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RESEARCH

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Involving national stakeholders in a systems approach to map drivers of childhood obesity and actions to prevent childhood obesity in Denmark: the Generation Healthy Kids Study

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Abstract

Background Childhood obesity is a preventable global public health challenge, increasingly recognized as a complex problem, stemming from complex drivers. Obesity is characterized by multiple interdependencies and diverse influences at different societal levels. Tackling childhood obesity calls for a holistic approach that engages with complexity and recognizes that there is no single “magic bullet” intervention to prevent obesity. To facilitate a shared understanding of the complex structures and relationships that determine children’s weight development, systems approaches have shown promising potential. However, systems approaches require more development and research in public health.

Aim This paper describes the processes of gathering national stakeholders to create a system map of childhood obesity drivers in Denmark to map existing obesity prevention initiatives and define real-world actions to prevent childhood obesity in local communities in Denmark. The system map and action ideas will inform the development of community-based activities in a large-scale national study, the Generation Healthy Kids Study.

Methods During two workshops in the autumn of 2022, national stakeholders ($n=45$) were involved in generating and revising a system map. We used a scripted approach inspired by group model building and community-based systems dynamics methods to engage stakeholders, collect and visualize their knowledge on childhood obesity, create consensus on the drivers of childhood health, identify local and national intervention opportunities for prevention of childhood obesity and develop actions to create system changes.

Results The study identified the following six sub-systems of factors influencing childhood obesity: (1) family; (2) diet and dietary habits; (3) physical activity and active living; (4) mental health and wellbeing; (5) screen, media and sleep; and (6) competencies of professionals.

Conclusions A systems approach to childhood obesity was useful to generate a shared understanding of the underlying drivers of childhood overweight and obesity and has potential for informing initiatives at local and national level in Denmark. However, challenges were experienced regarding the usefulness of the system mapping process,

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with a tension between the map as a step in a shared process towards actions and the map as means to gain a deeper understanding of the complex system of childhood overweight and obesity and how to change the system.

Background

Childhood overweight and obesity has been identified as a major challenge for the twenty-first century [1]. In European countries, one in three school-aged children are living with overweight or obesity [2]. In Denmark, 13% of primary school children are characterized as overweight or obese, increasing to 19% at time of school graduation [3].

Overweight and obesity during childhood can lead to a range of physical and psychological health problems [4, 5], such as an increased risk of bullying, stigmatization as well as impaired psychological wellbeing [6, 7]. Having obesity in childhood increases the risk of overweight, obesity, cardiometabolic disease and cancer in adulthood [8]. Additionally, there is a strong social gradient in childhood overweight and obesity, with children of parents with a lower education being at greater risk of developing overweight or obesity than their peers [9].

Obesity is a complex problem with multiple and complex drivers, and no country has yet been able to reverse the obesity epidemic [10]. The development and persistence of obesity can best be understood and explained by a bio-socioecological framework "...that has created the conditions for a scenario in which biological predisposition, socioeconomic forces, and environmental factors together promote deposition and proliferation of adipose tissue and resistance to efforts of obesity management" [5].

Preventing childhood obesity requires multi-level and multi-component interventions as well as multi-level systemic awareness [11, 12]. Multi-level systemic awareness may be defined as the critical skills needed to work on complex problems from a systems perspective, for example, looking at multiple perspectives of an issue; recognizing that a system's structure drives its behaviour; and being comfortable with ambiguity [13].

Interventions that utilize a co-creating and capacity strengthening approach by involving stakeholders in identifying, prioritizing, developing and implementing interventions have recently been proposed as promising to address childhood obesity [14]. Participatory approaches to address this complexity using methods from community-based systems dynamics (CBSD), such as participatory system dynamics and group model building (GMB), have been used to address complex health problems in communities [14–18], across areas such as physical activity [19], mental health [20], alcohol [21] and non-communicable diseases [22].

Interventions building on a participatory systems approach combine relevant evidence, best practice and knowledge about local contexts with the aim to create sustainable solutions together with stakeholders [23]. A participatory system approach implies that a variety of engagement and solutions should occur at the individual, interpersonal, community and organizational levels of the system. This strategy has recently been proposed as a promising approach to address childhood obesity [24]. Though new research is increasingly emerging on this approach [25], the literature is sparse on studies within obesity prevention testing a combination of both a participatory systems approach and a large cluster randomized trial [26]. This paper describes such a study. We report on the work and learnings from gathering national stakeholders in two workshops to create a collective system map of childhood obesity drivers in Denmark. The outputs will be used to inform actions in a Danish intervention research study entitled "Generation Healthy Kids" (GHK) [27]. This study is part of the larger study GHK, which is a cluster-randomized school and community trial designed to investigate the effects of a multi-setting, multi-component intervention on weight development, health and wellbeing in Danish school children [27].

In this study, we engaged key national stakeholders to (a) create a system map of childhood obesity drivers, (b) identify existing obesity prevention initiatives and (c) develop new possible actions to prevent childhood obesity in Denmark. This was done by involving participants in two GMB workshops, in which the process revolved around the framing question: "Which factors influence the development of childhood obesity in Denmark?"

