**Title: Whole Systems Approaches to Diet and Healthy Weight: A Scoping Review of Reviews**

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**Abstract**

**Background**

Obesity is a global epidemic affecting all age groups, populations and income levels across continents, though is known to disproportionately affect socioeconomically disadvantaged populations. The causes of obesity are complex, informed by diet and weight practices, but shaped by social, commercial and environmental factors and government policy. Consequently, a Whole System Approach (WSA) – which considers the many causes of obesity and shifts the focus away from individuals as points of intervention and puts an emphasis on understanding and improving the system in which people live – is required. This scoping review of reviews aims to: determine how WSAs to diet and healthy weight have been implemented and evaluated nationally and internationally; to determine what models or theories have been used to implement WSAs; describe how WSAs have been evaluated; determine if WSAs are effective; and to identify the contribution of the public and/or service users in the development of WSAs**.**

**Method**

Systematic searches were carried out using CINAHL, Scopus, PsycINFO (ProQuest), the Cochrane Library, and MEDLINE. Included review papers were those that focused on the application of a whole system approach to diet and/or healthy weight, and/or reported the theory/model used to implement or simulate this approach. Databases were searched from 1995 to March 2022 using a combination of text and Medical Subject Headings (MeSH terms). In addition, reference sections of identified articles were examined for additional relevant articles. Covidence software was used to screen titles and abstracts from the electronic databases and resolve conflicts.

**Results**

A total of 20,308 articles were initially retrieved; after duplicate removal 7,690 unique title and abstracts were reviewed, and 110 articles were selected for full text review. On completion of full text review, 8 review articles were included for data extraction. These included: one umbrella review, four systematic reviews, a rapid review, and two literature reviews (one of which was on strategic reports written for government and public health policy). Evaluations of WSA were mainly process evaluations although health outcomes were assessed in some studies. Several conceptual frameworks or mathematical modelling approaches have been applied to WSAs for diet, healthy weight and obesity to inform their planning or delivering, and to understand/map the associated systems. Common mathematical approaches include agent based or system dynamic modelling. Underlying both conceptual and mathematical models is an understanding how the elements of the complex systems impact each other to affect diet, healthy weight and obesity. WSA implementations have reported some success in positively impacting health outcomes including reducing Body Mass Index, reducing sugary food intake and increasing physical activity. Public and user involvement in WSA was not widely reported.

**Conclusion**

The application of WSA to diet and healthy weight shows promise, yet the research is lagging behind their implementation. Further robust evidence for using WSA to address diet and healthy weight are required, including incorporating process and outcome evaluations (perhaps using established approaches such as Systems Dynamic Modelling). Furthermore, the analysis of epidemiological data alongside longitudinal process and outcome evaluation regarding the implementation of a WSA is required.

**Keywords:** Whole systems approach, obesity, health weight, diet, systems science, health, policy.

**Introduction**

Excess weight and obesity is a complex problem that affects all ages and socioeconomic groups [1] but disproportionally affects those living in greatest socioeconomic deprivation [2]. It is estimated that 38.2 million children under the age of 5 were overweight or obese in 2019 [3], and obesity has been linked to a range of comorbidities including diabetes, cardiovascular disease, hypertension and certain types of cancer [4]. Thus, reductions in the prevalence of obesity would improve the quality of life of individuals by reducing the years lived with illnesses associated with these conditions. Moreover, it would also reduce the mortality rate and enhance the life expectancy of individuals [5]. Globally, poor diet is a leading risk factor for the development of excess weight or obesity [6].

There is a broad agreement, though, that causes of obesity are complicated and embedded in complex systems of interdependent causal factors [7] that operate at multiple levels and across settings [8]. The World Health Organisation’s European Regional Obesity Report 2022 suggested policy interventions that target environmental and commercial determinants of poor diet at a population level are likely to be most effective in reducing obesity, addressing dietary inequalities and achieving environmentally sustainable food systems [9]. As behaviours that lead to obesity are highly socially patterned, changing them in an equitable fashion requires simultaneous multiple interventions at a range of levels [10]. As there is no one solution to tackling obesity, successful action to promote healthy weight and diet across the life course requires a coordinated collaborative approach [1].

Whole Systems Approaches (WSAs) have become a popular guiding framework for planning public health responses to combating social and health problems with poor diet and unhealthy weight being recently targeted [11,12,13,14]. However, a shared definition or model of what a WSA should look like in practice (i.e., how it should be developed and effectively implemented) is lacking. Further, the meaning of the term ‘systems approach’ varies for different authors and organisations, often with contradictory definitions [15]. Moreover, despite the increased interest in, and attempts to apply, WSAs to address overweight and obesity, robust evidence for their effectiveness remains in its infancy [12,14,16,17]. In many cases evaluations have been process focused rather than both process and outcome focused (where changes in obesity-related outcomes are assessed alongside changes to structures and processes in the system).

In an evidence review commissioned by the National Institute for Health Care and Excellence (NICE) to identify key elements of a WSA to obesity [15], it was reported that an ‘authentic’ WSA draws on complexity science and complex adaptive systems which explain the ways in which factors and relationships interact and create particular sets of outcomes. The authors identified ten features of a WSA: 1) Identification of a system and its boundaries; 2) Capacity building; 3) Creativity and innovation; 4) Establishing relationships; 5) Engagement; 6) Establishing strong methods for communication across the system; 7) Embedding action and policies within organisations; 8) Developing leadership throughout the system; 9) Robust and sustainable and 10) Monitoring and evaluation. Theoretical understandings of how WSAs work to produce anticipated outcomes is important to improve the understanding of the processes involved in implementing a successful WSA for tackling obesity. Lack of theoretical underpinnings to the models used in implementing whole systems approaches could lead to difficulty when attempting to distinguish in what context a particular model would be most appropriate or effective and what processes it entails. This reduces the value of the accumulated evidence base as we are less able to identify characteristics or features that may contribute to the effectiveness of the implementation of WSAs in different settings. In order to address this, we undertook a review of reviews to identify evidence about the implementation of WSAs and the various approaches, theories or models used to underpin them.

