 11$, 64% effective), followed by manipulations of serving size pictures on packaging ($n = 3$, 67% effective) and provision of caloric information ($n = 2$, 0% effective).

Health equity elements were evaluated in 10 of the 16 interventions, with two finding significant differences based on sociodemographic characteristics. In both cases, the interventions used multiple BIs so these differential effects cannot necessarily be entirely attributed to information provision.

3.3.2 | Salience and social norms

In total, 62 interventions used salience ($n = 62$, 76% effective). Of these, 26 interventions used salience exclusively ($n = 26$, 69% effective) and another 36 used it as part of a multiple BIs intervention ($n = 36$, 81% effective). The most common types of interventions used visual cues such as positive emoticons next to healthy options ($n = 21$, 76% effective) or social modelling of behaviour by teachers, staff or other children ($n = 21$, 90% effective). The next most common intervention used priming ($n = 12$, 75% effective), such as providing a sample of a vegetable snack before a main meal containing the same or similar item, whereas verbal cues were the least used and effective interventions ($n = 10$, 50% effective).

Health equity elements were evaluated in 23 of the 62 interventions, with seven interventions finding statistically significant differences by sociodemographic characteristics differences. Three of these came from a single intervention that showed that an on-screen prompt during preordering meals was more effective with non-White students, low SES and male students compared with their White, high SES and female counterparts.⁴¹ Three interventions showed differential effects for age where tangible rewards had greater effectiveness for younger children (aged 5–8) than older children (9–12).^{42,43} One study showed differential effects by the child's BMI and demonstrated that children with healthy weight were more sensitive to social modelling of a peer's eating compared with children with overweight or obesity.⁴⁴

Seven interventions had short-term (less than 1 month) and 13 long-term (greater than 1 month) follow-ups. Six of the seven short-term follow-up showed sustained effectiveness, while

only seven of the 13 long-term follow-ups showed sustained effectiveness.

3.3.3 | Defaults

In total, seven interventions used defaults ($n = 7$, 71% effective). Five of these interventions focused on defaults exclusively ($n = 5$, 80% effective), whereas another two used defaults as part of a multiple BIs intervention ($n = 2$, 50% effective). The defaults usually involved changing the default side option from an unhealthy side option (e.g., fries) to a healthier option (e.g., apple slices) ($n = 5$). Other examples include changing the default meal to a healthier option with a less healthier option available upon request ($n = 2$). None of these interventions evaluated the health equity implications or the sustained effectiveness.

3.3.4 | Physical environment

In total, 51 interventions made changes to the physical environment ($n = 51$, 80% effective), 41 interventions focused on physical environment exclusively ($n = 41$, 72% effective), whereas another 10 were part of multiple BIs interventions ($n = 10$, 90% effective). The most common interventions manipulated portion size ($n = 18$, 92% effective). The next most common intervention changed accessibility ($n = 13$, 85% effective). Examples of accessibility changes included the following: creating convenience lines for healthy foods, slicing fruits to make them easier to eat or placing healthy products in prominent places. The least-used interventions changed the unit size by cutting a single unit (e.g., 100 g cookie) into smaller units (e.g., four 25 g cookies) ($n = 2$, 50% effective) or changing the size of plates, utensils or serving containers ($n = 5$, 100% effective).

At least one health equity element was evaluated in 29 of the 51 interventions, with only five finding any significant differences by sociodemographic characteristics. For age, in three interventions, older children (aged 6+ y/o) consumed more when given a larger portion size compared with younger children (under 5 y/o).^{45–47} In one other intervention, sliced fruit increased consumption for younger children (aged 6–9 y/o) more than for older children (10–12 y/o).⁴⁸ In one intervention, increased dishware size increased the amount of food self-served and consumed by children of low SES.⁴⁹ One of these interventions had a short-term follow-up and two had a long-term follow-up; all showed sustained effectiveness.

