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Development and application of the Demands for Population Health Interventions (Depth) framework for categorising the agentic demands of population health interventions

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Abstract

Background The ‘agentic demand’ of population health interventions (PHIs) refers to the capacity, resources and freedom to act that interventions demand of their recipients to benefit, which have a socio-economical pattern. Highly agentic interventions, e.g. information campaigns, rely on recipients noticing and responding to the intervention and thus might affect intervention effectiveness and equity. The absence of an adequate framework to classify agentic demands limits the fields’ ability to systematically explore these associations.

Methods We systematically developed the Demands for Population Health Interventions (Depth) framework using an iterative approach: (1) developing the Depth framework by systematically identifying examples of PHIs aiming to promote healthier diets and physical activity, coding of intervention actors and actions and synthesising the data to develop the framework; (2) testing the Depth framework in online workshops with academic and policy experts and a quantitative reliability assessment. We applied the final framework in a proof-of-concept review, extracting studies from three existing equity-focused systematic reviews on framework category, overall effectiveness and differential socioeconomic effects and visualised the findings in harvest plots.

Results The Depth framework identifies three constructs influencing agentic demand: exposure — initial contact with intervention (two levels), mechanism of action — how the intervention enables or discourages behaviour (five levels) and engagement — recipient response (two levels). When combined, these constructs form a matrix of 20 possible classifications. In the proof-of-concept review, we classified all components of 31 interventions according to the Depth framework. Intervention components were concentrated in a small number of Depth classifications; Depth classification appeared to be related to intervention equity but not effectiveness.

Conclusions This framework holds potential for future research, policy and practice, facilitating the design, selection and evaluation of interventions and evidence synthesis.

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Keywords Population health, Diet, Physical activity, Interventions, Socioeconomic inequalities

Background

Despite numerous policies attempting to address unhealthy diets and physical inactivity, globally, these practices remain common and differentially distributed across populations [1, 2] contributing to health inequalities [3]. Population health interventions (PHIs) target whole populations or population groups with an aim to reduce disease risk. These have been described as more appropriate, effective and equitable for primary prevention than interventions targeted at those known to be at high risk of disease [4]. However, PHIs can take a number of different forms, and the abundance of evidence available on them can be overwhelming for policymakers to make sense of [5]. Understanding how PHIs work, in what context and for whom [6] and the effect of different interventions on population subgroups is important to drive effective and equitable change [7]. One aspect of PHIs that has been proposed to influence intervention effectiveness and equity is the degree of personal agency required of individuals in order to benefit from an intervention [8]. Personal agency includes capacity, resources and freedom to act and achieve an intended outcome [9].

We use the term ‘agentic demand’ to describe the actions required of individual and organisational actors to enable PHIs to achieve their intended effects. Agentic demand likely exists on a continuum [8]. Interventions with high agentic demands on individuals often target individuals’ knowledge and behaviours and rely on individuals’ capacity to act in accordance with the intervention aims [10] and make use of their personal resources, for example time, cognitive or financial resources to benefit [11]. To illustrate, England’s Change4Life campaign provided prompts to recipients to increase walking by getting off the bus one stop earlier than their destination. To realise the health benefit from this campaign, individuals must have and make use of sufficient cognitive resources to understand the prompts, determine how to act on them, remember to act on them, make use of their temporal resources and continue to do so over the long term. In contrast, interventions with low agentic demands on individuals alter the context within which behaviours are produced and reproduced [12], focusing on environmental conditions, social institutions and norms that shape individual behaviour [10]. These require little or no personal resources from individuals to realise the intervention aim. For example, when a food manufacturer reformulates packaged snacks to reduce the salt content, individuals will benefit as long as they continue eating the

snacks as before, although such an intervention may place high agentic demands on food manufacturers.

Over the last 30 years, there have been almost 700 proposed policies for obesity prevention in England. The majority of these placed high agentic demands on individual recipients with only 19% placing low agentic demands on recipients [3]. The ability to meet the agentic demands of interventions is likely to be influenced by a range of social and economic factors. Given that personal resources are distributed unequally across the socioeconomic gradient, the capacity to respond to and benefit from PHIs with high agentic demands may also be unequally distributed. Theoretically, these interventions may be less effective and contribute to widening health inequalities [8, 10, 13], yet empirical evidence on this topic is, to date, mixed [14, 15].

While acknowledged as an important concept [14], much of the literature exploring agentic demands of interventions applies a simple dichotomy of high vs low agency [16, 17]. An existing framework identified a third intermediate category for interventions which focus on creating supportive environmental conditions but still place an agentic demand on individuals [13], for example placing healthy food within a canteen setting creates a conducive environment yet requires individuals to choose the food. Furthermore, agentic demands are often conflated with other intervention dimensions including intervention mechanisms and the high risk vs population approaches [11]. While these may be related, they are not synonymous. For example, interventions operating via financial mechanisms are often uniformly categorised as interventions with low agentic demand, yet not all necessarily are. The Healthy Start scheme issues vouchers to low-income families in the UK which can be exchanged for fresh fruit, vegetables and milk. To receive vouchers, families must register for the scheme with a health professional’s signature [18]. After using the vouchers to purchase subsidised food, they then must have the equipment and knowledge required to prepare the food, placing agentic demands on recipients. In contrast, when visiting a workplace cafeteria with discounted prices on healthy meals, the recipient simply selects the subsidised food, requiring no more agency than any other food selection [19]. These examples illustrate the potential value of a more nuanced and standardised method to classify the agentic demands of PHIs.

To date, the literature has also failed to account for the agentic demands placed on other actors involved in

PHIs. For example, a change in school vending machine policy to increase availability of healthier foods may place relatively low agentic demands on users of the machine for them to benefit but requires agreement from the school leadership team and implementation by the vending machine contractor — both activities with high agentic demands. This brings a layering effect of agentic demands in PHIs, yet understanding what these actors are required to do to implement interventions has not been systematically explored [20].

Current approaches to classifying agentic demands of PHIs are inadequate for capturing their nuance and diversity. A framework to achieve this has potential to improve evidence synthesis by providing a consistent and comprehensive approach to classifying agentic demand. Such a framework may also inform intervention design and prioritisation for use by researchers, public health practitioners and policymakers for understanding how interventions influence inequalities. Here, we describe the development of such a framework — the Demands for Population Health Interventions (Depth) framework — and demonstrate its application in a proof-of-concept evidence synthesis to explore its association with intervention effectiveness and equity. Our aim was to develop a framework relevant to all PHIs, but to keep the work manageable, we focus here on PHIs aiming to support healthier diets and physical activity.