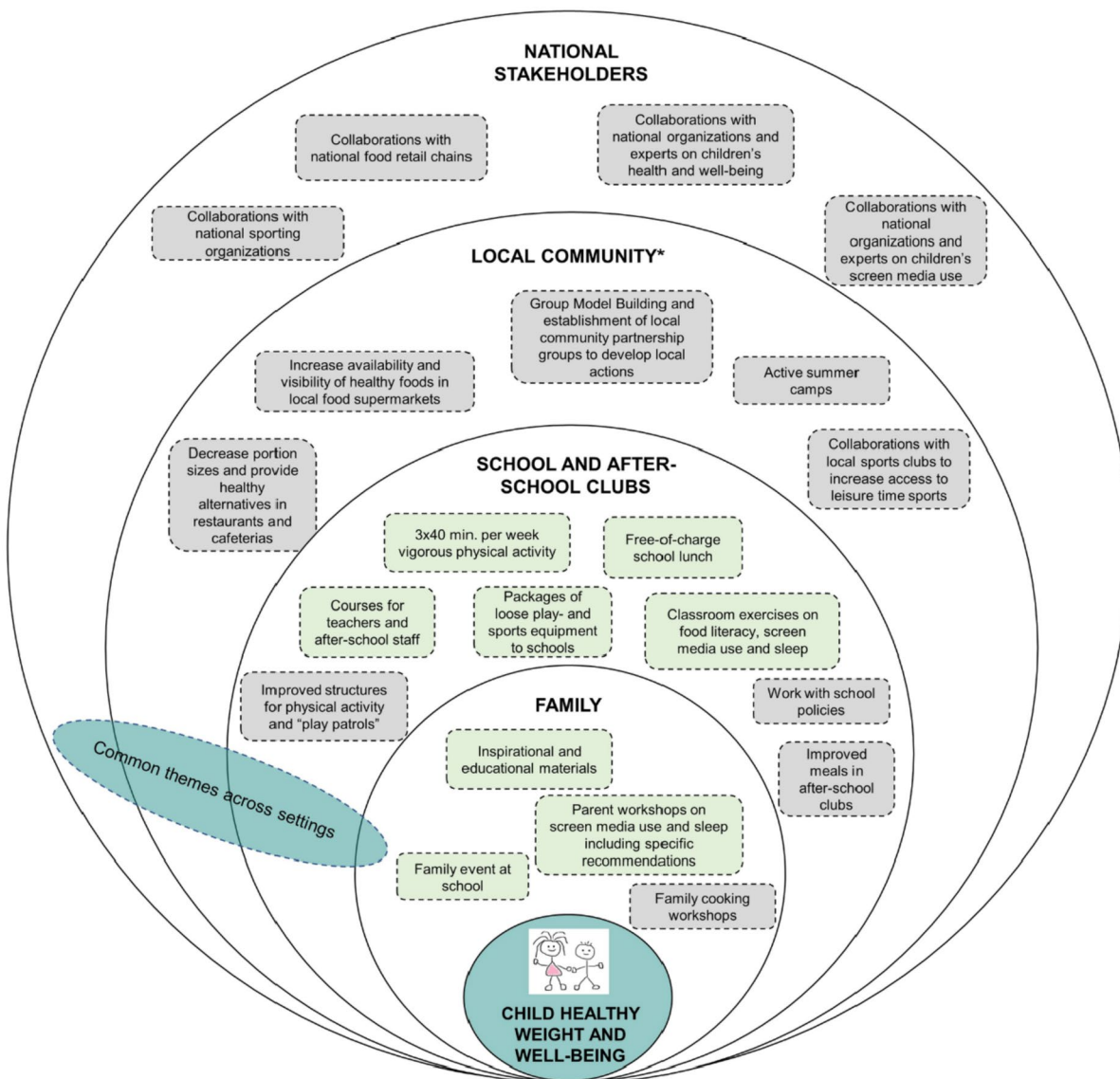
Methods

Study design and recruitment of stakeholders

GHK (<https://clinicaltrials.gov/study/NCT05940675>) is a school- and community-based intervention study with the overarching aim to promote healthy weight development and wellbeing in school-aged children (6–11 years, 1st–3rd grade) and to decrease social inequality in health. GHK is based on the combination of a randomized controlled intervention trial and a systems approach, guided by the Medical Research Council (MRC) framework on designing and evaluating complex interventions [28]. GHK includes pre-defined core intervention components delivered at the school level, focussing on four behavioural components influencing childhood overweight and obesity: diet, physical activity, screen media use and sleep habits, as well

as co-creation and community capacity-building in the surrounding local communities. GHK intervenes across the community, school and family settings through numerous intervention components. The GHK study comprises a two-school-year cluster-randomized trial designed to examine the effect of the multi-setting, multi-component school- and community-based intervention program. The trial will include 23 school districts in Denmark (12 intervention and 11 control), and the intervention will run for approximately 20 months, from October 2023–June 2025 (Fig. 1) [27].

National level stakeholders were involved (1) to generate support for GHK, (2) to ensure that the GHK intervention is anchored in a shared understanding of the underlying drivers of childhood overweight and obesity in Denmark, (3) to build upon existing successful initiatives in Denmark and (4) to facilitate access to potential local collaborators in the intervention communities. Stakeholder involvement was done through bilateral preparatory meetings (July–October 2022) and two inter-related workshops for national stakeholders at which a system map of childhood obesity drivers in Denmark was



Note: Intervention components marked with green are core components implemented uniformly at all intervention schools. Intervention components marked with gray are developed in co-creation with local and national stakeholders.

*The local community intervention will focus on the local community around eight of the 12 intervention schools.