3.3.5 | Incentives and precommitments

In total, 46 interventions used incentives to change children's diet-related outcomes ($n = 46$, 78% effective), 20 interventions focused on incentives exclusively ($n = 20$, 75% effective) and another 26 used incentives as part of multiple BIs interventions ($n = 26$, 81% effective). Most interventions used tangible incentives such as stickers,

stationary, temporary tattoos or toys ($n = 35$, 80% effective), whereas nine others used social incentives ($n = 9$, 78% effective) such as verbal praise or competition. Only four interventions used precommitment devices, such as a preordering system for school lunches or a F&V subscription programme ($n = 4$, 75% effective).

At least one health equity element was evaluated in 21 of the 46 interventions, with 10 reporting at least one significant difference by sociodemographic characteristics. There were mixed results for age, with three interventions being more effective on younger children (aged 6–9 y/o) than older children (aged 10–12 y/o),^{43,50,51} whereas two other interventions showed the opposite.^{42,43} Incentives that successfully influenced younger children included tangible monetary rewards (25c), stickers or toys. Incentives for older children included a precommitment pledge and tangible incentives such as stickers and stationary. One intervention showed that small monetary rewards (25c) were more effective for low SES children compared with their high SES counterparts.⁵²

In total, 13 interventions had short-term follow-ups and 20 interventions had long-term follow-ups. Six of the 13 interventions with short-term follow-ups had sustained effectiveness, whereas 10 of 20 interventions with long-term follow-ups showed sustained effectiveness.

3.4 | RoB assessment

3.4.1 | Randomized control trial

In total, 37 studies had only one to three out of eight RoB categories graded as low risk, 46 had four or five RoB categories graded as low risk and only six had six to eight, which suggests most studies had many sources of potential bias. In general, the greatest RoB came from the randomisation procedure (87% of studies graded high or unclear risk), attrition bias (59% graded high or unclear risk) and knowledge allocation (100% graded high or unclear risk). Studies generally accounted for differences in baseline characteristics (18% high risk) and outcomes (31% high risk).

3.4.2 | Nonrandomised studies

Overall, 17 studies were graded as low RoB. The remaining 41 studies were graded as high RoB, with 29 of these being before–after studies.

Thirty (52%) interventions were graded as high risk for selection criteria due to a lack participant representativeness, 37 (64%) were high risk for differences in baseline characteristics and 34 (59%) for differences in baseline outcomes. For adjustment, 38 (66%) interventions were graded as high risk for not appropriately adjusting for common confounders and 47 (81%) interventions for not controlling for extra confounders. Only 10 (17%) interventions were graded as high risk for outcome ascertainment, whereas 39 (67%) were graded as high risk for attrition bias. Most studies being graded as low risk for outcome ascertainment reflects that most studies used direct

observation, either using researcher observation or scales, to measure outcomes.

3.5 | Secondary outcomes—cost

When the cost of the intervention was reported, there was evidence that behaviour change could be cost-effective. However, only eight of the interventions reported either implementation costs or a cost-effectiveness analysis.^{6,50,52–56} Examples of reported implementation costs include \$2000 USD per school,⁵⁴ \$12.50 (plus teacher labour costs) per child,⁵³ while another intervention cost only \$0.03 USD per cafeteria tray.⁵⁶ Multiple interventions estimated the cost per additional serving of F&V to be between \$0.01 USD and \$1.72 USD.^{6,50,52} Additionally, one food retail intervention actually increased profits,⁵⁷ demonstrating the revenue potential of guiding consumers towards healthier products. However, all interventions but one were based in the United States, and all but one occurred within school cafeterias, which limits the generalisability of these findings to other settings or to BIs interventions in general. Additionally, when implementation costs are provided, there is lack of comprehensive cost-benefit analyses.

4 | DISCUSSION

Overall, this systematic review included 108 articles, with 137 unique interventions. Just under three-quarters of included interventions demonstrated at least one statistically significant positive effect on children's diet-related outcomes. These findings show that even small changes in children's physical and social environments can significantly influence their diet-related outcomes. However, evidence on the sustained effectiveness and the health equity implications of interventions was limited. Most studies were at high RoB, leaving open questions about the robustness of the results.