Methods

Below we describe the three steps taken to develop, test and apply the Depth framework. Firstly, we sought to develop a draft framework by systematically identifying PHIs aiming to increase healthier diets and physical activity and coded the actors and their actions. Secondly, we tested the framework by seeking expert qualitative feedback and reliability testing and used the results to refine the framework. Thirdly, we assessed the applicability of the framework within an evidence synthesis. While this is presented as a sequence of steps, in reality, it was an iterative process (Fig. 1). A detailed account of the methods is included in Additional File 1, and protocols were preregistered on Open Science Framework (<https://osf.io/nz23j/>).

Step 1: Developing the Depth framework

a) Identify examples of PHIs aiming to promote healthier diets and physical activity

In step 1, we aimed to identify a range of PHIs aiming to promote healthier dietary and physical activity outcomes that could be used to identify a range of actors and their actions from which to develop the Depth framework. In step 1a, we conducted a systematic search to identify systematic reviews likely to include PHIs aiming to promote healthier diets and physical activity. The search strategy was based on the concepts of (1) dietary and physical

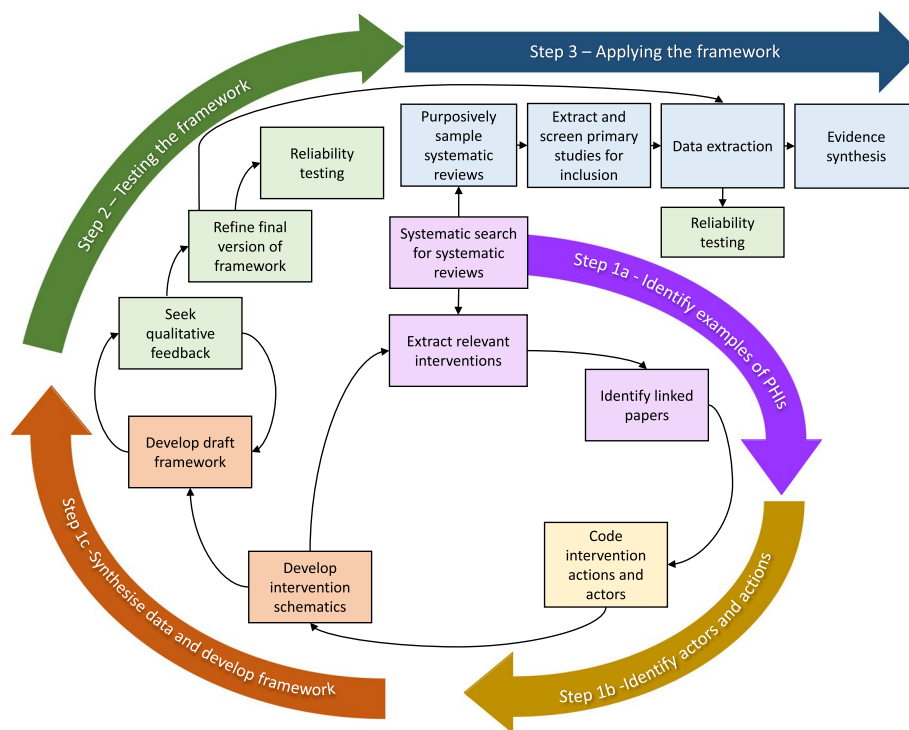


Fig. 1 Iterative methods for developing and applying the depth framework

activity outcomes AND (2) systematic reviews AND (3) health interventions (Additional file 1: Appendix 2). We included interventions available to whole populations, or population groups defined by non-health indicators in the PROGRESS-PLUS criteria [21], which explored impacts of interventions on dietary or physical activity outcomes with a dietary, physical activity or body weight measurement. We included experimental designs and did not limit inclusion by date or country. Full eligibility criteria are available in Additional file 1: Table S1.

We conducted a two-stage systematic search using purposive and random sampling of articles where appropriate, to maintain a manageable number and breadth of reviews. Firstly, we searched nine databases (MEDLINE, Embase, Science Citation Index, CINAHL, Transport Research International Database, Social Science Citation Index, PsychINFO, Applied Social Science Index and Abstracts and International Bibliography for the Social Sciences) to identify systematic reviews that would be likely to include dietary or physical activity PHIs. We removed duplicates, and two reviewers (K. G. and C. P. J./C. F. /E.R. L./E. I./R. P./D. V. T./R. A. M.) independently screened the titles and abstracts of 25% randomly selected records in duplicate ($n=8077$) followed by the full texts of those included following this screen ($n=749$). Disagreements were resolved by discussion between two reviewers and referred to a third reviewer if it was not possible to resolve. After examining full texts, 408 reviews met the inclusion criteria. From these, we purposively selected nine reviews that were likely to include a breadth of intervention types both within and between reviews rather than reviews reporting multiple studies of similar interventions and selected reviews that collectively spanned different population groups, settings and environments (PRISMA diagram available in Additional File 1: Figure S1). We identified potentially relevant interventions from the tables of study characteristics in included reviews. We retrieved full-text articles describing these potentially relevant interventions ($n=375$), and two reviewers independently screened them to identify PHIs exploring the impacts of interventions on dietary and physical activity outcomes ($n=74$). To retrieve as much information as possible for each included intervention, we searched Google Scholar, PubMed and funders' websites to identify linked articles, for example protocol papers, funder reports or process evaluations. The final collection included 74 interventions, described in 314 articles (PRISMA diagram available in Additional File 1: Figure S2).

b) Identifying actors and their actions

In step 1b, we used the data in the 74 interventions identified in step 1a to identify all intervention actors and

their actions. *Actors* referred to people required to conduct an action for the intervention to have its intended effect on diet or physical activity. *Actions* were defined as what the actor was required to do in order for the intervention to have its intended effect. We coded all actors and actions explicitly described in the 314 articles from the point at which intervention implementation is agreed. We coded actors and actions separately for each intervention component defined as a single pathway or chain of action within an intervention with an intended outcome of dietary or physical activity change. These are singular aspects of interventions that recipients might 'see', for example cycle lanes or point of decision prompts. Many interventions contained multiple components. An example is provided in Additional File 1: Table S2.

c) Synthesising data and developing the Depth framework

In step 1c, we combined actor and action codes for similar intervention types to develop schematic flow chart diagrams explaining 'who had to do what' for each intervention component to be implemented and have their intended effects. We developed the diagrams iteratively, merging similar interventions to refine each diagram. This process was repeated to produce a final set of diagrams ($n=8$), used to identify concepts, which we organised into a draft conceptual framework (Additional File 1: Appendix 5). The core research team met to apply the framework to intervention examples and used this to refine and reorganise the draft framework.