Fig. 1 Overview of the entire GHK study illustrating the various organizational levels and intervention components [27]

created and possible actions to prevent childhood obesity in local communities in Denmark were defined (October–November 2022). A coordinator from GHK together with the research team identified and recruited stakeholders from government policy level (e.g. government employees, department heads, municipality leaders) and non-governmental organizations and private enterprises (e.g. supermarket chains, national sport providers, interest organizations). These stakeholders were selected on the basis of authority and capacity to initiate nationwide actions that are likely to influence the childhood obesity situation in Denmark. By using both an open invitation (via LinkedIn) and targeted emails (73 email invitations were sent), our aim was to recruit 40–50 key national stakeholders from diverse organizations. A total of 38 organizations participated in 2 workshops, with 40 participants at the first workshop (WS1) and 45 at the second (WS2) (Additional file 1: Table 2).

The participatory systems approach

In line with Meadows (2009), we define a system as “[a] set of elements or parts that is coherently organized and interconnected in a pattern or structure that produces a characteristic set of behaviors, often classified as its ‘function’ or ‘purpose’” ([29], p. 188). This implies that a system can be anything from a setting (a school, a family, a local community), or an obesogenic environment. The study used facilitation techniques from GMB, a participatory method for involving stakeholders in the process of developing conceptual system maps [17, 30]. System mapping is the term used to describe when stakeholders, through one or more workshops, build an overview of a complex problem with the aim of illustrating complexity and identifying potential opportunities to intervene in the system (leverage points), informing policy and practice and enhancing stakeholder and community participation [31, 32]. GMB is used to develop a system map, a graphical representation of the components of a dynamic system’s causal structure, variables and causal links with polarity and feedback loops [33].

Feedback and circular causality are central for a system map and hence the term causal loop diagram is often used [32]. The concepts of polarity and feedback have been debated [33], and here we rely on the definitions from classic system dynamics textbooks, such as Sterman [34] and Hovmand [17]. Positive polarity “... mean[s] that increasing the cause variable increases or adds to the effect variable with everything else being held constant.” Negative polarity means “...that decreasing the cause variable decreases or subtracts from the effect variable with everything else being held constant” [17] (p. 3). Feedback loops can be positive or negative. Positive loops reinforce change while negative loops are self-correcting, that is,

they oppose disturbances; thus, positive feedback loops are also called reinforcing loops and are often denoted by $a+$ or **R**, and negative loops are often called balancing loops and are denoted by $a-$ or **B** [34]. Creating a system map provides a shared logic model for key stakeholders in a study and therefore represented a key first step in initiating collaboration on development and implementation activities in the larger GHK study [27, 35].

The system mapping process in the GHK study consisted of several elements (Fig. 2). GMB focussed on child obesity [36] has usually been composed of three consecutive workshops, specified in a script [37–39], which was modified for the GHK study to two workshops on the basis of participants’ availability and to reduce the participant burden. Other studies have also modified the original GMB workshop process for different purposes [25]. Before the GMB workshops, invitations were sent out widely to a kick-off meeting, which included presentation of the GHK study and an evidence brief on obesity with specific references to general health, and wellbeing among children in Denmark.

Group model building workshop 1 (WS1) – 6 October 2022

During WS1, a short evidence brief on obesity among children focussing on documented challenges, prevalence, consequences and prevention approaches was presented. Afterwards participants engaged in discussions around the framing question: “What factors influence the development of childhood obesity in Denmark?” Activities in the workshop included graphs over time (participants graphed factors that influence the development of childhood obesity in Denmark) and the building of a connection circle [the content of the graphs over time (variables herein) were entered into a connection circle as they were shared by participants]. Participants identified connections between the variables, and added new variables and described the polarity, denoting a positive or inverse relationship of change between the two variables. This process and the resulting system map was created using the Systems Thinking in Community Knowledge Exchange (STICKE Version: 3.0.14) software [40]. Subsequently, participants were asked to write down existing national interventions targeting the prevention of childhood obesity that could be of interest for the GHK study using a prespecified template.

Group model building workshop 2 (WS2) – 24 November 2022

In WS2, the system map developed during WS1 was revisited and refined until stakeholder agreement was achieved. A final system map was built, from which the stakeholders were invited to identify priority areas for action/interventions (Fig. 3). The identification of