4.1 | Study characteristics

Interventions that used before–after study designs consistently reported positive statistically significant findings compared with interventions that used RCTs and CBA study designs. Before–after studies tend to overestimate intervention effects due to the uncontrolled biases inherent in such designs.⁵⁸ In contrast, the findings in highly controlled lab-based RCTs ($n = 7$) may not translate into real-world settings.¹⁰ These results reinforce researchers' calls for BIs interventions to implement more robust study designs, with a higher degree of external validity.^{3,17}

Expectedly, 78% of the interventions in this review took place within educational settings. Schools provide greater accessibility to large numbers of children and control over some of the environmental conditions that reduce potential sources of confounding. The over-emphasis on school settings has left a sizable gap in the literature,

particularly in the home and food retail environments, which are settings where a substantial amount of children's food choices are made and calories are consumed.⁵⁹ The lack of evidence in the food retail environment is disappointing given the extensive research into the physical and social elements within such environments that drive consumer behaviour conducted by private companies.⁶⁰

Fruit and vegetable consumption was the most common outcome investigated. When F&V and healthy MSSB outcomes were combined and compared against unhealthy MSSB, we found that interventions targeting healthier options were typically more effective than those targeting unhealthy options. This result contrasts to a previous systematic review, which included adult populations, that showed that reducing unhealthy eating was easier than increasing healthy eating.¹⁰ However, children often struggle to evaluate the long-term health consequences of their decisions against short-term rewards and have been consistently shown to have higher discount rates (present-oriented preferences) compared with adults.⁶¹ Therefore, it is less surprising that children may not be able to appropriately weigh-up the short-term reward of eating tasty and convenient unhealthy foods against the intangible and delayed reward of long-term health.

4.2 | Behavioural insights type

The lack of evidence of information provision interventions for children may be due to existing evidence in adults that show limited effects of these types of interventions.¹⁰ Our results also showed the limited effectiveness of interventions using information provision alone (29% effective). A previous review showed that cognitively oriented interventions, like information provision, were the least effective largely because they require the greatest cognitive input and thus are most susceptible to cognitive biases.¹⁰

Interventions using information provision in combination with other BIs were more effective (67%), suggesting that information provision can contribute to behaviour change but is insufficient by itself. We also found interventions that used health facts rather than calorie information were more effective. Health facts may be more effective as they often elicit an emotional response, whereas, for many, caloric information is an abstract or foreign concept.¹⁷ People generally find interpreting numeric information difficult, which is a major health communication problem, particularly for children.⁶²

Interventions most commonly used salience. Social modelling was both the most effective and prevalent subtype of interventions using salience. Social modelling creates social norms that signal a code for appropriate behaviour and is particularly powerful if presented at the time of decision making and by actors that are important to children.⁶³ Visual cues were equally as effective as social modelling, and implementation generally involved minimal time and less monetary investment. Visual cues go beyond simple information provision by providing relevant cues that appeal to the emotional state of individuals.¹⁷ For children, simple cues such as smiley face emoticons or attractive names of healthy products were enough to improve diet-related outcomes.^{64,65}

Few studies directly examined the impact of defaults alone, but those that did demonstrated high effectiveness. Defaults influence behaviour largely through status quo bias, by which, cognitive inertia guides people to stay with the current option (e.g., having to evaluate alternative options) or the default option communicates the socially expected choices (e.g., 'regular size' signals).³ Both mechanisms are likely to influence children disproportionately compared with adults as children often defer to people of authority for decisions or look to others for social norms. Defaults are typically low-cost as they change the choice architecture with no redistribution of underlining resources.⁹ The behaviour change potential of defaults makes their scarcity in this review even more surprising and highlights an area that deserves further investigation.

Changes to the physical environment was a common and effective intervention in this review. Our results support previous findings with adults that show the efficacy of modifying portion size, increasing accessibility and presentation of healthy foods.^{3,11,12} Increased portion sizes were generally associated with increased consumption but seemed to have less effect for younger children (under 5 y/o) than for older children, which suggests portion size may become a more important environmental cue as children get older. Portion size control may be particularly important for unhealthy, usually ultra-processed, foods that may promote overconsumption through their high energy density, high palatability and disruption of gut-brain signalling.⁶⁶

Accessibility was frequently used in these interventions to either make healthy foods more accessible or unhealthy food less accessible. Accessibility relates to the time or effort required to mentally and physically access an option.¹² Food retailers have contributed substantial resources to research and experimentation of how accessibility impacts consumer behaviour.⁶⁰ Unfortunately, these insights are often not publicly available. Instead, they are commonly used in retail environments to increase profits by driving demand for products with higher margins. Other times, they are used to charge companies extra for premium shelf space. In both, these profit mechanisms tend to favour the promotion of unhealthy foods. In environments where the incentives are shifted from profits to child well-being, such as the school environment, manipulating the accessibility of healthy foods is a particularly low-cost and effective approach.