Step 2: Testing the Depth framework

In step 2, we iteratively developed the draft framework and associated user instructions based on qualitative feedback from relevant experts and reliability testing.

a) Seeking expert qualitative feedback

In step 2a, we conducted four online workshops with academic and policy experts ($n=20$) with experience of developing, implementing, evaluating or synthesising evidence of PHIs to promote healthier diets and physical activity. The disciplinary backgrounds of participants were public health (80%), health economics (5%), health psychology (10%) and health services research (5%). We circulated a copy of the draft Depth framework ahead of the workshops. During the workshops, participants applied the draft Depth framework to six intervention examples and used this experience to contribute to a structured discussion. The discussion aimed to explore the content validity and practical utility of the Depth framework and was facilitated by a member of the research team. We audio recorded the workshops, and two researchers wrote detailed field notes (Additional File 1). Following workshop feedback, we extensively

refined the Depth framework in three key areas: (1) terminology and categorisation, (2) framework structure and (3) user instructions. We sought verbal feedback on the revised Depth framework from a purposively selected subsample of workshop participants and produced a final version.

b) Reliability assessment

In step 2b, we conducted an online survey to assess the inter-rater reliability of the final version of the Depth framework (Additional File 1: Appendix 6). We recruited a new sample of academic experts ($n=22$) with similar experience as in step 2a to code 53 intervention examples randomly selected from those identified in step 1a. We used the KappaSize R package [22] to estimate an approximate sample size for the number of interventions to assess, as previously used to validate the typology of interventions in proximal physical microenvironments (TIPPME intervention typology) [23]. We estimated the sample size based on the following parameters: alpha value of 0.05, power of 0.8, probability of 0.7, a null hypothesis of a kappa of 0.4 and an expected kappa of 0.7. This suggested that two independent reviewers applying the final Depth framework to 53 interventions would be required to test if $\kappa > 0.4$. The online survey involved reading a description of the final Depth framework and user instructions (Additional File 2) and applying the framework to each intervention example. We encouraged participants to provide free text responses to justify or explain each decision. Each intervention example was independently coded by two participants. We asked each participant to code up to five intervention examples based on the time they had available.

We calculated Cohen's Kappa to assess inter-rater reliability of each categorical item in the survey. Open-ended text answers were coded and compared by one researcher. Kappa values were interpreted as follows: ≤ 0 no agreement, 0.01–0.2 none to slight, 0.21–0.40 fair, 0.41–0.60 moderate, 0.61–0.8 substantial and 0.81–1.00 as almost perfect agreement. Of three constructs and four actors included in the Depth framework, Cohen's kappa assessment classed two each as fair, moderate and no agreement and one as none-slight agreement (Additional File 1: Table S5). Disagreements arose due to confusion between the concepts, failure to identify recipient groups and difference in approaches when interventions were poorly reported. We used step 3 to explore this and develop detailed application guidance.

Step 3: Applying the depth framework

In step 3, we demonstrated the application of the Depth framework in a proof-of-concept review. We explored the association between intervention agentic demand,

as categorised by the Depth framework, and reported overall and differential effectiveness by socioeconomic position (SEP). To identify studies that reported effects by SEP, we first searched all articles identified in step 1 for those that included a term related to equity in their title based on a validated filter for ethnic and socioeconomic inequalities ($n=24$) [24]. From amongst these, we purposefully selected three systematic reviews that provided a breadth of intervention types across dietary and physical activity behaviours and presented a differential effect by SEP [15, 25, 26]. From these three systematic reviews, we extracted included studies ($n=87$), removed duplicates ($n=9$) and screened full-text articles ($n=78$) according to the inclusion criteria. We included PHIs aiming to promote healthier diets and physical activity according to the inclusion criteria in step 1 and which reported both a measure of overall effectiveness and measures of effectiveness in subgroups differentiated by at least one measure of SEP. Measures of SEP included income, occupation, education at household, parental or area level. We excluded simulation and modelling studies. Two reviewers screened 50% of the full-text articles in duplicate, and due to good agreement, the remaining 50% were screened by only one reviewer.

We then extracted data from primary included studies ($n=31$) on study characteristics, outcome measures and coded interventions according to the Depth framework. We followed application rules developed specifically for this step (Additional File 2). Two reviewers (K. G. and G. V. or L. B.) independently extracted data according to the final Depth framework, and a third reviewer (J. A.) resolved disagreements. We calculated inter-rater reliability of this process as described in step 2b. Overall effectiveness data was classified into one of three categories: (1) results favour intervention — any changes in dietary or physical activity outcomes associated with the intervention are in a direction that supports public health; (2) no difference — no change in relevant outcomes associated with the intervention; and (3) results favour control — any changes in relevant outcomes associated with the intervention are in a direction that does not support public health. If a primary outcome was stated, we categorised intervention effects for this. If a primary outcome was not stated, we classified intervention effectiveness for each relevant outcome and selected the most common effectiveness category across all outcomes. We used statistical significance of outcomes to categorise intervention effects.

We extracted data on equity effects across levels of SEP, based on statistical significance. We categorised equity effects into one of three categories: (1) likely to reduce inequalities — the intervention preferentially improves outcomes in people of lower SEP; (2) no preferential

impact by SEP, including those where there was an overall effect but no differential effect by socioeconomic subgroups or where there was no overall effect or differential effect by SEP; and (3) likely to widen inequalities — the intervention preferentially improved outcomes in people of higher SEP. We generated harvest plots to aid evidence synthesis by data visualisation [27], plotting each Depth classification according to effectiveness and equity.

Results

The Depth framework

Here, we summarise the final version of the Depth framework. Additional File 2 provides a full description and application guidance.

The framework is applicable to single intervention components of PHIs, for example a cycling strategy may include two components: cycling proficiency training and installing lighting on existing cycle lanes. The demands of each component may also vary in different recipient groups. For example, for existing users of a cycle lane, installing lighting improvements makes an existing journey feel safer and more pleasant. However, new users of the cycle lane will need to be aware of the lighting installations, may need to acquire cycling equipment and will need to feel confident to cycle and choose to cycle on the paths in order to benefit. This places different agentic demands on new and existing users. Users of the framework should identify each possible intervention component and recipient combination and apply the framework to each one separately. The concepts presented herein apply to single component-recipient combinations. While we developed and tested it here using dietary and physical activity PHIs, we believe it may be more widely applicable.

We identified three constructs influencing the agentic demand of PHIs for diet and physical activity: exposure to the intervention component (two levels), mechanism of action of the intervention component (five levels) and engagement with the mechanism of action (two levels) (Table 1). When combined, these constructs form a matrix of 20 possible classifications (Table 2). We have not sought to order, score or name these categories. Rather, we hypothesise that intervention component-recipient combinations with similar agentic demands will be grouped within the same framework classification. It may be possible for a component-recipient combination to be classified into multiple categories if there are multiple mechanisms of action. We also identified four types of non-recipient actors potentially involved in dietary and physical activity PHIs (Table 3): (1) macro-environmental, (2) micro-environmental, (3) informal gatekeepers and (4) secondary recipients. The ability of these actors to execute the actions required for the interventions to

achieve their intended effects will be variable and influenced by structural factors. Further development of the actions required of these actors was limited by poor reporting, and we were unable to proceed further than classifying actors.