**Aim**

To synthesize existing evidence reviews that investigate how whole systems approaches to diet and healthy weight have been implemented and evaluated nationally and internationally. This review sought to answer the following questions: 1. What models or theories have been used to implement WSAs to diet, healthy weight or obesity? 2. How have WSAs to diet, healthy weight or obesity been evaluated to date? 3. What evidence is there of the effectiveness of WSAs to diet, healthy weight and obesity? and 4. What has been the contribution of the public and/or service users in the development of WSAs to diet, healthy weight or obesity?

**Methods**

The conduct of this review was based on the framework and principles reported by Arskey and O’Malley [18] and further developed by Levac et al. [19]. The review included the following five key stages: 1) Identifying the research question; 2) Identifying relevant studies; 3) Study selection; 4) Charting the data; and 5) Collating, summarising and reporting results. Arksey and O’Malley [18] reported an optional ‘consultation exercise’ which involves including practitioners and service users in the review to identify potential additional references for inclusion. Therefore, we included members of the public through our Participant Involvement in Research group (PIRg), where four members actively engaged in all five stages after receiving training in conducting systematic reviews. See Smith et al. [20] for guidance on involving service users in conducting systematic reviews.

**Information sources and search strategy**

The following five databases were searched from 1995 to 2022 to identify eligible studies for the review: CINAHL, Scopus, PsycINFO (ProQuest), the Cochrane Library, and MEDLINE. This timeframe was deemed sufficiently wide (12 years before the Foresight report and its accompanying complex systems map of obesity [21,22]) to include all relevant evidence. The search strategy included a combination of keywords and database-specific terms, including the medical subject headings (MeSH) that cover WSAs in promoting diet and healthy weight: diet, nutrition, malnutrition, eating habit, eating behaviour, food choice, unhealthy diet, healthy weight, unhealthy weight, obesity, obese, overweight, underweight, fat, body fat, body mass index, body weight, physically inactive, physically active, physical inactivity; whole system approach and related terms such as systems approach, system modelling, collaborative working, joint working, multiagency, multiagency working, interagency, interprofessional collaboration, interprofessional teamwork, and community wide. These terms were modified to meet the search requirements of each database. Included papers were those reporting WSAs and their implementation, to identify the levers and opportunities influencing this. In addition, reference sections of identified articles were scrutinised for additional relevant articles.

**Eligibility criteria**

Review papers were included if they satisfied all the following eligibility criteria: a review of any type; available in English language; published between 1995-March 2022; focus of the review was on the application of a WSA to diet, healthy weight or obesity; reported the approach, theory or model used to implement a WSA. Papers that did not meet these criteria were excluded from the review.

**Selection of reviews**

The results from the literature searches were exported into Covidence, a web-based screening and data extraction tool [23]. Duplicate articles were removed. The review team comprised of 13 members of the wider PHIRST research team screening the title and abstracts to determine each article’s eligibility for full-text screening based on the eligibility criteria. The PIRg, part of the NIHR-funded PHIRST Connect team, were included in the review team and participated in the title and abstract screening, as well as full-text review to identify eligible articles [24]. Reviewers met throughout the screening process to resolve conflicts and discuss uncertainties related to study selection [19]. The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) chart (see Figure 1 below) reports the phases of article identification and selection [25].

Records identified through electronic searching

(n=20,306)

Records remaining after duplicates removed

(n=7,690)

Records screened via titles and abstracts (n=7,690)

Articles excluded

(n=7,580)

Full text articles assessed for eligibility

(n=110)

Full-text articles excluded with reasons (n=104):

* Duplicate (n=1)
* Outcome of research is not diet or healthy weight (n=3)
* Not a review (n=6)
* No data relevant to a WSA in application to diet and/or healthy weight (n=94)

Full-text articles included

(n=8)

Included

Eligibility

Identification

Screening

**Figure 1: PRISMA flow diagram illustrating the search strategy**

Full-text screening was carried out independently. A data extraction form was developed by the authors to confirm relevance and to extract study characteristics such as: author information (title, author name and year of publication), aims and objectives of the review, type of review (e.g. systematic, rapid etc.), PICO (population, intervention, comparator and outcomes as seen in systematic reviews), inclusion criteria (where appropriate), models or theories used to implement WSAs, evidence of the effectiveness of WSAs, and public/service user contribution in the development of the WSA. This form was reviewed by the research team and piloted by all reviewers before implementation, resulting in minor modifications to the standardised form. Reviewers OAF and CB met to resolve any conflicts, and to ensure consistency between reviewers and the research question/purpose [19]. OAF mapped the initial process of data extraction onto the form. KB and HAG reviewed and corroborated the extracted data on the form, ensuring that all relevant data was included. Articles were excluded at this phase if they were found on detailed inspection, to not meet the eligibility criteria (see Fig. 1).

**Results**

Electronic searches identified 20,306 articles, resulting in 7,690 unique articles to be screened for inclusion after duplicates were removed (see Figure 1). Titles and abstracts were assessed for their relevance to the review based on the inclusion criteria: 7,580 were excluded resulting in 110 articles being retained for full-text screening. Full texts of these articles were obtained and after applying the inclusion criteria, 104 articles were excluded; one article was a duplicate, three articles did not have outcomes addressing diet and/or healthy weight and/or obesity, six articles were not reviews; 94 articles did not provide data relevant to a whole system approach to diet and/or healthy weight and/or obesity; 2 articles were retrieved from references list searches of the six remaining articles. Thus, eight articles were included in this scoping review of reviews (see Figure 1). Characteristics of the included reviews are shown in Table 1. Of the eight reviews identified, one was an umbrella review [26], four were systematic reviews [16,27,28,29], one a rapid review [12] and two were literature reviews, one of which was on strategic reports written for government and public health policy [30] and the other focused on obesity, prevention and interventions in pregnant women, infants, children, and adolescents [31].