Incentives were among the most effective BIs interventions. Incentives varied, but their effectiveness did not differ between tangible and social incentives. Incentive-based interventions are regularly viewed as costly or labour intensive; however, children were motivated by very small tangible rewards (e.g., pencils, toys and glow sticks). The efficacy of social rewards may highlight cost-effective and sustainable insights into deploying health interventions with limited resources. For example, two interventions used competition with fellow students or students from fictional schools to increase F&V consumption.^{67,68} Likewise, simple social rewards such as verbal praise from school staff or ringing a bell during school lunch were effective incentives for children.^{51,69}

Preordering or precommitment devices were rarely used in this review but highlight a key area for further exploration given the

proposed mechanisms behind their efficacy. First, preordering removes hunger-based decisions typical of mealtime and removes the environmental cues associated with selecting less healthy options.⁷⁰ Second, preordering enables the modification of the choice architecture to promote healthy default options⁷¹ or opportunities for targeted healthy nudges.⁴¹

4.3 | Health equity

The WHO recommends equity be a central component in the design and implementation of health policies to ensure inequities do not worsen and are actively reduced.²⁸ Over half of the interventions in this review failed to explore even one equity element. Sex and age were most commonly tested for differential effects, as these characteristics are typically readily available during data collection.²

Only 10 interventions investigated differences by SES and only eight by ethnicity, which is concerning given the wide-spread patterning of children with obesity by SES levels and ethnicity.² In some jurisdictions, like New Zealand, the lack of investigation into ethnic differences contradicts constitution arrangements and undermines the fundamental principles of health equity. For example, *Te Tiriti o Waitangi*, New Zealand's founding document, enshrines the right of Māori (New Zealand's indigenous population) to the same levels of health as non-Māori. Research is required to demonstrate how it upholds the Principles of the Treaty.

Even when equity elements were investigated, rarely were differential effects observed. One potential explanation for this lack of investigation or detection of differential effects may be because interventions were underpowered to detect significant effects between subgroups. Another explanation is the reliance on field experiments made obtaining detailed individual-level data difficult. Future studies should prioritise subgroup analyses and investigate health equity as a central research question. The lack of analysis of differential effects limits the policy relevance of Bls interventions as health equity is a key consideration for policymakers.⁷²

4.4 | Sustainability

A small proportion (15%) of interventions included a follow-up period, which highlights a major limitation in the literature. Of these studies investigating effects post intervention, only about half showed sustained effectiveness. Further, just under half of the interventions failing to show effects at follow-up had initially demonstrated effectiveness post intervention. This is a cautionary note for interpreting the efficacy of Bls interventions without follow-up measurements. More evidence of the long-term effects of these interventions is required to make conclusions about their sustainability for policymakers.

Another issue for assessing the sustainability of interventions using Bls was the relatively short duration of studies. Forty percent of studies lasted less than one week and 92% lasted less than 6 months.

It is entirely likely that changes in diet during a 1-week intervention do not have lasting effects on children's dietary behaviour when the intervention is removed or perhaps even during a longer exposure to the intervention (as behaviour change may be initially driven by a novelty effect).

Unfortunately, only a small proportion of studies reported the implementation costs or conducted a cost-effective analysis. A small sample did show that interventions could be implemented at a low cost, which if scaled could be substantially reduced. For example, the placement of temporary visual cues in school cafeteria trays cost as little as three cents per tray, which if implemented permanently would incur lower costs once manufacturing was established.

4.5 | Strengths and limitations

This review has several methodological strengths. First, the search strategy included a sensitivity analysis, which is particularly pertinent given the majority of papers contained no reference to Bls terms. Second, the search strategy also included six databases, references from 10 systematic reviews and backward reference searching of included studies. Third, a second reviewer ensured that the data extraction and RoB assessment procedures were applied consistently.