Applying the Depth framework

We applied the Depth framework within a ‘proof-of-concept’ review. We identified three parent systematic reviews exploring differential socioeconomic effects of dietary and physical activity interventions [15, 25, 26], from which we extracted and screened 87 full-text articles on PHIs. We included 33 articles reporting 31 interventions (Additional File 3: Table S11). We were unable to identify intervention components for five interventions due to insufficient detail. From the remaining 26 interventions, we identified 163 intervention component-recipient combinations (median = 4.5; range = 1–24 per intervention) and classified the three Depth framework constructs for 115 of the 163 identified component-recipient combinations. It was not possible to classify the remaining 48 component-recipient combinations due to insufficient detail. Where a framework construct was classified, inter-rater reliability for first assessments ranged from moderate (engagement) to substantial (exposure, mechanism of action) (Additional File 1: Table S8).

We classified the exposure of component-recipient combinations as active ($n=26$) and passive ($n=89$); mechanism of action as socio-cultural ($n=15$), cognitive ($n=65$), financial ($n=5$), physical-environmental ($n=30$), biomedical ($n=0$) and engagement as active ($n=97$) or passive ($n=18$). The most common classification was passive exposure, cognitive mechanism and active engagement. Nine classifications and one mechanism of action (biomedical) were not represented at all in the review. Within the 163 intervention component-recipient combinations, we identified that macro-environmental ($n=135$) and micro-environmental actors ($n=158$) were present in the majority of intervention component-recipient combinations, and that the presence of informal gatekeepers ($n=26$) and secondary recipients ($n=37$) was less common.

Harvest plots [27] show the distribution of intervention component-recipient combinations across the Depth framework disaggregated by overall effectiveness (Fig. 2) and differential effectiveness by SEP (Fig. 3). Given the absence of intervention components within some classifications and a small number of components within others, it is only possible to draw tentative conclusions. Figure 2 indicates that the overall effectiveness of interventions on dietary outcomes favoured the intervention group within all but two framework classifications (exposure — active,

Table 1 Constructs of the Depth framework for classifying intervention agentic demand

Construct	Level definition
Exposure <i>How the recipient group first comes into contact with the intervention component</i>	Active Recipients must change their existing daily activities or initiate new activities to come into contact with the intervention component Passive Recipients do not need to make a change from existing daily activities to come into contact with the intervention component. Passive exposure typically occurs when interventions aim to alter settings for existing users
Mechanism of action^a <i>How the intervention component enables the intended behaviour or discourages an alternative behaviour</i> <i>Mechanisms of action can occur at the individual level or as part of a wider system</i>	Socio-cultural Intervention components that aim to change a community or society's attitudes, beliefs, norms and values related to the intended behaviour Cognitive Intervention components that aim to change individual knowledge, attitudes, beliefs or skills concerning the intended behaviour Financial Intervention components that aim to change the relative monetary cost of intended behaviours. This includes reducing the monetary cost of engaging in the desired behaviour or increasing the monetary cost of alternative behaviours. The provision of free or reduced-price tangible goods is also included here Physical-environmental Intervention components that aim to change the availability, accessibility, safety, placement or properties of infrastructure, facilities, objects or stimuli in the wider environment, including the digital environment Biomedical Intervention components involving drug or medical techniques that aim to alter the intended behaviour or biological systems
Engagement^b <i>The degree to which recipients are required to be aware of or interact with the intervention component's mechanism of action in order to benefit as intended</i>	Active Requires recipients to be aware of the mechanism of action and have purposive interaction with it in order to benefit Passive Does not require recipients to be aware of or interact with the mechanism of action in order to benefit. It is possible for recipients to be aware and interact with the mechanism of action, but not a necessity

See Additional File 2 for full Depth framework guidance including an applied example

^a Multiple mechanisms of action may be present within a single intervention component, and all should be identified and assessed separately

^b Engagement should be classified for each mechanism of action identified

mechanism of action — physical environmental, engagement — passive and exposure — passive, mechanism of action — financial, engagement — active). In both these cases, there were few ($n \leq 3$) observations. Findings related to the overall effectiveness of interventions on physical activity outcomes were more mixed. Overall, amongst the most commonly used mechanism (cognitive) for dietary and physical activity outcomes, there was some indication that interventions appeared to be consistently effective when exposure was passive rather than active.

Figure 3 shows that only three intervention components appeared to reduce socioeconomic inequalities. These included a province-wide physical education policy in Canada [28], sugar-sweetened beverage taxation [29] and a community coalition to promote physical activity [30]. The harvest plots were dominated by data points in the middle column, representing no overall impact on socioeconomic inequalities. There were a considerable

number of components targeting cognitive mechanisms that appeared to consistently widen socioeconomic inequalities, although this was less common with passive rather than active exposure. Interventions with sociocultural and physical environmental mechanisms demonstrated little impact on inequalities.

Despite many interventions containing multiple component-recipient combinations, there was less variation in the number of different Depth framework categories represented within each intervention (median = 2; range = 1–5 per intervention), indicating that many multi-component interventions include multiple components in the same framework category. Figure 4 provides examples demonstrating a spectrum of clustering of intervention components. Given the sparseness of data in our proof-of-concept review, it is not possible to determine whether clustering of framework classifications is associated with intervention overall or differential effectiveness by SEP.

Table 2 Matrix classification and intervention examples for Depth framework constructs

	Mechanism of action ^a				
	Socio-cultural	Cognitive	Financial	Physical environmental	Biomedical
Active					
Active	< 1% (n = 1) <i>Example:</i> Group nutrition education	18% (n = 21) <i>Example:</i> Online self-monitoring of fruit and vegetable intake	2% (n = 2) <i>Example:</i> Free bus pass for older adults	< 1% (n = 1) <i>Example:</i> Afterschool physical activity provision	0% (n = 0)
Passive	0% (n = 0) <i>Example:</i> Choosing to move to town with strong cycling culture	0% (n = 0) <i>Example:</i> Sign up to receive SMS aiming to change individual beliefs on importance of healthy diet	0% (n = 0) <i>Example:</i> Provision of food vouchers that cannot be used to purchase HFSS food	< 1% (n = 1) <i>Example:</i> Installing online HFSS ad blocker	0% (n = 0) <i>Example:</i> Semaglutide drug to suppress appetite and reduce food consumption
Passive					
Active	12% (n = 14) <i>Example:</i> Girl scout troop leader joins in with group physical activities	37% (n = 42) <i>Example:</i> Educational material within existing church bulletin	3% (n = 3) <i>Example:</i> Implementation of SSB tax increases monetary cost	11% (n = 13) <i>Example:</i> Provision of free fruit at lunch time ^b	0% (n = 0)
Passive	0% (n = 0) <i>Example:</i> SSB tax signals SSBs considered unhealthy	2% (n = 2) <i>Example:</i> Provision of fruit at lunch time ^b	0% (n = 0) <i>Example:</i> Car parking charges in workplace	13% (n = 15) <i>Example:</i> Restrict sugar sweetened beverage portion sizes in schools	0% (n = 0) <i>Example:</i> Fluoridation of tap water

n number of intervention component-recipient combinations identified in each category in step 3 (framework application). % Percentage of component-recipient combinations identified in each cell compared to total number identified (n = 115). Examples, identified from framework application or author knowledge