From the eight reviews identified as having met the inclusion criteria, two studies [12,16] report the findings of a systematic review and rapid review of primary research studies that have involved some form of evaluation of the implementation of a WSA focussed on tackling diet and healthy weight/obesity. Bagnall et al. [16] and Safefood [12] are therefore the only existing reviews that can be drawn on to answer all four of the research questions identified in our protocol [17] and set out above. Whilst the other six reviews do not provide evidence that help to address research questions 2, 3 or 4 (see above), they do draw on evidence to identify theories, frameworks and models that are potentially useful for implementing a WSA. The synthesis that follows therefore aims to draw on all reviews to set out what models or theories have been used to implement WSAs. The findings from Bagnall et al. [16] and Safefood [12] set out how WSAs have been evaluated to date, what evidence there is of their effectiveness, and what the contribution of the public and/or service users has been in the development of WSAs.

The Bagnall et al. [16] review used the ten features of a WSA set out by Garside et al. [15] to identify the extent to which interventions featured in articles that met their inclusion criteria could be said to be taking a WSA approach to healthy weight/obesity. The systematic review of 65 studies included 33 focused on obesity. Findings showed improved health outcomes such as reductions in Body Mass Index (BMI), increased parental and community awareness, community capacity building, nutrition and physical activity environment changes, and improved safety and wellbeing of community members [16]. Of the 33 obesity focused studies, 13 included all ten features outlined within Garside et al. Of those studies, five reported health or wellbeing outcomes, for example, consumption of sugary drinks, changes to BMI, changes to physical activity. Two reported outcomes that were associated with the social determinants of health (social economic factors), while eleven reported mainly process outcomes. From the review, it was apparent that all ten features of a WSA were not required to achieve changes in health. Improvements in nutrition and physical activity were shown in an evaluation of the Central California Regional Obesity Prevention Program [32], which met all ten WSA guidance features. BMI, parental awareness and community capacity building was improved in an evaluation of the Romp and Chomp programme in Australia [33,34], which met nine out of the ten WSA guidance features. BMI was also improved in two non-RCTs of Be Active Eat Well (BAEW) in Australia [35,36] which met seven out of the ten WSA features and Shape up Somerville an intervention in the USA [37], which met eight out of the ten guidance features. Improvements in fitness and BMI z-scores (BMI z score is a measure of how many standard deviations a child or young person’s BMI is above or below the average BMI for their age and gender) were observed in a prospective cohort study of Healthy Living Cambridge Kids in the USA, which met four of the ten WSA features [38]. Taken collectively it would appear that having all ten features of the WSA guidance is beneficial but not always necessary to lead to improvement in BMI or obesity. The success of a WSA was attributed to some key facilitators. These included the full engagement of stakeholders, good governance, trust and capacity, sufficient time to build relationships, sufficient finance, and the embedding of the WSA within broader policy so that other less obvious policy changes may also impact obesity (e.g., town planning). This meant ensuring that WSA principles were established within the objectives of individual organisations, rather than being something organisations were required to do in addition to their core work. Although initial findings are promising, a cautionary approach was advised when advocating the benefits of a WSA. Many study descriptions of what constitute a WSA, and the outcomes reported in some studies, were limited or lacked longitudinal follow-up. Furthermore, consistency in definition, application and thorough evaluation of WSAs was lacking.

The rapid review of WSAs to obesity prevention commissioned by Safefood in 2021 [12] aimed to progress understanding of WSAs to childhood obesity. The review identified 14 studies that explored WSAs to obesity. Most interventions involved a town or city-level community intervention, with varying durations. Three of the 14 studies reported positive outcomes in health behaviours and/ or anthropometric measures such as improvements in BMI and BMI z-score. These studies included the ‘Healthy Living Cambridge Kids USA’ [38], ‘Romp and Chomp’[33,34] and ‘Shape Up Somerville’[37] (similar to the Bagnall et al. study above [16]), all were deemed to have strong to moderate methodological quality. Seven studies reported mixed findings on the effectiveness of WSA; three reported negative outcomes; and, one study was on-going at the time of the review, the Amsterdam Healthy Weight Approach (AHWA) in the Netherlands but has subsequently been reported [26]. For the AHWA a logic framework was developed describing the mechanisms underpinning a whole-systems approach to childhood overweight and obesity prevention [26]. The aim of the logic framework was to inform further AHWA development, monitoring, and evaluation and to promote lessons learned and share understanding of the wider working principles of WSAs in public health to others embarking on WSAs. The Safefood [12] review identified that facilitators to implementing a WSA were: the need for strong leadership; allocating sufficient time to building relationships; community involvement and capacity building; ensuring consistency in language of WSA across sectors and allocating adequate time, resource and financial support. Funding and evaluation commitments using existing population and health surveillance data to implement a WSA to preventing childhood obesity was also recommended.