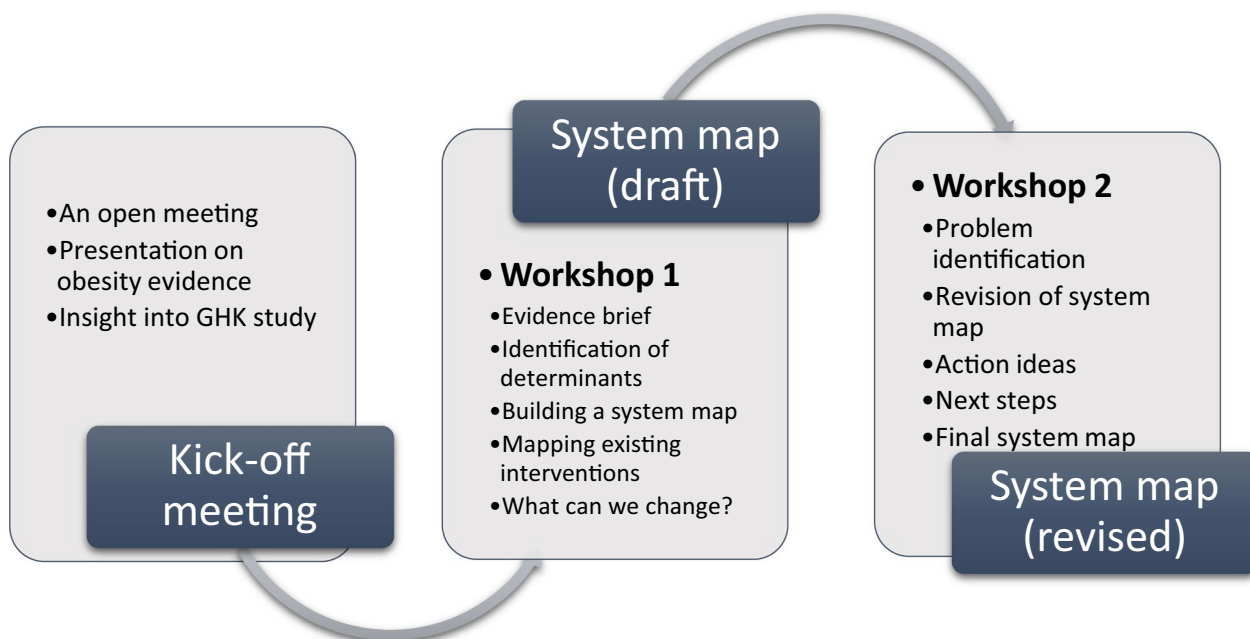


Fig. 2 Overview of the GHK system mapping process using GMB method

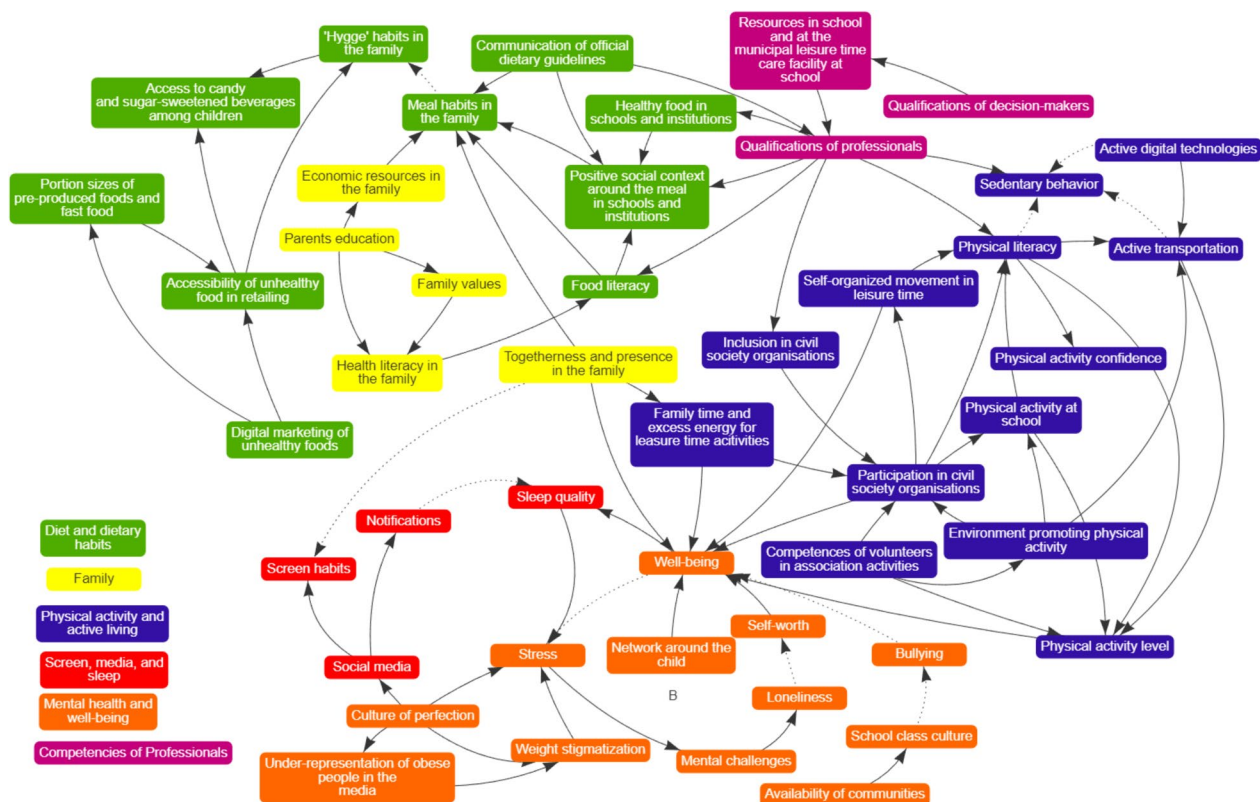


Fig. 3 Developed system map, with colours representing each sub-system – yellow: family; green: diet and dietary habits; blue: physical activity and active living; orange: mental health and wellbeing; red: screen, media and sleep; purple: competencies of professionals. Fully extended arrow represents a positive polarity. Dashed arrows represent a negative polarity. “B” denotes balancing feedback loop

priority areas was based on a “power-to-change” technique, meaning that the participants were asked to identify where on the developed map changes had to occur, and where they themselves had the leverage to change the system. Hereafter, action ideas were identified and written down using a prespecified template and shared among all participants (Additional file 2: Fig. 1) (Table 2).

Between WS1 and WS2, the research team identified possible overall themes of the map through reading of all observation notes (written by researchers) and sketches (done by participants) during WS1. The intent of this was to align and make the system map more accessible to the participants in WS2 and to assess whether any important variables written by the participants were missed and should be addressed during WS2. The identified themes and missed variables were presented for the participants at WS2 for their opinion. After WS2, two of the authors (K.R. and A.B.G.H.) colour coded the systems map into six broad thematic areas (which was agreed upon between the stakeholders in WS2), and the final system map was sent to all WS participants for their comments, verification and acceptance.