HFSS high fat, salt and sugar, SSB sugar-sweetened beverage

^a Multiple mechanisms of action possible within a single intervention component. Some examples may be classified under multiple mechanisms, e.g. group nutrition education also operates by cognitive mechanisms

^b Intervention authors note two mechanisms of action: (1) increased availability of fruit (physical environmental) and (2) repeated exposure lead to changes in individual preferences (cognitive)

Table 3 Categories of actors potentially involved in population health interventions

Actor category	Definition
Macro-environmental	Actors at organisational level such as industries, services or supporting infrastructure, which operate at international, national or local level, e.g. food manufacturers, local or national governments. It was rarely possible to specify macro-environmental actors; however, it was clear that action was required at this level to initiate or implement interventions
Micro-environmental	Actors at the level of individual spaces or naturally occurring groups of places where people gather for specific purposes, e.g. actors within schools, individual supermarkets, restaurants, parks. These are usually geographically distinct, relatively small and potentially influenced by individuals
Informal gatekeepers	Actors linked to the intended recipient in a nonprofessional manner, e.g. parents. These informal gatekeepers must change their behaviour in order for the intervention to achieve the desired effect in the intended recipient
Secondary recipients	Secondary recipients are individuals who may benefit from intervention 'spill over' effects, e.g. other members of a household who are affected by food purchasing decisions

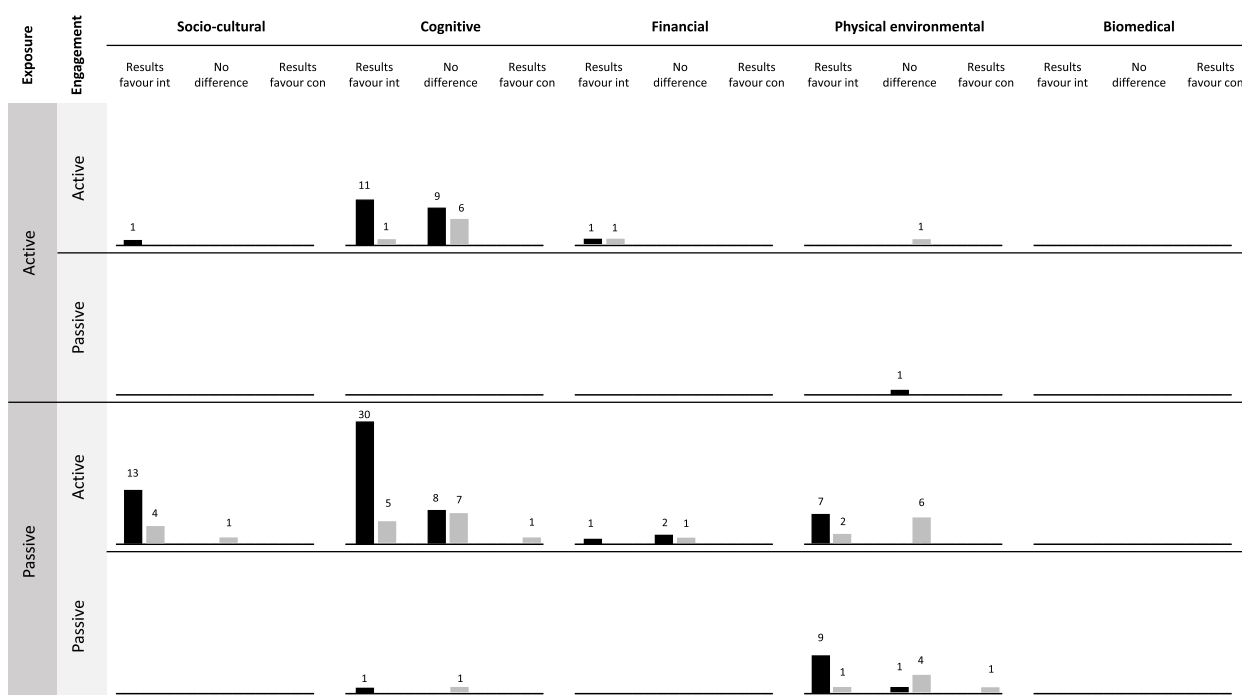


Fig. 2 Harvest plot illustrating association between Depth classification and overall intervention effectiveness. *Black bars*: dietary outcomes; *Grey bars*: physical activity outcomes. *Bar height and numbers*: number of component-recipient combinations represented in each classification. *Int*: intervention group; *Con*: control group. Depth classification is at intervention component-recipient level and effectiveness reported at intervention level

We provide a detailed account of the application rules we followed for this review in Additional File 2. These were guided by our aim to test the framework. Others may wish to apply different rules based on their reasons for using the framework, and these should be agreed at the beginning of a project. The application rules we used stem from initial learning from the inter-rater reliability, and proof-of-concept review, which is presented in Table 4. Others may find useful when developing application-specific rules.

Discussion

Statement of principal findings

The Depth framework is a novel method to standardise the classification of the agentic demands of PHIs developed with a focus on dietary and physical activity PHIs. The framework is based on three constructs: exposure, mechanism of action and engagement. It also identifies four categories of actors that may be involved in PHIs: macro-environmental actors, micro-environmental actors, informal gatekeepers and secondary recipients, yet it was