Bleich et al., [27] conducted a systematic review of community-based childhood obesity prevention studies, where as part of the system there was also a policy change to support the intervention. All studies were from high income countries. Some encouraging findings were shown for improvement in BMI or BMI z-scores. A total of nine studies were included; five were randomized controlled trials (RCTs) and four non–RCTs. Five studies were conducted in the community setting in combination with at least one other setting such as the home, three were conducted in the community and schools, and one study was conducted only in the community. BMI or BMI z-scores were reported in four of the nine studies. Two studies reported significant improvements in physical activity levels and one in vegetable intake. The authors concluded that evidence is moderately convincing that diet and physical activity interventions conducted in the community with a school component are more effective at preventing obesity. They also highlighted that the high level of variability across the research designs may have contributed to inconsistent findings. Notably, studies varied in their use of research design methodologies (e.g., RCTs vs quasi-experimental studies), were located in non-uniform settings, and used different intervention types to improve health (e.g., physical activity or combined diet and physical activity).

Nader et al. [31] conducted a literature review of 1,438 articles that focused on obesity, prevention and interventions in pregnant women, infants, children, and adolescents. The rationale for the focus on pregnancy and children was based on intervening as early as possible. They included review articles initially, then used these to refine their search for examining the early life cycle approach to the prevention of childhood obesity. It was not clear how many articles met the final criteria for inclusion in the review. They reported that in a Cochrane review [39] article that obesity prevention interventions may produce the largest magnitude of effect early in life, while two Institute of Medicine (IOM) reports emphasized both the need for interventions early in life [40] and the use of a ‘systems perspective’ to fill in gaps in obesity research evidence that can more effectively guide policy [41]. They conclude from their review that early intervention and a systems approach need to be combined as the next logical step in tackling obesity. The authors propose a framework comprised of eight pathways to guide the implementation of a systems approach targeting obesity in early life. They identify that local, state and national policies influence the physical environment (1) and the social environment (2). Policy also influences the health care system (3) and the physical and social environment influence each other (4). The physical and social environments influence family practices and individual behaviour (5) as does the healthcare system (6). The healthcare system also influences the physical and social environments (7) and finally family practices and individual behaviour also feedback and influence local, state and national policies. They go on to identify a set of goals or targets for health across pregnancy, infancy and toddlerhood and provide examples of interventions that would be considered appropriate for each of the eight system pathways identified. They also go on to provide recommendations for how such a WSA should be evaluated in the future and conclude that taking their outlined approach and evaluating it are the next logical steps in tackling the obesity epidemic.

Skinner and Foster [29] conducted a systematic review to examine the causes and consequences of obesity using systems science. Systems science incorporates systems dynamic modelling, agent based modelling or discrete event simulation as an approach to look at complex social interventions. A total of 21 studies were included that addressed four areas in systems science. These included: 1) translating obesity interventions to a large scale; 2) Determining the association of obesity with other health or economic outcomes; 3) Reporting the effect of geography on obesity and; 4) The effect of social networks on obesity. The authors concluded that more specific complex models are required that map obesity from childhood into adulthood. In order to incorporate a systems model to obesity in children to adulthood there is a need to ensure there is multidisciplinary involvement, and skills from social scientists, clinical scientists, public health researchers, and researchers with systems science knowledge to input into the development of mapping the system.

Johnston et al. [30] conducted a review of systems science and obesity policy to provide a novel framework for analysing and rethinking population-level planning. Their aim was to demonstrate the use of a systems-based framework to assess solutions to complex health problems such as obesity. They explored the utility of the Intervention Level Framework (ILF) and identified a set of recommendations and specific interventions for decision-makers to implement ILFs to obesity for large scale behaviour change [42]. To achieve this, they reviewed twelve reports published between 2004 and 2013, these consisted of nine strategies or reports written by or for governments or health authorities in the United States and Canada, one Cochrane review of interventions to prevent childhood obesity, and two reports produced by the Institute of Medicine (IOM). They used the ILF framework to code the recommended strategies (or interventions) for tackling obesity within each of the 12 selected reports according to which level of the system they were operating: 1) Paradigm (deepest held beliefs or the ethos of an approach e.g. adopt a holistic view of health); 2) Goals (or targets) e.g. achieve a childhood obesity rate of 5%; 3) Structure (across the system) e.g. recommendations about cross-sectoral collaborations such as food producers and schools; 4) Feedback loops and delays (loop dynamics) which involves collecting and analysing data about the relationships between different factors in the system and how changes in one may influence or cause changes elsewhere e.g. evaluate the effect of a new tax on unhealthy foods; or 5) Structural elements (subsystem specific) e.g. improving food and physical activity environments and running health promotion campaigns targeted at particular groups. They also coded recommended strategies based on variables listed in the Foresight Obesity systems map [22] forming a taxonomy of 30 variables organized around four subsystems; 1) social and individual psychology; 2) food production and consumption; 3) physiology and clinical care; and 4) physical activity. They found that the majority of strategies focused on altering the determinants of energy imbalance through targeting food intake and physical activity at an individual level and that 76% of recommended strategies were Structural (i.e., ILF level 5). The findings suggest there is considerable scope for increasing the systems focus of policy design to address obesity. They concluded that the ILF provides a template to encourage systems thinking and more strategic policy design grounded in complexity science that goes beyond the focus on individual responsibility alone.

Langellier et al. [28] conducted a systematic review of complex systems approaches to diet using Agent Based Models (AGMs) and System Dynamic Models (SDM) incorporating epidemiological data. A total of twenty-seven studies were included. Twenty-two Agent Based Model (ABM) studies and five System Dynamic Model (SDM) studies were included. Factors that influenced diet in the complex system were neighbourhood (e.g., residential segregation), interpersonal (e.g., social influence) and individual-level (e.g., food purchasing decisions), while food pricing, food environment, advertising, nutrition labels, and social norms influenced policy decisions. For those using SDM, several studies used longitudinal data to estimate the values of parameters related to either the population (i.e., initialized the population based on demographic and health data from the baseline observation of a cohort study) or processes under investigation. Most studies used empirical data to inform values of key parameters for each of the models, however there was variation in approaches to model calibration and validation. The authors recommended that integrating complex systems modelling like SDM with policy intervention research shows promise for preventing obesity. They suggested that the Childhood Obesity Modelling for Prevention and Community (COMPACT) study is an example of where systems approaches are linked with community obesity interventions where the model can be updated as new implementation and evaluation data become available, it is then that the intervention can be refined to get the optimal outcome [43,44].