Both workshops were led by the Centre for Clinical Research and Prevention, facilitated by two experienced facilitators (K.R., main author and P.B., co author), and supported by a team including a modeller, a wall builder and note takers. The format, venue and timeframe (3 h) were the same for both workshops and included a meal. Participants were placed in working groups of three according to a seating plan, which was based on maximal variation, seating people from different organizations together to obtain as different perspectives as possible.

Results

The system map

Figure 3 shows the system map developed during the GMB workshops, illustrating the participants’ views on the most important factors influencing childhood obesity in Denmark. Six sub-systems were identified: (a) family; (b) diet and dietary habits; (c) physical activity and active living; (d) mental health and wellbeing; (e) screen, media and sleep; and (f) competencies of professionals. To analyse and understand the system map, we first describe the six sub-systems identified; secondly, we describe variables, connections, polarity and feedback loops; and lastly, we describe what we see as the causal mechanisms of the system. An overview can be seen in Additional file 1: Table 1.

Sub-systems

We identified six sub-systems (family; diet and dietary habits; physical activity and active living; mental health and wellbeing; screen, media and sleep; and

competencies of professionals). Breaking down the system map into smaller sub-systems makes the system map easier to understand, and each sub-system corresponds to one part of a dynamic narrative [34], which is unfolded in causal mechanisms of the system in Additional file 1: Table 1. The six sub-systems are interconnected, with each sub-system having approximately two connections to other sub-systems (Fig. 3).

Variables, connections, polarity and feedback loops

The system map consists of 47 variables, which were distributed in the six sub-systems as follows: 12 variables in the sub-system of mental health and wellbeing; 13 in physical activity and active living; 10 in diet and dietary habits; 5 in family; 4 in screen, media and sleep; and 3 in competencies of professionals.

The map mainly shows connections with a positive polarity and one feedback loop (Fig. 3). A balancing feedback loop was identified in the mental health and wellbeing theme showing that where stress increases mental challenges, which again increases loneliness which decreases self-worth, which in turn influences wellbeing and then feeds back into stress. Thus, a promotion of wellbeing among children, would be expected to decrease stress, mental challenges and loneliness and to increase self-worth. In other words, wellbeing would be a strategical good leverage point, as it affects many parts of the feedback loop.

Causal mechanisms of the system

We use the system map to qualitatively interpret and unravel hypothetical causal mechanisms in the system under study [41]. Causal mechanisms relate to system function, that is, how the system works [15, 34], whereas system structure consists of the feedback loops, connections and variables, that is, what the system is made up of. In this regard, the column “causal mechanisms of the system” in Additional file 1: Table 1 is an elaboration of how the system works, that is, delineating which variables, connections and feedback loops are involved in the different causal mechanisms. The system map surfaced causal mechanisms that influence more sub-systems due to a greater number of connections to other sub-systems (Fig. 3), for example, “Qualifications of professionals” in the sub-system competencies of professionals, which is the single variable with most connections to variables in other sub-systems. Here the participants described how an increase in professionals’ qualifications (e.g. teachers) would influence two sub-systems, namely, diet and dietary habits and physical activity and active living. Increased qualification of professionals could lead to (1) an increase in the promotion of the positive social context around the meal in schools and institutions, food

literacy and healthy foods in schools and institutions and (2) positive changes in physical literacy, inclusion in civic society organizations and decreases in sedentary behaviour.

Suggested action ideas proposed at WS2

Table 1 describes the 31 proposed action ideas proposed by participants at WS2 and which sub-system they influence. Their number on the map refers to Fig. 1 (Additional file 2), where each action idea is inserted into the system map, and which sub-system they are expected to influence is described. Most proposed ideas concerned the physical activity and active living sub-system ($n=13$, blue) and diet and dietary habits (green, $n=6$), while fewest ideas were developed to influence screen, media and sleep ($n=3$, red); competencies of professionals ($n=3$, purple); and mental health and wellbeing ($n=2$, orange) (Table 1). See Additional file 2: Fig. 1 for a graphic illustration of the action ideas as part of the system map.

Discussion

We engaged key national stakeholders to create a system map of childhood obesity drivers, locate existing obesity prevention initiatives and develop new possible actions to prevent childhood obesity in Denmark. This was done by involving participants in two GMB workshops, where the process revolved around the framing question: “What factors influence the development of childhood obesity in Denmark?” We identified six sub-systems of factors influencing childhood obesity: (1) family; (2) diet and dietary habits; (3) physical activity and active living; (4) mental health and wellbeing; (5) screen, media and sleep; and (6) competencies of professionals. The systems approach to childhood obesity was useful to generate a shared understanding of the underlying drivers of childhood overweight and obesity and collaboratively devise ideas and actions that could identify new ways to intervene and address obesity in local communities.

The system map

The system map, indicating how the different sub-systems and factors are connected, provided a basis for discussing the underlying structure and function of the system and the ways in which to leverage the system through both existing interventions and new ideas for interventions (called actions). In this way the system map also acts as a strategic tool for identifying potential leverage points for action. Leverage points can be described as places to intervene in a system [29, 33]. Changing a system requires identification of the most obvious leverage points and knowledge of their potential to create an impact. In systems approaches, actions are conceptualized as having a different impact at different levels.

Frameworks such as “The Intervention Level Framework” [42], “The Public Health 12 framework” [43] and “Action Scales Model” [44], which all are inspired by Meadows’ work, have conceptualized this [29]. These frameworks illustrate places to act in a system ranging from the most impactful to the least impactful leverage points. Although we considered it outside the scope of this study to conduct a thorough classification of all action ideas according to the mentioned frameworks, the proposed ideas included both initiatives at a lower potential impact level (e.g. one-off events such as cooking evenings for families; idea no. 21, Table 1), while several others were at structural/higher level (e.g. regulations concerning ultra-processed food; idea no. 20, Table 2).