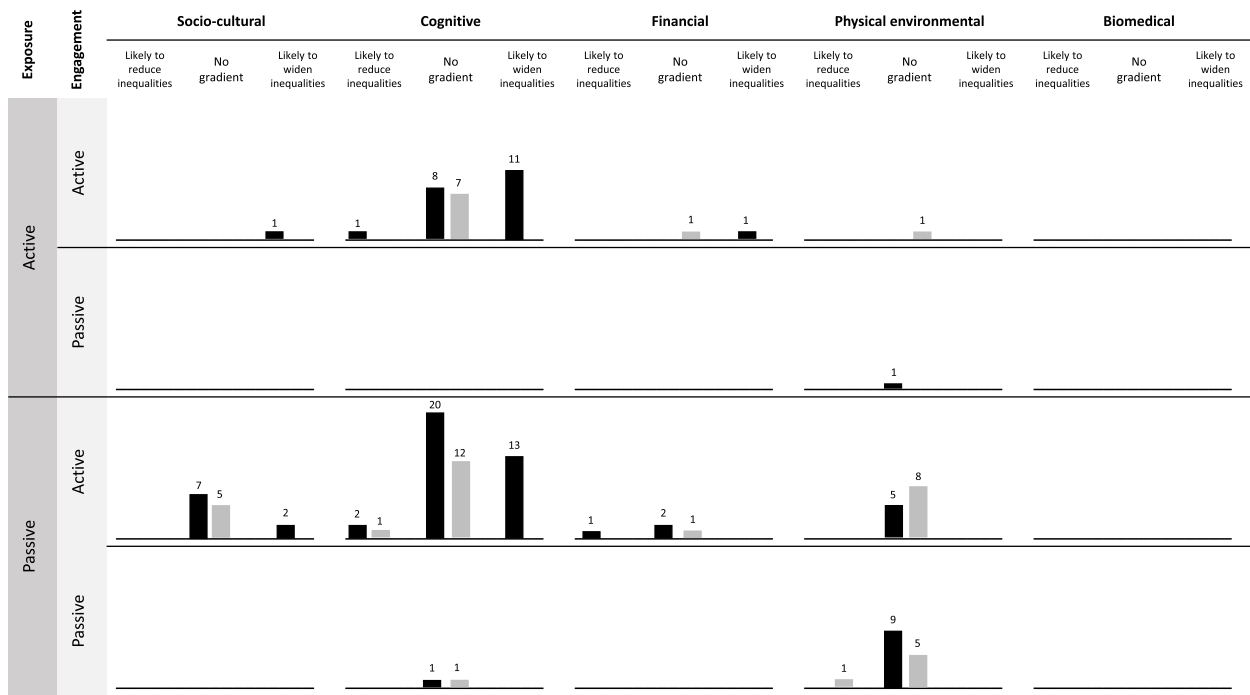


Fig. 3 Harvest plot illustrating association between Depth classification and differential effect by SEP. *Black bars*: dietary outcome; *Grey bars*: physical activity outcomes. *Bar height and numbers*: number of component-recipient combinations representing each classification. Depth classification is at intervention component-recipient level and equity reported at intervention level

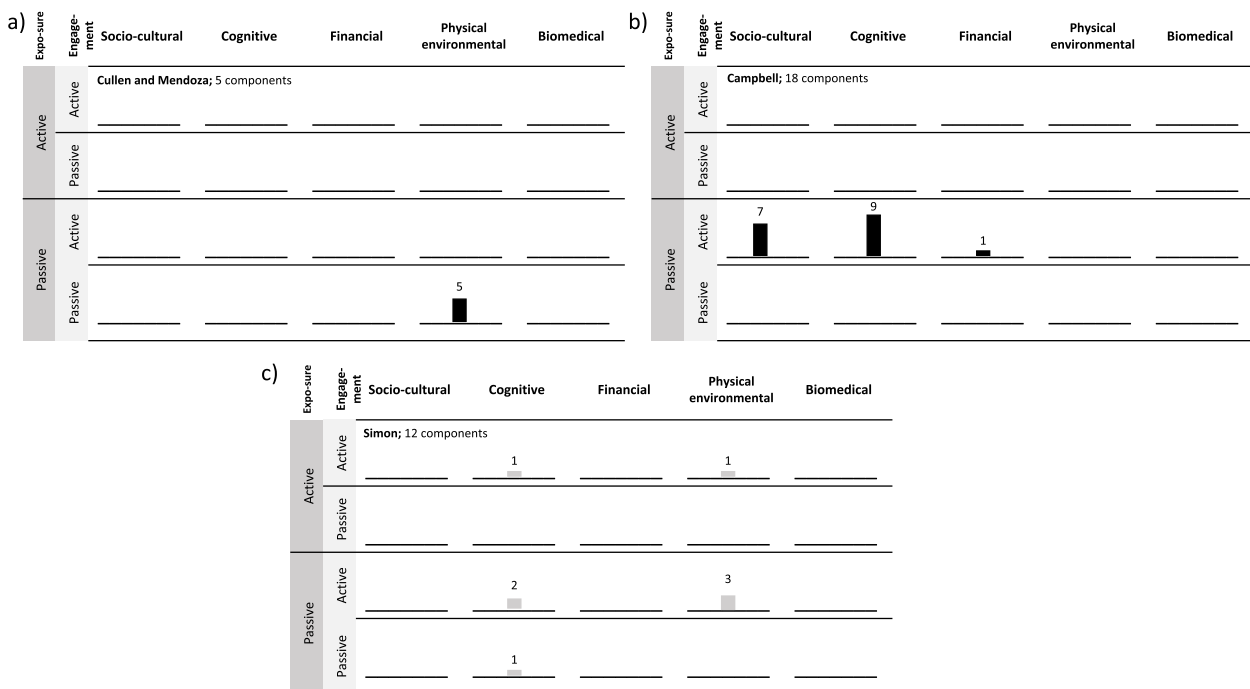


Fig. 4 Harvest plots to illustrate the differences in distribution of intervention component-recipient combinations within multi-component interventions. **a** Intervention with components concentrated within one framework classification. **b** Intervention with component distributed across multiple mechanisms of action but maintain the same exposure and engagement. **c** Intervention with components distributed across all framework constructs. Depth classification is at intervention component-recipient level and effectiveness reported at intervention level

Table 4 Initial learning for applying the Depth framework**Identify component-recipient combinations a priori**

Prior to extracting data on framework constructs, we advise agreeing on the intervention component-recipient combinations. This reduced the number of disagreements at the extraction stage. We identified intervention components to the greatest level of granularity to improve agreement between researchers

Implicit vs explicit information

Not all relevant information is included in intervention reports. For example, some reports may not describe or have explored all mechanisms of action. The degree to which reviewers include only information explicitly included in the report or draw on implicit and wider topic knowledge will be dependent on the review aims and should be agreed a priori

Dealing with insufficient information

Intervention descriptions may not provide sufficient information to classify the framework constructs. In our review, where applicable, we chose to classify framework constructs as 'insufficient information to code' based on the intervention description. Other approaches may include seeking additional information from a wider range of sources (see below)

Information sources

The information sources included within reviews will influence what information is available. We used only data reported in papers that reported equity outcomes, but other approaches such as identifying linked papers, grey literature and speaking to study authors may be used to aid classification

Consistent application

The framework requires users to apply categorical classifications to constructs that lie on continua. Different users may draw these distinctions in different places. Nevertheless, distinctions should be agreed, reported and applied consistently

not possible to classify the agentic demand on the actors due to a lack of available information on their actions. The framework was developed through an extensive, iterative process drawing on a systematically assembled pool of dietary and physical activity interventions and feedback from public health research and policy experts to test its content validity and reliability.