Sawyer et al. [26] conducted a recent umbrella systematic review of the dynamics of the complex food environment underlying dietary intake in low-income groups and produced a data informed systems map based on the 43 reviews included. Studies were extracted if they reported the economic, social, physical and political food environment associations with dietary intake. The authors reported that the dietary intake system operated within an economic paradigm based on supply and demand, and that the system incorporates five sub-systems: 1) geographical accessibility; 2) household finances; 3) household resources; 4) individual influences; and 5) social and cultural influences. A causal loop diagram comprising 60 variables was reported. Their findings revealed how poor dietary intake in low-income groups can sustain a food environment that increases the accessibility, availability, affordability and acceptability of unhealthy foods. They proposed that in order to reshape system dynamics that are currently driving unhealthy food environments, innovative strategies are needed to facilitate longer-term management of household finances and socially-oriented practices around healthy food production, supply and intake. The diagram (cited as figure 2) conveyed a map of the system that could be applied to other areas/regions for consideration, the systems structure, and relevant feedback loops and goals of the system. Included in the map was reference to ‘lived experience’ through individual and social and cultural influences.

**Table 1: Descriptive and PICO Characteristics of included reviews**

| **No.**  | **Authors (date) and Title of the article**  | **Aims/objectives**   | **Review type**  | **Population (where reported)**  | **Intervention (where reported)**  | **Study design and Comparator (where reported)**  | **Outcomes (where reported)**  | **Overall Conclusion**  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1  | Bagnall, Radley, Jones, Gately, Nobles, Dijk, Blackshaw, Montel, and Sahota [16] Whole systems approaches to obesity and other complex public health challenges: a systematic review  | To undertake a systematic review of national and international published evidence on WSAs targeting obesity, other public health areas and areas outside public health (such as social care, crime and justice)  To understand what is known about WSAs and how they can be implemented in practice  | Systematic review  | Any population where a WSA has been used, at local, regional, national and international level  | WSAs, defined as those that: -Consider, in concert, the multifactorial drivers of overweight and obesity, as outlined by Foresight, public health or the social determinants of health; Involve transformative co-ordinated action (including policies, strategies, practices) across a broad range of disciplines and stakeholders, including partners outside traditional health sectors; Operate across all levels of governance, including the local level so that such approaches are reinforced and sustained, and Identify and target opportunities throughout the life course (from infancy to old age)  | **Study design:** primary research or evaluation studies including RCTs, non-RCTs, natural experiments, before and after studies, mixed methods evaluations (including case study), process evaluations (qualitative and mixed methods); cost-effectiveness, cost-benefit and cost-utility studies **Comparator:** Any or none  | Health outcomes, e.g., weight, Body Mass Index (BMI), type 2 diabetes, diet and nutrition, physical activity, psychological well-being & quality of life; co-morbidities related to obesity, reductions in health inequalities, reductions in premature morbidity and mortality, cardiovascular disease and obesity-related cancers. Organisational outcomes e.g., cross-sector collaboration; new partnerships; environmental changes; resource allocation; leadership etc. Process outcomes, e.g., what each project aimed to achieve and barriers and facilitating factors associated with achieving or not achieving those aims. Outcomes may be at individual, local, regional or national/ federal/ principality level. Process and implementation outcomes e.g. training, recruitment, sustainability, people’s views on barriers and facilitators to implementation of WSAs. Cost, cost-effectiveness, cost-benefit or cost-utility.  | Systems approaches to tackle obesity can have benefit, but evidence of how to operationalise a WSA to address public health problems is still in its infancy. Not all ten features of a WSA identified by Garside et al. [15] are needed to achieve positive changes in health outcomes |
| 2  | Johnston, Matteson and Finegood [30]  Systems science and obesity policy- a novel framework for analysing and rethinking population-level planning  | To demonstrate the use of a systems-based framework to assess solutions to complex health problems such as obesity.  To explore the utility of the Intervention level framework (ILF) by identifying a rich set of recommendations garnered for a variety of purposes from decision-makers working in different environmental contexts.  Identify with deeper understanding through application of the ILF how best to act in addressing the complex problem of obesity   What are the various system levels and the specific interventions required to support large-scale change   | Literature Review of strategies, policies and academic evidence  | 9 strategies or reports written by or for governments or health authorities in the United States and Canada, 1 Cochrane review of interventions to prevent childhood obesity, and 2 reports produced by the Institute of Medicine (IOM). – 7 focus on childhood obesity  | Used the ILF framework to code the recommended strategies for tackling obesity within each of the 12 selected policy docs/systematic review according to which level of the system they were operating at; 1) Paradigm (deepest held beliefs) a sort of ethos of an approach e.g. adopt a holistic view of health; 2) Goals (or targets) e.g. achieve a childhood obesity rate of 5%; 3) Structure (across the system) e.g. recommendations about cross-sectoral collaborations such as food producers and schools; 4) Feedback loops and delays (loop dynamics) which involves collecting and analysing data about the relationships between different factors in the system and how changes in one may influence or cause changes elsewhere e.g. evaluate the effect of a new tax on unhealthy foods; or 5) Structural elements (subsystem specific) e.g. improving food and physical activity environments and running health promotion campaigns targeted at particular groups. |  |  | ILF provides a template to encourage systems thinking and more strategic policy design that goes beyond the focus on individual responsibility alone to target obesity.   |