Mapping of action ideas and existing interventions

With inspiration from the system map, participants suggested 31 action ideas for local and national interventions (Table 1 and Additional file 2: Fig. 1). In the future GHK study, efforts will be made to implement a selection of these action ideas in collaboration with national stakeholders across six local communities. In these local communities we will involve several settings that are important for children’s health and wellbeing, including: families, schools, municipal leisure time care facilities at schools (after school club), municipality, leisure associations, interest organizations, local enterprises, etc.

It is interesting that most of the action ideas developed in the system map had the potential to influence the physical activity and active living theme ($n=12$, blue) or diet and dietary habits theme ($n=6$, green), while fewest action ideas were developed to affect screen, media and sleep ($n=3$, red); competencies of professionals ($n=3$, purple); and mental health and wellbeing ($n=2$, orange). This may suggest that workshop participants focussed more on physical activity and diet as important factors that influence the development of childhood obesity in Denmark. Similarly, the majority of the existing interventions mapped by the participants focussed on either physical activity or diet or both. Thus, a reflection based on suggested actions for GHK (Table 1) and existing intervention suitable for GHK, could be the need to focus on other leverage points to influence the system, namely screen, media and sleep; mental health and wellbeing; and competencies of professionals.

System structure

The system map conveys an understanding of the structure of the system showing dynamic interrelations between the various factors. A first look at the system map gives a clear impression of the elements and how they are interconnected (i.e., arrows). We also see that the system map is primarily dominated by connections

Table 1 Suggested new action ideas for local interventions by national stakeholders

No. at map	System map theme and action ideas developed	Sub-system
Physical activity and active living		
1	“Physical activity targeted children with limited sporting experience”: focus on playing and having fun, rather than competition. Focussing on including families/children not usually involved in civil society sports organizations. Already exists in 40 municipalities (Jump4Fun and Danish Gymnastics Association)	– Sedentary behaviour + Physical literacy
2	“Training community for children 9–11 years and their families”: focus on activity and community rather than competition. Can help socially disadvantaged and severely obese children out of bullying, loneliness and unhappiness. Increases physical, social and mental health (and more equality in health). FitforKids offers teams in all municipalities. Free participation	– Sedentary behaviour
3	“Ensure access and inclusion for all to recreational activities”: require that no civil society organizations can reject children. Initiatives to ensure children from vulnerable families can be part of association activities. Initiative already exists but can be expanded. Require that civil society sports organizations can’t have elite teams without having inclusive teams where everyone can join. Require that all civil society organizations have a socially inclusive track	+ Increase in civil society organizations
4	“All 1st grade classes are by default a member in a local civil society sports organization”. This could be handled by the municipal leisure time care facility at school; pupils will have the possibility to opt out. Existing local civil society sports organization must set up satellite teams at relevant municipal leisure time care facilities at schools. In this local initiative, the municipality must help with the structure, establishment and premises. The local associations must be ready in the early afternoon hours and see the teams as an introduction team. Will require finances for coordination and salary for instructor	+ Participation in civil society organizations A
5	“Movement buddies”: volunteer mentors for children who help children get involved in sports association, for example, by introducing them to organizations in the local community, help with transport etc.	+ Physical courage + Network around the child
6	“Overview of leisure-time activities”: could make it easy to get an overview of the possibilities of activities in civil society sports organizations and association activities	+ Participation in civil society organizations
7	School children in 7th–9th grade should not be allowed to leave school during school time (to prevent shopping unhealthy food and sweets)	
8	Funds for activities for the schools in “Generation Healthy Kids” (GHK): funds could be used on activities that support GHK in the schools. The point is that the schools themselves decide and it is easy. In this way, ownership can be increased to work with the agenda of GHK	
9	Car-free zone around the schools – maybe 1 km around the school	+ Environment promoting physical activity
10	“Education in voluntariness in secondary school”. Propose to 8th–9th grades that they can use the optional subject to become a trainer/volunteer and strengthen their skills for association activities and in civil society organizations	+ Competences of volunteers in association activities
11	School design to promote physical activity and the opportunity for outdoor learning	+ Environment promoting physical activity + Sedentary behaviour
12	Extra staff in the municipal leisure time care facility at school dedicated to the task of helping families in need with children’s participation in leisure activities	+ Physical activity at school
Family		

Table 1 (continued)