We have demonstrated that it is possible to apply the Depth framework to PHIs aiming to promote healthier diets and physical activity within a proof-of-concept review. Our findings for overall effectiveness favoured the intervention in nearly all Depth framework classifications. Depth framework classification appeared to demonstrate differential effects by SEP. In particular, interventions requiring passive exposure may be more equity promoting than those reliant on active exposure. The two most frequent framework classifications fell within the cognitive mechanism of action with some evidence that this class has the potential to widen health inequalities. Our review did not include any examples in nine framework classifications — particularly those with passive engagement or biomedical mechanisms, reflecting an absence of evidence. At this stage, this makes it difficult to compare findings across all Depth framework classifications.

Strengths and weaknesses of the framework

The Depth framework makes inroads on unravelling the agentic demands of PHIs for diet and physical activity outcomes on recipients, presenting 20 potential classifications. Existing literature distinguishes the agentic demands of PHIs according to two or three classifications [8, 13]; while these have been important to draw

attention to the overarching concept, our work demonstrates considerable diversity of intervention agentic demand that may not be captured by previous classifications. The identification of three constructs within the Depth framework attempts to explain how agentic demand operates within interventions and contributes to opening the lid on the 'black box' of how interventions work to begin dissecting the reasons for intervention successes and failures. Furthermore, the application guidance developed alongside the framework aims to ensure that users can apply the framework consistently.

We acknowledge that the Depth framework does not adequately address all areas that we set out to explore. Particularly, it was not possible to develop a detailed classification of the agentic demands on the four categories of actors, due to a lack of reporting of the actions required from these actors. More systematic identification of specific actors at the macro-environmental, micro-environmental and gatekeeper levels and the actions required of them in intervention descriptions would help to further develop this work. Similar limitations were identified when classifying obesity policy in England [3]. We did not consider it appropriate to simply use the same three constructs identified in the Depth framework for all actors as this could miss important differences involving power, motivations and population reach of additional actors. As such, the framework cannot address questions relating to intervention implementation and acceptability to actors. However, given that macro-environmental and micro-environmental actors were required in the majority of interventions, this is an important area to explore further. Related literature that was beyond the scope of

our methods included regulatory compliance, exploring the conditions required for such actors to comply with intervention implementation [31], and this literature may be a starting point to explore this further.

The framework imposes categorical classifications on constructs that lie on continua, presenting challenges for consistency and reliability. Despite this, we established a process that enabled our team to reach full agreement on Depth classification (Additional File 2). We do not provide this as a definitive instruction manual, rather to be transparent in how we reached the framework classifications in this study. We invite other users to draw inspiration from our approach but acknowledge that they may require a different approach to achieve different aims. We encourage users to agree in advance how they will apply the framework for their purpose and report this transparently.

The current Depth framework identified three constructs, yet some additional intervention features, for example whether the intervention occurs in an environment proximal or distal to the behaviour, may also influence the agentic demands of interventions. At this stage, we deemed that including additional constructs would introduce a level of granularity too great to allow useful evidence synthesis. However, as the framework is used more widely, further important constructs may arise within specific classifications, and we encourage researchers to reflect and report on these.

Strengths and weaknesses of the methods

A key strength of the methods employed to develop the Depth framework is the use of standardised methods in each step, yet we made pragmatic decisions to keep the process manageable. We used systematic methods to search for our initial intervention corpus to develop the framework (step 1), conducting additional searches to identify all articles and reports related to each intervention. While our search strategy aimed to identify a breadth of intervention types, our reliance on this corpus of published interventions may have omitted some intervention types leading to missing categories in the framework. Furthermore, we used the same intervention examples during the development and testing of the framework. However, the framework was applied to a new set of interventions within the proof-of-concept review indicating its wider applicability.

We adopted a proof-of-concept approach to conducting the final review, focusing on a purposive sample of three existing relevant reviews, which limited the number of included studies. Thus, this 'proof-of-concept' approach is unlikely to provide a definitive account of

all dietary and physical activity interventions reporting on equity effects of interventions, and a comprehensive search may have yielded interventions across more Depth classifications [32]. However, this may also be related to the paucity of studies reporting on the equity effects of dietary and physical activity PHIs. The limited number of interventions included in this review limits our ability to draw definitive conclusions or make comparisons between Depth classifications, especially given the concentration of interventions in a small number of classifications. Additionally, as the source reviews focused on studies reporting differential effects by SEP, they are unlikely to capture all relevant studies of effectiveness. It is therefore likely that our findings are more representative of differential effectiveness than overall effectiveness outcomes.

Within the proof-of-concept review, we did not assess the method of measurement of diet and physical activity, and null results may arise in some categories due to measurement methods that are not sufficiently sensitive to detect changes, for example brief dietary recall questions. Additionally, study designs and measurement methods may vary across the Depth classifications, and this may introduce some bias. Furthermore, all included studies were based in high-income countries, and it is unclear how the effectiveness and equity effects of interventions differ within other contexts. A strength of the research was involving academic and policy experts in the qualitative assessment and reliability testing of the Depth framework during step 2. While these audiences represent the main users of the framework, the majority of participants were academics, and therefore, some user groups may be inadequately represented in the development of the framework. In addition, the core research team comprised only of academics.

The lack of detail provided within intervention reports, particularly those with multiple components, was a barrier to establishing the reliability of the framework. It is unclear whether this was due to limited journal space, limited theorisation of interventions, omissions on the part of authors or a combination of these factors. As proposed elsewhere, greater use and reporting of intervention theories of change or programme theory may help address this challenge [6]. During our proof-of-concept review, we applied the framework based on information explicitly provided in reports. While this may have enabled us to reach agreement, the approach led to many cases of 'insufficient information'. It also limited our classifications to the authors' interpretation of how an intervention operates, and authors may not have identified all possible mechanisms of action. For example, one

intervention providing fruit in schools proposed a single mechanism of action of improving availability (physical environmental) [33], yet a similar intervention identified repeated exposure (cognitive) as an additional mechanism of action [34]. To address this issue, other users may choose to draw on their expertise and existing knowledge when applying the Depth framework, rather than sticking rigidly to information included in intervention reports.