| 3  | Nader, Huang, Gahagan, Kumanyika, Hammond and Christoffel [31] Next steps in obesity prevention – altering early life systems to support healthy parents, infants, and toddlers  |  Aims appear to be to combine multidisciplinary expert understanding of the strengths and weaknesses of current approaches to prevention of childhood obesity with a literature review to support the need for and refine a broader early life cycle approach to the prevention of childhood Obesity      |  Expert panel discussion and Targeted Literature Review  | Pregnant women, infants, children, and adolescents  | N/A  | N/A  | N/A  | A twin approach to tackling obesity is proposed: (1) Intervention is necessary before, during, and after pregnancy, and for very young children, and (2) systems approaches are needed for sustainable prevention of childhood obesity and its consequences.  |
| 4 | Langellier, Bilal, Montes, Meisel, Cardoso, , and Hammond [28]  Complex Systems Approaches to Diet: A Systematic Review | To conduct a systematic review of studies that have used Agent Based Models (ABM) or Systems Dynamic Models (SDM) to understand the complex systems that influence population diet, with particular emphasis on identifying the complex system structures explored and methods used by each study. | Systematic review | Models were generated using available empirical population data. Twenty-two ABMs studies and five SDM studies were included. | Data extracted from each study either included ABM or SDMs that included purpose, diet and nutrition outcomes, integration with empirical evidence, and model design elements. | Simulation models using empirical epidemiological data | Factors for that influenced diet in the complex system were neighbourhood- (e.g., residential segregation), interpersonal- (e.g., social influence) and individual-level (e.g., food purchasing decisions). Food pricing, food environment, advertising, nutrition labels, and social norms influenced policy decisions. | Complex systems approaches to diet and nutrition can be used to understand mechanisms driving population-level diet, increasing use of models for policy decision support, and leveraging the wide availability of epidemiologic and policy evaluation data to improve model validation. |
| 5 | Sawyer, Lenthe, Kamphuis, Terragni, Roos, Poelman, Nicolaou, Waterlander, Djojosoeparto, Scheidmeir, Neumann-Podczaska and Stronks [26] | Dynamics of the complex foodenvironment underlying dietary intake inlow-income groups: a systems map ofassociations extracted from a systematicumbrella literature review | Systematic umbrella review | Low-income youths and adults in high/upper-middle income countries | Data was extracted from 43 review articles and after expert consensus to develop an evidenced based systems dynamics causal model of dietary intake | Information on thedeterminants and associations between economic, social, physical and political food environment on dietary intake | The dietary intake system operates within and economic paradigm based on supply and demand. The system incorporates five sub-systems: 1. geographical accessibility; 2. household finances; 3. household resources; 4. individual influences; and 5. social and cultural influences. Causal loop diagram comprising 60 variables, conveyed goals which undermine healthy dietary intake. | To target dietary intake, innovative strategies that incorporate causal loop diagrams and a systems paradigm are required to target the complexities of the accessibility, affordability and acceptability of unhealthy foods.  |
| 6 | Skinner and Foster [29], Systems Science and Childhood Obesity:A Systematic Review and New Directions | To conduct a systematic literature review of studies thatused systems science methodologies to study obesity in thecontext of public health.  | Systematic review  | Types of models used in systems science  | Systems science models lined to obesity | Studies must examine obesity in the framework of systemsScience, include original analyses, rather than discussing onlyhow systems science could be used, and must include obesity in the model, as a predictorand/or outcome. | The 21 included studies addressed four l areas of systems science in obesity: (1) translating interventions toa large scale, (2) the effect of obesity on other health oreconomic outcomes, (3) effect of geography on obesity,and (4) the effect of social networks on obesity. | Further research is required on applying systems science to childhood obesity that will require multidiscipline involvement, and skills from social scientists, clinical scientists, public health researchers, and researchers with systems science knowledge |
| 7 | Bleich et al. [27]. A Systematic review of community-based childhood obesity prevention studies  | To conduct a systematic review that included community-based childhood obesity prevention studies in high income countries where the interventions were delivered in a community where there was a change of policy. | Systematic review | Children | Childhood obesity prevention studies in high income countries | RCT, non RCTs, quasi experimental. | A total of nine studies were included; five were randomized controlledtrials (RCTs) and four non–RCTs. Five studies were conducted in the community setting incombination with at least one other setting such as the home, three were conducted inthe community and schools, and one study was conducted only in the community. BMI orBMI z-scores were reported in four of the nine studies. Two studies reported significantimprovements in physical activity and one in vegetable intake. | Evidence is moderately convincing that diet and physicalactivity interventions conducted in the community with a school component are moreeffective at preventing obesity. A high level of variabilityacross research designs may have led to inconsistent outcome findings. |
| 8 | Safefood [12]. Whole Systems Approach to childhood obesity: A review of the evidence  | A rapid review of WSAs to obesity to support policy makers and local decision makers to progress understanding of WSAs to childhood obesity. | Rapid Review | Children | Studies that included a WSA to childhood obesity. | Study of any type | 14 studies were identified. Three of the 14 studies reported positive outcomes in healthy behaviours and/ or anthropometric measures such as improvements in BMI and BMI z-score seven reported mixed findings;three negative outcomes; and, one study was on-going at the time of the review, but has subsequently been reported [26]. | When implementing a WSA to obesity prevention, political structures, visibility of leadership, cross-departmental government policy alignment; flexible local approaches that target health inequalities; increased community involvement and engagement; and, long-term funding and evaluation are required. |

**Discussion**

Despite the increased application of WSAs to diet, healthy weight and obesity, evidence for effectiveness at a process or health outcome level of analysis remains in its infancy. The aim of this scoping review of reviews was to synthesize the evidence from reviews that investigated how whole systems approaches to diet and healthy weight have been implemented and evaluated, what models have been used, how has WSA implementation been evaluated, evidence of effectiveness and whether members of the public or service users have been involved in the process of developing, implementing and evaluating a WSA.

