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# Using Systems Approaches to Catalyze Whole-of-Community Childhood Obesity Prevention Efforts

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## Introduction

Obesity is a growing global pandemic, with economic, social, and health consequences that cost the world USD\$2 trillion annually<sup>1</sup> and affect the lives of an estimated 641 million people.<sup>2</sup> The limited success of current efforts to address obesity may be due to a failure to account for the complex “systems” that keep obesity deeply embedded in the communities and individuals it affects.

This article addresses the need at the community level to examine holistically the existing systems that are at work in the obesity challenge. Doing so would help determine what needs to change and how in order to improve the health and well-being of the population. A bold and substantive systems approach to obesity prevention has the potential to create a paradigm shift across the United States. Evidence-based interventions focused on energy balance, diet quality, and other health-promoting behaviors coordinated through all aspects of community life—including healthcare, local government, food and beverage (retail, farmers markets, food banks and pantries, restaurants), early childcare, education, transportation, and the built environment (parks, sidewalks, bike lanes, playgrounds)—provide an opportunity to deliver a comprehensive approach and more potent medicine for turning the tide on obesity.

## The global state of obesity

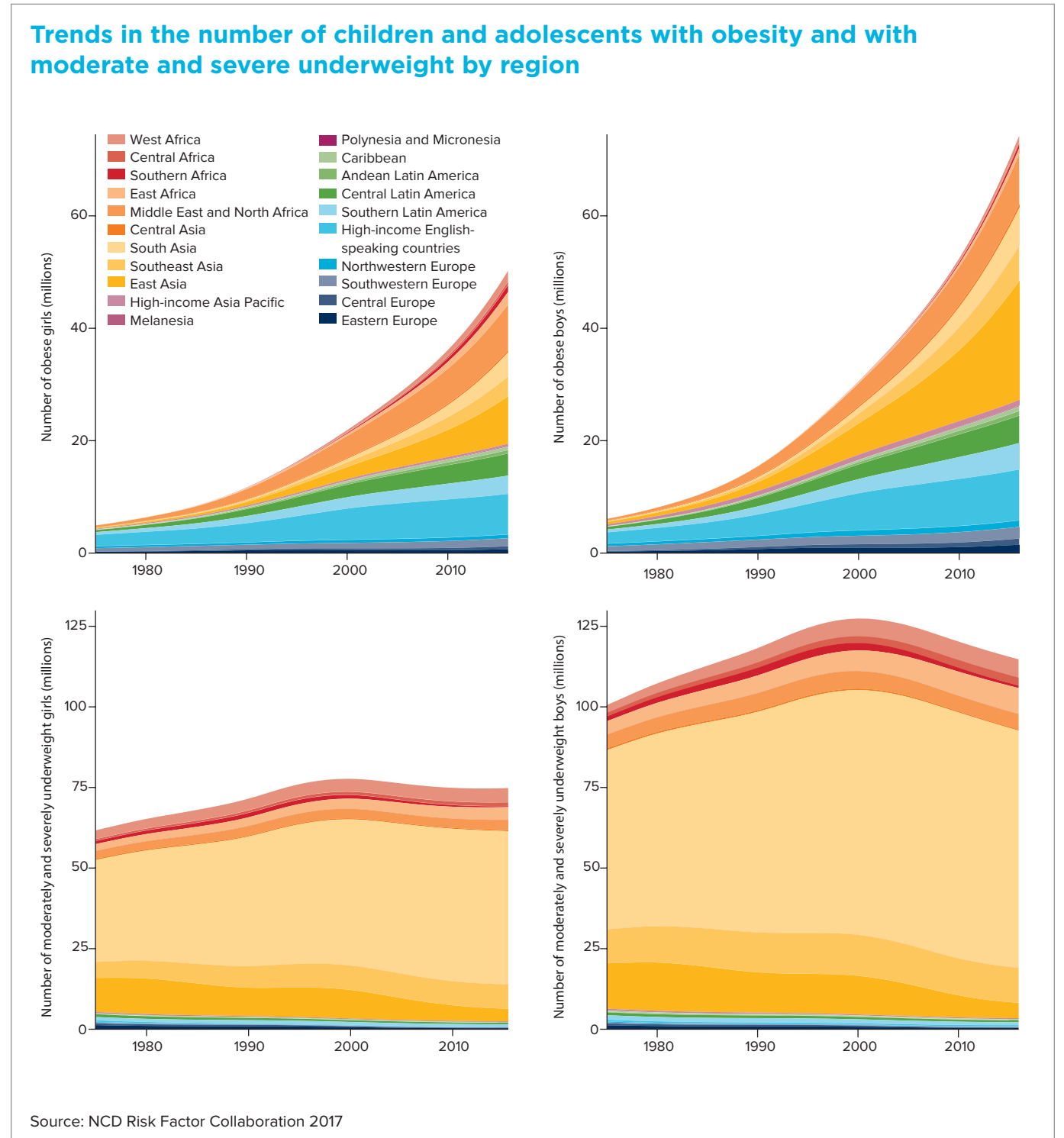
Obesity affects every age group, with entrenched differences based on geography and socioeconomic group. Across the world, an estimated 14.9 percent of women (375 million) and 10.8 percent of men (266 million) had obesity in 2014, compared to just 6.4 percent and 3.2 percent in 1975, respectively.<sup>3</sup> While recent global obesity rates appear low compared to those of some high-income countries such as the United States (41.1 percent of women and 37.9 percent of men in 2015–16),<sup>4</sup> stark differences exist by region, with some of the highest rates and sharpest increases among low- and middle-income countries.<sup>5</sup>