Unanswered questions and future research

This is unlikely to be the final version of the Depth framework, and we anticipate that others will suggest modifications and adaptations as they use it. We have developed the Depth framework for interventions targeting dietary and physical activity interventions, but it is likely to be applicable to other behaviours beyond these, such as tobacco use or alcohol consumption. Our proof-of-concept review identified an absence of interventions within some Depth classifications, but we considered it premature to remove these before it has been used more widely. Further work could explore whether such interventions are possible and, if so, why they are so infrequently reported. Possible reasons include the following: they are uncommonly used, less likely to be evaluated when used or used for behaviours beyond diet and physical activity. Either way, these areas may represent particularly fruitful opportunities for innovation. Relying on existing intervention reports to develop a deep understanding of the agentic demand on other intervention actors was not sufficient to address our original aims. In order to address this, further work is required to examine and report intervention implementation in detail. Furthermore, our review focused on exploring the relationship between placement on the Depth framework and overall and differential effectiveness. Future research could explore associations with other outcomes such as intervention acceptability, safety, empowerment and equity based on measures beyond SEP, such as those included in the PROGRESS-Plus criteria [21]. We have demonstrated it is feasible to use the Depth framework within a 'proof-of-concept' review, and intervention agentic demand appeared to influence intervention equity but not overall effectiveness. However, the methods used did not allow us to definitively answer this question. Previous reviews using less nuanced approaches to classifying intervention agentic demand found that upstream PHIs led to larger improvements to population health than 'downstream' individual approaches for dietary [11, 14, 35], physical activity and wider health behaviours including tobacco and alcohol control [11, 35]. Our current proof-of-concept review is not directly comparable given we did not

explore the degree of effectiveness. Future research could explore this using the Depth framework. A review utilising an existing three-category framework of agentic demands [13] found the majority of policies reviewed had a neutral impact on inequalities, regardless of agentic demand, yet this finding may be due to the less nuanced approach for classifying agentic demand [15].

Extending our approach to a wider corpus of literature is a next step that is likely to advance the evidence base and our understanding of how different intervention components influence effectiveness and equity. Such a review may need to make use of strategies such as contacting study authors to obtain additional equity data or utilising existing expert topic knowledge to interpret intervention details. Such a review could also explore whether the distribution of components across framework classifications in multicomponent interventions is associated with intervention effectiveness and equity. For example, some intervention components that place a lower agentic demand on recipients, such as those requiring only passive exposure and engagement, may mitigate the higher demands from other components such as those that require active exposure or engagement. Distribution of intervention components across the framework may diversify the potential for an intervention effect across individuals and contexts. In contrast, concentration of multiple components in the same framework classification may reinforce particular effects.

While we have utilised the Depth framework within a review to retrospectively assess intervention agentic demand, the framework could also be utilised prospectively by researchers, public health practitioners and policy makers to design, refine or evaluate interventions.

Conclusions

The Depth framework provides a method of classifying intervention agentic demand that advances current approaches by addressing the complexity of PHIs and provides guidance for consistent classification. It provides a description of a concept proposed to influence differential intervention effects by SEP and thus has the potential to play a role in understanding how interventions work for different population groups. We encourage users to build on the current framework, exploring its transferability to other behaviours and its association with other relevant outcomes. Future work to understand how the Depth framework can inform intervention design is critical to ensure that implemented interventions account for agentic demand and do not inadvertently reinforce existing socioeconomic inequalities in health.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s44263-024-00043-8>.

Additional file 1: Detailed methods and results for developing and testing the Depth Framework. **Table S1.** Eligibility criteria for selecting intervention examples. **Figure S1.** Selection of systematic reviews PRISMA diagram. **Figure S2.** Intervention selection PRISMA diagram. **Table S2.** Example of intervention coding for 'Get Up and Do Something' [8–10]. **Figure S3.** Example of initial intervention schematic 'Provision of outdoor gym equipment'. **Figure S4.** Iterative development of intervention schematics. **Figure S5.** Final intervention schematic for provision of training, education or information. **Figure S6.** Draft framework demonstrating intervention actors (Y axis) and agency demand on individuals (x-axis). **Figure S7.** Recruitment and data collection process for step 2a. **Table S3.** Questions to guide Part 2. **Figure S8.** Participant recruitment to online workshops. **Table S4.** Participant characteristics. **Figure S9.** Overview of the framework application process. **Table S5.** Statistical inter-rater agreement for individual framework items. **Table S6.** Explanation for key discrepancies between participants. **Figure S10.** PRISMA diagram for step 3. **Table S7.** Reviewer agreement on intervention components before discussion. **Table S8.** Inter-rater reliability statistics. **Figure S11.** Harvest plot illustrating association between DePtH classification and intervention effectiveness. **Figure S12.** Harvest plot illustrating association between DePtH classification and intervention equity. **Figure S13.** Harvest plots to illustrate the differences in distribution of intervention component-recipient combinations within multi-component interventions. **Appendix 1.** Systematic review eligibility criteria. **Appendix 2.** Medline search strategy. **Appendix 3.** Systematic reviews selected for identifying interventions in step 1. **Appendix 4.** Included interventions and papers in step 1. **Appendix 5.** Detailed description of draft framework. **Figure S14.** Conceptual diagram to describe the actors, their actions and resulting agency demands of PHIs to promote a healthy diet and PA. **Table S9.** Definitions and examples of components in Figures 1.5A and 1.5B. **Figure S15.** Draft framework. **Appendix 6.** Inter-rater reliability survey questions. **Appendix 7.** Individual intervention component distribution across the DePtH framework.

Additional file 2: **Figure S16.** Outline of stages required to apply the framework to population health interventions. **Table S10.** Definitions and applied examples of DePtH constructs. **Appendix 1.** – Application rules provided to participants taking part in the online inter-rater reliability survey (Step 2b). **Appendix 2.** – Worked example of applying the DePtH framework.

Additional file 3: Details of interventions included in testing the DePtH framework. **Table S11.** Table of study characteristics.

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Authors' contributions

K.G. and J.A. were involved in the conception, design, data collection, analysis and interpretation of the study. M.P, D.O, J.P, M.W, A.S were involved in the conception, design and interpretation of the study. C.P.J, R.P, R.A.M, D.V.T, E.R.L, C.F. and E.I. were involved in study screening during systematic identification of interventions. G.V. and L.B. were involved in study screening and data extraction in the systematic review. K.G. and J.A. drafted the manuscript and all authors provided comments and approved the final version.

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Availability of data and materials

Additional detail is included in the additional files, and protocols were preregistered on Open Science Framework (<https://osf.io/nz23j/>). An online version of the depth framework is available on www.mrc-epid.cam.ac.uk/depth-tool. This can be used by researchers and policy makers when applying the depth framework.

Declarations

Ethics approval and consent to participate

The University of Cambridge School of Humanities and Social Sciences Research Ethics Committee granted ethical approval [21.284] for step 2. All participants in step 2 provided written informed consent to participate.

Consent for publication

Not applicable.

Competing interests

RAM worked part-time as a clinical investigator for Medhealth Research and Analytics Ltd, a research and development company between Oct 2020-Feb 2023. Responsibilities included assisting in the research and writing up of clinical trial proposals on various medical conditions, including Alzheimer's disease, lower back pain, depression during menopause, and brain-computer interface (BCI) for stroke rehabilitation. The remaining authors declare no competing interests.

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