Although this review provides a comprehensive examination of Bls interventions targeting children's diet-related outcomes, it is not without limitations. First, due to heterogeneity between studies, we had to categorise intervention effectiveness into a binary variable, either significant or nonsignificant finding, which may overstate the effectiveness of some interventions. Further, without calculating intervention effect sizes, we lack precision on the magnitude of the intervention effectiveness. Second, publication bias, where studies failing to produce statistically significant results are less likely to be published than studies with significant findings, may have led to an overestimate in the effectiveness of Bls studies. Third, our review excluded all multicomponent studies that included a non-Bls aspect, such as an education curriculum. Considering that obesity is a complex problem, it is likely that effective obesity prevention interventions must include multiple policy approaches and that interventions using Bls alone are insufficient to make substantial changes in rates of children with obesity. As such, the results of this review highlight aspects of Bls that may be more effective to inform future interventions.

The lack of intervention follow-up made the examination of obesity-related outcomes impracticable—leading to very few studies investigating changes in weight status. While changing children's consumption of fruits and vegetables is likely to improve children's overall diet and nutritional intake, it does not necessarily translate to improved obesity-related outcomes. First, individuals can negate the effect of increased healthy behaviours by partaking in other less healthy behaviours.⁶² For example, increasing fruit and vegetable consumption may inadvertently help individuals internally justify the consumption of less healthy foods. Second, increasing fruit

and vegetable consumption is not directly linked with less overall caloric intake.⁷³

4.6 | Future research and policy implications

Future research on BIs interventions should focus on providing evidence of their sustainability. To better inform policy, future interventions require longer study durations and follow-ups to access the sustainability of behaviour change. There is also a need for better documentation and analysis of the costs of interventions to determine their cost-effectiveness. There is also an urgent need for evidence of the health equity implications of BIs interventions, particularly for analyses of SES and ethnicity. Future studies should attempt to obtain sample sizes with sufficient statistical power to detect meaningful differences, including enough data to test for differential effects by sociodemographic characteristics.

There is currently an overemphasis on interventions in education settings, thus additional studies in food retail and home settings would provide a substantial contribution to the existing evidence. Finally, there is a need for additional interventions utilising a non-lab based RCT study design to overcome the reliance on studies with a high RoB, such as before-after studies, which may misrepresent the effectiveness of these interventions.

This review highlights areas where BIs may be useful for developing and implementing obesity-related policy. Importantly, this review has reinforced previous findings suggesting that information provision alone is insufficient for changing behaviour. It is clear that more effective BIs, such as changing defaults or the physical environment, are required to induce and sustain behaviour change. The large amount of studies in the school environment with significant findings, coupled with the governments' ability to regulate most school settings, suggest this is an area where governments can most easily affect behaviour change in children. Secondary findings in this review demonstrate that such interventions can be implemented at a very low cost. However, in sum, the current evidence does not provide strong evidence for policymakers as there is a lack of evidence of sustained effectiveness, impact on obesity-related outcomes or implications for health equity. Additionally, only seven interventions reported either their implementation costs or a cost-effectiveness analysis, which is a major barrier to providing policy recommendations.

5 | CONCLUSION

Overall, interventions using BIs can influence children's diet-related outcomes. Interventions manipulating defaults, changes to the physical environment and incentives were the most effective, along with interventions adopting multiple BIs simultaneously. Interventions in education settings were most common and effective, with more evidence required in home and food retail settings. Future studies should investigate the impact of interventions using more

comprehensive study designs, in a range of settings. These studies should include health equity analyses, long follow-ups and obesity-related outcomes. Within this evidence, the policy implications are limited.

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CONFLICT OF INTEREST

No conflict of interest was declared.

AUTHOR CONTRIBUTIONS

TC conceptualised the review, developed and implemented the search strategy, abstract screening, full text review, data extraction and data analysis. ABS conducted the double reviewing and contributed to the development of the RoB assessment. All authors contributed to the manuscript. FS is the PI on the STOP project and provided oversight on all aspects of the review.

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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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