One of the strongest predictors of adult obesity is weight status during childhood, which calls for early prevention efforts.<sup>6</sup> Globally, 5.6 percent of girls and 7.8 percent of boys had obesity in 2016—totaling approximately 124 million children aged 5 to 19 years. Increases in obesity have been observed over the past four decades in every geographic region (figure 1).<sup>7</sup> National data from the United States estimate obesity rates at 17.8 percent and 19.1 percent for girls and boys, respectively, with the highest rates among historically underserved groups, including Hispanic (25.8 percent) and non-Hispanic black (22 percent) children.<sup>8</sup> Similar disparities exist among ethnic minority populations in other high-income

countries. In New Zealand, for example, there were 12.4 percent of children aged 2 to 14 years with obesity in 2017–18. However, rates were much higher among Māori (16.9 percent) and Pacific (30 percent) children and have increased steadily over the past decade from 11.8 percent and 23.1 percent, respectively, in 2006–07.<sup>9</sup>

Interest in studying the double burden of malnutrition (the simultaneous presence of undernutrition [one or more of stunting, wasting, or micronutrient deficiencies] and overweight/obesity) is on the rise.<sup>10</sup> The negative health outcomes, reduced productivity, and economic consequences for affected individuals, communities,

Figure 1



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## Addressing weight bias and stigma

The evolving dialogue, research, education, and advocacy surrounding the weight bias, weight-based discrimination, and stigma that people with obesity may experience must be acknowledged. The consequences for both mental and physical health throughout a person's life cannot be understated. The University of Connecticut's Rudd Center for Food Policy & Obesity—a nonprofit organization leading the charge in developing strategies to address weight bias and stigma—states that the “social consequences of obesity include discrimination in employment, barriers in education, biased attitudes from healthcare professionals, stereotypes in the media, and stigma in interpersonal relationships. All these factors reduce quality of life for vast numbers of people with overweight and obesity and have both immediate and long-term consequences for their emotional and physical health.” In alignment with this movement of inclusivity, social justice, and reduced stigma, this article and the obesity field more broadly is readily adopting “person-first language” when describing “individuals with overweight and obesity,” rather than “obese individuals.” Also of note are the diverse perspectives, vocabularies, and nomenclature of varying stakeholder groups when addressing issues related to obesity, fatness, body size, body diversity, behaviors, and health.

Source: University of Connecticut Rudd Center for Food Policy & Obesity, n.d.

For more information, see Himmelstein, Puhl, and Quinn 2017; Sonnevile 2019; University of Connecticut Rudd Center for Food Policy & Obesity, n.d., World Obesity Federation, n.d.

and nations amplify inequalities for vulnerable populations.<sup>11</sup> A recent *Lancet* Commission report suggests that obesity is one of three major co-occurring pandemics alongside undernutrition and climate change. These pandemics are paramount societal and public health challenges and a triple threat to the most vulnerable populations.<sup>12</sup> Globally, there are more children severely underweight than with obesity. However, if trends continue, childhood obesity will surpass moderate and severe underweight by 2022.<sup>13</sup> While further discussion of undernutrition and climate change issues are beyond the scope of this article, the systems approaches discussed below are applicable to societal and public health issues beyond obesity.

### Consequences of obesity

The economic, social, and health consequences of obesity are well documented. Global obesity-related costs amount to USD\$2 trillion annually—approximately 2.8 percent of the world's gross domestic product.<sup>14</sup> Individuals with obesity are at elevated risk of numerous comorbidities, including type II diabetes, cardiovascular disease, and 13 types of cancer that collectively account for 40 percent of cancer diagnoses in the United States.<sup>15</sup>

An additional burden of obesity—and a rising interest among researchers, practitioners, and advocacy groups—is the stigma and weight-based discrimination experienced by individuals with the disease.<sup>16</sup> Weight

stigma and discrimination cause psychological, social, and physical damage to patients and hinder progress in treating obesity for both adults and children.<sup>17</sup> In keeping

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with the movement to respectfully address people with chronic disease, this article uses “person-first language”<sup>18</sup> (see box 1 for more information).