**What models or theories have been used to implement WSAs to obesity?**

Our review highlighted the various approaches and models that have been used or proposed for use in WSAs to diet, healthy weight and obesity (See Table 2). These include systems science that incorporate mathematical simulations, such as Agent Based Models and Systems Dynamics Models for mapping the complex system with key features of the system and feedback loops to show how system components links together [29]. According to Skinner and Foster [29] there is a need for multidisciplinary involvement in mapping a system and more specific models that represent diet and healthy weight in children. In Langellier et al.’s [28] systematic review of complex systems approaches, twenty-seven studies highlighted that neighbourhood- (e.g., residential segregation), interpersonal- (e.g., social influence) and individual-level (e.g., food purchasing decisions) factors influenced diet, while food pricing, food environment, advertising, nutrition labels, and social norms influenced policy decisions. Encouragingly there were some longitudinal studies reported in their review. The most recent review was conducted by Sawyer et al. [26] and involved 43 studies that described economic supply and demand factors as the main components underpinning the obesity system. A total of 60 variables were reported and a systems map that could be applied to areas of low income. Four A’s were described as influencing unhealthy food choice: accessibility; availability; affordability; and acceptability of unhealthy foods. Encouraged in Sawyer et al.’s [26] review was the incorporation of lived experience of the participants, a key feature of public health research in recent years, and that will be more prominent in the design and evaluation of public health research into obesity (NIHR, 2019). In Bagnall et al.’s [16] review they described articles based on the extent to which they included Garside et al.’s [15] key features of a WSA. Thirteen of the 33 studies focussed on WSAs of obesity, included some of the key features. Findings suggest that all ten features were not required for implementation of a WSA to show effectiveness. Key WSA facilitators according to Bagnall and colleagues were full engagement of stakeholders, good governance, trust and capacity, sufficient time to build relationships, sufficient finance, and the embedding of the WSA within broader policy so that other less obvious policy changes may also impact obesity. In the review conducted by Safefood [12] they described the Amsterdam Healthy Weight Approach (AHWA), and a AHWA logic framework [26] that has shown merit in WSA development, monitoring and evaluation.

Collectively, several models and theories have been described across the reviews with little guidance on what model or theory is most suitable. From the available models, care should be taken to what the purpose of the model is – is the intention to map system characteristics, or guide for implementation of interventions, policy change and evaluation? If the aim is to map obesity, systems dynamic models consisting of causal loop diagrams as described by Sawyer et al. [26] may be appropriate. If the aim is to integrate the systems map with policy interventions and community interventions with the target population being children, then the models used in the Childhood Obesity Modelling for Prevention and Community Transformation (COMPACT) study may be relevant.

**Table 2: Lists the various models and features extracted from the review articles to describe a systems approach to diet, healthy weight and obesity.**

|  |
| --- |
| **Various models and features described as a WSA** |
| Amsterdam Healthy Weight Approach (AHWA) [12] |
| Amsterdam Healthy Weight Approach Logic Framework (AHWA-LF) [12] |
| Agent Based Model (ABM) [29] |
| ANGELO (Analysis Grid for Environments Linked to Obesity) Framework [12] |
| Childhood Obesity Modelling for Prevention and Community Transformation (COMPACT) [28] |
| Discrete Event Simulation (DES) [29] |
| Intervention-Level Framework (ILF) [30] |
| NICE and Garside’s list of 10 key features of a WSA [16] |
| System Dynamics Model (SDM) [29] |
| Systems Framework To Prevent Obesity by Targeting Early Life [31] |
| Systems Science Properties and Nine Properties of Obesity [29] |

**How have WSAs to obesity been evaluated to date?**

From the reviews identified, just two focus on studies where implementation of a WSA to obesity has been evaluated; Bagnall et al. [16] and the Safefood review [12]. Examples of process and outcome-based evaluations have been reported. Bagnall et al. [16] present their process analysis synthesis across all included studies making it difficult to ascertain evidence that relates specifically to obesity. Based on their summary table however it is likely that the process analysis for obesity studies is based on eight mixed methods evaluations [45,46,47,48,32,49,50,33] and seven qualitative studies [51,52,53,54,55,56,57]. Quality assessment of these studies is summarised in terms of numbers of studies meeting or not meeting quality criteria but specific studies are not referenced in the text covering this assessment. Many studies did not meet several quality criteria or did not provide sufficient information for an assessment to be made. The Safefood review focused only on studies reporting quantitative outcome data.

Outcome evaluations across these two reviews include:

Six non-randomised controlled trials [Johnson et al. [35] (Bagnall et al. [16] only; rated as good quality); Sanigorski et al. [36] (Bagnall et al. [16] only; rated as good quality); Economos et al.[37] (both; rated as moderate to good quality by Bagnall et al.[16] and moderate quality bordering on strong by Safefood, [12]); Hoelsher et al. [58] (Bagnall et al. [16] only; rated as moderate quality); Bell et al. [59] (Safefood [12] only; rated as moderate quality); Verbestel et al. [60] (Safefood [12] only; rated as strong)];

Five mixed methods evaluations [DH, [50] (Bagnall et al. [16] only; rated as moderate quality); de Groot et al. [33] (Bagnall et al. [16] only; rated as moderate to poor quality); de Silva-Sanigorski et al. [34] (both; rated as moderate to poor quality by Bagnall et al. [16] and moderate quality by Safefood [12]); Amed et al. [49] (Bagnall et al. [16] only; rated as poor quality); Gadsby et al. [61] (Safefood [12] only; rated as poor quality)];