No. at map	System map theme and action ideas developed	Sub-system
13	“Family mentor”: a volunteer mentor who helps vulnerable families with everyday challenges, for example, help children with homework or transport to leisure time activities and budgeting and planning of everyday life to support vulnerable families in everyday life	+ Economic resources in the family
14	“Job and education mentor”: includes a range of initiatives for parents who contribute to parents’ education and family life. The Danish Red Cross has nationwide support for supporting parents in vulnerable positions, for example, helping with adherence to education and job seeking. Parents are assigned a volunteer mentor from the Red Cross. A bridge can be built to this existing intervention	+ Economic resources in the family
15	“Family friend”: helping vulnerable families by meeting them without prejudice and understanding their point of view. We must look at how we help the families to take action instead of finger pointing. Some know what is healthy/unhealthy, right/wrong, but need to be shown the way instead of getting prescribed a certain way of living	+ Economic resources in the family
16	“Creating communities”: supporting the child’s and family’s social network by building a bridge to the Danish Red Cross’ existing family network, which could alleviate loneliness	+ Togetherness and presence in the family
17	“Parent training”: pedagogical training of parents. Giving parents qualifications and skills to navigate modern life and a culture of perfection	+ Parents’ education
Diet and dietary habits		
18	“Food school for families”: Invite family and other relations to school, where they are told/shown what food the children eat (and perhaps help prepare) at school. Download any inspiration from KBH’s food schools and their commitment to Copenhagen Cooking 2022, Kalvebod Fælled Skole	+ Meal habits in the family + Food literacy
19	“Improving regulations for pricing and product placement of unhealthy foods in supermarkets”	– Accessibility of unhealthy products in retail – Access to candy and sugar-sweetened beverages for children
20	“Regulation of ultra-processed food products” – regulation of content and promotion of healthy “ready meals”	– Portion size of pre-produced foods and fast-food
21	“Cooking healthy meals together”. Event or courses for children and their parents where they cook healthy meals together to improve food literacy in families	+ Food literacy + Health literacy in the family
22	“Better regulation of marketing of unhealthy foods and sweets to children”, for example, no toys in in Kinder Surprise	– Accessibility of unhealthy products in retail
23	“Mandatory warning labels on unhealthy foods”. Labeling of unhealthy foods: foods with salt, sugar or fat above a threshold must have warning labels (in line with tobacco)	+ Communication of official dietary guidelines
Competencies of professionals		
24	“Implementation and sustainability of health promotion and developing health literacy skills among decision-makers in the municipality” (school leaders, politicians, etc.)	+ Qualification of decision-makers

Table 1 (continued)

No. at map	System map theme and action ideas developed	Sub-system
25	“Political action is necessary at several levels”. Politicians must take children’s health seriously. Locally, we must strive to motivate local politicians to work for children’s health and well-being. We must work for political/structural initiatives at all levels, for example, a national Public Health Act. We should also use the Children’s Convention actively in the dialogue with politicians and use the leading stakeholders to pave the way	+ Qualifications of decision-makers
26	“Use professionals in new contexts”: Scout leader in sports, nutrition advisor in association activities, kitchen worker in social studies, experiences from day-care for school. Focus on professional competences – where can we learn from each other and get a better result together	+ Qualifications of decision-makers
Media		
27	“Physical gaming for particularly vulnerable people who are at risk of obesity”	– Social media
28	“Digital strategy: easy-to-remember rules for healthy screen use”	+ Screen habits
29	“Use of digital tools for parents who want to include children in the kitchen”. Investigate how GoCook’s current cookery school app for iPad and smartphone can be further developed for younger school children and investigate values and digital tools to involve children in the kitchen	+ Food literacy
Mental health and wellbeing		
30	“Buddy system in school”: where a child gets paired with another older child, could provide security, community, role models and responsibility (in primary school)	+ Availability of communities
31	“Reduction of bullying on social media by increasing information on consequences of weight stigma”	– Bullying – Stress

with a positive polarity, meaning that the variables increase or adds to the variables it points to. In different sub-systems this results in different systems functions. In the sub-system physical activity and active living (blue) the framing is positive for health, as the connections reinforce behaviours and structures that promote physical activity. Contrasting to this are the sub-systems mental health and wellbeing; screen, media and sleep (orange and red, respectively); and some parts of diet and dietary habits (green), where the framing and connections are negative for health. This could indicate that national stakeholders found it more achievable to make a positive impact in the sub-system physical activity and active living, than for example, changing portion sizes of pre-produced foods and fast food, changing digital marketing of unhealthy foods or reducing the use of social media among children.

System function

System function is related to how the system as a whole works and has been termed system purpose or system goals [29]. Insight into system function is important for understanding and changing a system. More

comprehensive system maps of obesity-related behaviours in 10–14-year-old adolescents have identified a system function that sustains structures and behaviours which promote unhealthy weight among young children [15]. In our case, due to the limited number of feedback loops, it is difficult to draw unambiguous conclusions about the function of the system as a whole. However, the identification of causal mechanisms in the different sub-systems reveals some important aspects of system function (Additional file 1: Table 1). As an example, participants underlined the problem of high access to unhealthy food in retailing, which influences both children’s access to candy at home and family habits, which in turn influence families’ demand for candy and sugar-sweetened beverages in supermarkets.

Compare and contrast with previous studies

System mapping using techniques from CBSD and GMB are well described in the literature [11, 14, 31]. In the systematic review by Felmingham et al. [14], most studies were situated in specific local communities, 12 studies were part of a wider intervention, and 20 studies were stand-alone interventions. Our study stands out

by including national stakeholders in mapping national health issues. This could have relevance for the analytic generalizability of the findings [45], as the factors relate to a national level, and the map was built through in-depth scrutiny and higher-order abstraction.

Practical implications of the system mapping process for the wider GHK study

One of the aims of this study was to involve national stakeholders to facilitate access to potential local collaborators in the intervention communities. This process is currently ongoing (December 2023), thus concluding on the success of this is premature. Reflecting on the practical implications for the GHK study of the system mapping process with national stakeholders raises some questions. We experienced that some participants were sceptical about the system mapping process. This could be due to a perceived lack of practical relevance for the participants or a disbelief that the process would translate into changes in childhood overweight and obesity. This theme is also reflected in a recent scoping review on participatory system mapping, which highlights the difficulties of translating systems mapping results into policy action [31]. Using system mapping as part of a wider policy process – and in the case of GHK as part of a wider school- and community-based intervention study – also raises a tension between the outcomes of the process (the system map and action ideas) and the difficulties of implementing these in real life. Tensions have also been uncovered in the discrepancies between system mapping insights for researchers and participants. On the basis of observations of such tensions, van den Akker et al. [31] suggested that “...future research using participatory systems mapping would benefit from at least some acknowledgement of these potential power imbalances, which includes those between researchers and participants”. To some participants the map was solely understood as a step in the shared process towards actions, and not as a means to gain a deeper understanding of the complex system of childhood overweight and obesity and how to change this system. Thus, we consider it vital that system mapping is discussed and acknowledged in research groups endeavouring down the CBSD path, as misunderstandings between researchers and participants can easily arise.