Two prospective cohort studies [Chomitz et al. [38] (both; rated as moderate quality by Bagnall et al. [16] and strong by Safefood [12]); Vinck et al. [62] (Safefood [12] only; rated as moderate quality bordering on strong)];

A prospective cohort study with embedded non-randomized controlled trial (de Henauw et al. [63] (Safefood [12] only; rated as moderate quality bordering on strong);

two pre-post designs [Atalla et al. [64] (Safefood [12] only; rated as moderate quality); Mead et al. [65] (Safefood [12] only; rated as moderate quality);

one pre-post design with matched comparators from existing national survey data (Raine et al. [66] (Safefood [12] only; rated as moderate quality bordering on strong); an evaluation of unclear design [Schwarte et al. [32] (Bagnall et al. [16] only; unclear quality)];

and one nested case control study [Copeland et al. [67] (included in both reviews; rated as moderate to poor quality by Bagnall et al. [16] and as low quality by Safefood [12])].

The Safefood Review [12] also includes two papers focussed on the Amsterdam Healthy Weight Approach [68,69] and presents data on changes seen at a whole-city level on rates of obesity that present reasons to be optimistic. Also in a recent article by UNICEF [70] the positive outcomes of the AHWA are described. Full peer-reviewed publication of findings are still to emerge however, and until they are, attributing causality to the programme is cautioned against. Many study descriptions of what constitute a WSA and the outcomes reported were limited, or lacked longitudinal follow-up. Furthermore, consistency in definition, application and thorough evaluation of WSAs was lacking at the time of the reviews. With these research limitations highlighted, it makes it challenging to determine the effectiveness of WSAs to obesity.

**What evidence is there of the effectiveness of WSAs to diet, healthy weight and obesity?**

From what was reported and to guide future work on the application of WSA some lessons could be taken from the evaluation of a number of programmes which showed positive effects; the ‘Central California Regional Obesity Prevention Program’[32], the ‘Romp and Chomp’ programme in Australia [33,34], ‘Shape up Somerville’ in the USA [37], and the Healthy Living Cambridge Kids in the USA [38]. The Safefood [12] review included similar studies as Bagnall et al. [16] with the addition of the more recent Amsterdam Healthy Weight Approach (AHWA) in the Netherlands that has shown promising outcomes, and included a logic framework. Below we describe one WSA programme (AHWA) that shows the most promise in terms of leading to change, and that could be replicable in other cities. This has been evaluated in terms of process and outcomes, and a logic framework is also reported [26,70].

The city of Amsterdam, Netherlands committed to a long-term integrated approach to intervene with the children’s physical and social environment to tackle excessive weight reversal and obesity in children [71]. A further important element of this approach was a specific dedication to preventing children of healthy weight gaining excess weight due to obesity-promoting environments, and, to treat children with overweight and obesity through clinical practice and reduction of risk from obesogenic environments. In a review of what makes AHWA effective, key elements were described. The first active element of an integrated approach to childhood obesity is a holistic approach that incorporates many organisations. Second is leadership in the design and implementation of the AHWA. In particular, political-administrative support is essential for design and implementation as well as integration into policy. Third is the AHWA deployment of a combination of mutually reinforcing and well-founded interventions based on scientific knowledge of the systems approach. The fourth element is the importance of cooperation with various services as well as with public and private parties. Cooperation is required at the administrative, official and executive levels, in neighbourhoods and in schools. Identifying leaders or champions who feel responsible for the implementation and management of programme components is important to their implementation and success. The fifth active element is quite unique for the integrated approach to obesity: the learning approach, that is a move to evaluation of what works in certain areas and a shift in mindset that evaluation can be flexible, and lessons about the process of implementation are being learned as the initiative is underway, not only at the end. This adaptive nature of the system is a key feature of a WSA, and one which is often lacking in other approaches labelled as WSAs. The sixth element is that attention should be devoted to a long-term vision and the commitment to permanent change. Finally, seventh, is the effective and innovative use of communication and marketing at the political, administrative, as well as local public and private organisations to the population. Collectively the authors suggested that making progress only works if attention is paid to all seven of these elements, and ‘cherry picking’ because of a lack of budget, short time frames or lack of expertise does not work.

**What has been the contribution of the public and/or service users in the development of WSAs?**

The contribution of public and service user involvement in the development of WSA approaches has not been reported widely in the articles reviewed. This is with the exception of lived experience being mentioned in a model in the Sawyer et al. [26] review article and community involvement in Bagnall et al. [16]. Given the increased awareness, that service users need to be included as part of the development and research evaluation process, further support, funding and advocacy for service user involvement is required more broadly in public health research [24] and in WSA to obesity more specifically [14].

**Conclusion**

WSA to diet, healthy weight and obesity show promise, yet the research evidence for their effectiveness is lagging behind implementation, with the exception of a few well-designed studies. Further robust evidence for WSAs to obesity are required that incorporate process and outcome evaluations, and that follow key guidance as described by NICE and Garside et al. [15] or Sawyer et al. [26] or for those who have used systems science models like Systems Dynamic Modelling. From the reviews it was not possible to determine how much funding can impact on the success of a WSA to obesity, this should be considered in the future. Furthermore, greater inclusion of members of the public, who are the ultimate target beneficiary of WSAs to obesity, in the development and implementation of WSAs should be considered. Research seeking to evaluate the impacts of WSAs should also do more to include and report upon the inclusion of the public and/or service users in their work. The use of existing epidemiological data alongside longitudinal process and outcome evaluation data to monitor the design, implementation and long-term impact of WSAs to obesity should also be an ambition of future research.

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