In our view, downplaying the relevance of system mapping would be unwise as this approach holds many potential gains. Among these are that system mapping illustrates a very complex problem on just “one piece of paper”, which would otherwise require many pages of narrative explanation. This makes the approach more accessible and appealing to participants. Furthermore, system maps can be a helpful tool to guide and focus

discussions in organizations or communities by providing a form of agenda that shows relationships between the items being discussed. Finally, system maps can identify feedback loops that may help explain behaviour or generate insights, which may be hard to achieve with other approaches [46].

Strengths and limitations

System approaches often involves researchers as well as stakeholders such as in our study. Although the researchers’ role is often centred around the facilitator team (and not as participants), their role is important to consider as they naturally influence the results of GMB. Researchers are often responsible for selecting and recruiting stakeholders, choosing the framing question and revising and aligning the map between workshops. The latter tasks between workshops are made as transparent as possible to the stakeholders and is based upon interpretations of the participants work, either directly collected (their own physical notes and sketches) or through researchers’ observations during the workshop. The intention is to keep the influence from the researcher as limited as possible, though it cannot be eliminated completely [17].

The proliferation of systems approaches in public health can be seen as a reaction to shortcomings of traditional intervention research, exemplified in small trials, negligible effect sizes [47, 48], limited generalizability and lack of intervention sustainment [49–52]. System approaches such as CBSD are useful in addressing complex problems in public health, in our case childhood obesity, resistant to simple solutions and effective stand-alone interventions. Research in community-based systems interventions to prevent obesity points towards several mechanisms of action that could contribute to better implementation in practice; among these are capacity building, shared understanding of local problems, community involvement and local collaboration [35].

In systems mapping processes, both the research questions, framing and boundaries of the systems map and the composition of workshop participants can influence the results [31]. In the literature it is stressed that it is important to have a broad stakeholder representation and “...consider who affects or is affected by the system; who has on-the-ground knowledge and who has a strategic overview; who is often overlooked; are there provocateurs who could usefully be invited to challenge established narrative?” [53]. Ensuring a broad and diverse representation in the group of participants to create a comprehensive and inclusive system map should be a focal point for future studies [31]. In our study, organizations representing families and children could have been more strongly represented. A reduced diversity of stakeholders implies

a cost to system representation [53], but system mapping workshops are dependent on stakeholders accepting invitations, and thus it is a pragmatic endeavour to ensure representativity.

Unanswered questions in systems approaches relate to how best to measure effectiveness of the approach, including data collection tools [14, 26]. Collectively mapping a complex problem such as childhood obesity should be seen as part of a process leading to increased collaboration across disciplinary boundaries and acknowledgement of childhood obesity being part of a larger system. An important direction for future research is the recognition that system change requires strategies that will support empowerment in the local community, also after the system mapping process is completed [14].

Conclusions

Systems approaches may be used to generate a shared and valuable understanding of the underlying drivers of childhood overweight and obesity development. The approach has potential to inform and qualify practice initiatives at the community level in Denmark. Nevertheless, selection of participants, framing questions, workshops and mapping processes require careful planning to be successful. Some stakeholders mainly value the mapping process as a step towards prospective joint action planning, whereas others mainly value the mapping process as an opportunity to interact with peers on gaining a deeper understanding of the complex factors influencing childhood overweight and obesity development. Pre-workshop balancing of expectations among stakeholders is therefore imperative to optimize outcomes of the mapping process.

Furthermore, in understanding interactions and dynamic behaviours of complex health issues, a system approach can contribute to the identification of innovative leverage points for intervention. In this study we found a possible national interest favouring physical activity and diets schemes in targeting childhood obesity. The development of a national system map may be helpful to the GHK study to identify potential leverage points where system changes potentially could take place.

Abbreviations

CBSD	Community-based system dynamics
GHK	Generation Healthy Kids
GMB	Group model building
MRC	Medical Research Council
NGO	Non-governmental organization
OECD	Organisation for Economic Co-operation and Development
WS	Workshop
WP	Work package

Supplementary Information

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Additional file 1.

Additional file 2.

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Author contributions

U.T., R.K. and A.B.G.H. contributed to the design of the study. A.B.G.H., L.T.T., K.R., P.B., D.H. and U.T. planned and conducted the workshops, which were facilitated by P.B., K.R. and A.B.G.H. K.R. and A.B.G.H. wrote the first draft of the manuscript. All authors read, commented, edited and approved the final manuscript.

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Availability of data and materials

Data sharing is not applicable to this article as no datasets were generated or analysed during the current study. Protocols and scripts used for the workshops are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The larger GHK study is approved by the Regional Committee on Health Research Ethics for Southern Denmark (reference number S-20220094). Approval was obtained on 14 April 2023 (protocol version 1.1) with subsequent amendments approved 6 July 2023 (version 2.1), 14 July 2023 (version 2.2) and 8 August 2023 (version 3.0, current version). Any subsequent protocol amendments will be submitted to the Health Research Ethics Committee for evaluation and will also be added to the registration at www.clinicaltrials.gov (NCT05940675). Ethical approval for this study was sought and granted from the Danish Scientific Ethics Committee (S-20220059).

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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