### Causes of obesity

The causes of obesity are complex and interconnected, spanning poverty, food insecurity, culture, societal norms, federal and state policies, community assets, and practices at home. Obesity has been described as a “complex adaptive system” due to the varied, interacting, and emergent factors within and between individuals and their environments that influence the balance between energy intake and energy expenditure, or “energy balance.”<sup>19</sup>

From a biological perspective, positive energy balance (energy intake exceeding energy expenditure) is fundamental to the accumulation of adipose tissue

over time.<sup>20</sup> The human body has an astounding ability to tightly regulate energy balance through satiety and appetite signaling. Yet factors outside of homeostatic control can override such tight regulation and lead to increased energy intake. For example, the hormone ghrelin can induce appetite when high circulating concentrations of triglyceride molecules are present in the blood, perhaps from a diet high in saturated fat and excess sugars. A greater appetite can subsequently lead to a greater energy intake.<sup>21</sup>

Further, as biological factors impact behavior, our social and physical surroundings impact behavior and biology. Secular changes to the environment—characterized by increased availability, marketing, and consumption of highly palatable and nutrient-poor foods and beverages (often in large portions),<sup>22</sup> fewer opportunities for physical activity in daily living,<sup>23</sup> and increases in sedentary behavior and screen time<sup>24</sup>—are cited as major contributors to obesity. Major research efforts are currently under way to investigate the role of other factors, such as the microbiome,<sup>25</sup> infections,<sup>26</sup> and epigenetics,<sup>27</sup> for example, in the etiology of obesity.

This article describes two parallel movements in childhood obesity research: (1) the application of a systems science—its thinking, theory, and methods—to advance knowledge and prevention and (2) the growing evidence supporting whole-of-community interventions. Integrating these two movements can transform childhood obesity prevention worldwide. It will provide a template for determining what evidence-based strategies would be most beneficial in a community context and how to activate and engage community stakeholders to diffuse, disseminate, and implement those strategies. This article also underscores the importance of implementation science, an interdisciplinary body of theory, knowledge, frameworks, tools, and approaches that ensure interventions are strong, impactful, and sustainable.<sup>28</sup> Definitions for key terms are provided in box 2.

## Systems approaches to obesity prevention

Systems science is an interdisciplinary field that studies the nature of systems, from the simple to the complex, drawing from specific theories (e.g., chaos theory) and approaches (e.g., systems dynamics). Systems science recognizes that a system has interrelated and interdependent parts that can function synergistically with

boundaries that define and distinguish it from other systems.<sup>29</sup>

Over the past decade there has been an increasing call to integrate systems science into obesity prevention efforts.<sup>30</sup> This is because systems theory and systems-based approaches appear well suited to address the complexity inherent in public health problems such as obesity. For decades they have been applied to other complex health challenges such as infectious disease<sup>31</sup> and tobacco use.<sup>32</sup> In 2009 Ross Hammond, an authority on modeling complex dynamics in social, economic, and public health systems, argued that obesity was a challenging problem because of its scale, the

*Systems theory and systems-based approaches appear well suited to address the complexity inherent in public health problems such as obesity.*

range of diverse actors, and the number of mechanisms involved.<sup>33</sup> These are the features of complex systems. Therefore, the field of systems science, including its specific modeling techniques (see table 1), can help inform both the scientific study of obesity and effective policies to combat it.

Since that seminal article, there has been a proliferation of research highlighting the potential benefit of integrating systems science into obesity prevention.<sup>34</sup> Much of this work has been focused on the etiology of obesity, the discovery of relevant actors, and the realization that many drivers of obesity are interconnected. For example, the UK Foresight map was the first of its kind to illustrate the complexity of obesity. The map was created by a broad range of stakeholders, which eventually led to the development of a more integrated policy approach.<sup>35</sup> The UK Foresight map gave way to other research using similar qualitative systems modeling approaches to generate a systems map or causal loop diagram. Systems maps and causal loop diagrams are visual tools designed to help identify linkages among and between parts of a system. They have been used for decades as an integral part of formal, mathematical modeling techniques involving computer simulations.

Institutions and collaboratives such as the Global Obesity Prevention Center (GOPC) at Johns Hopkins University<sup>36</sup> and the Childhood Obesity Modeling for Prevention and Community Transformation (COMPACT)<sup>37</sup>

have advanced research by illustrating how a more complete suite of tools from the systems science toolbox can be applied to obesity prevention research.<sup>38</sup> For example, qualitative systems mapping generates useful insights—such as eliciting the mental models of stakeholders—bringing diverse stakeholders together and providing a starting point for understanding the structure of a complex system. However, deeper insights can be generated when more formal, mathematical models or simulation models are built from those qualitative systems maps.

While the full set of complex systems modeling methods is quite large, table 1 shows a few of the methods most widely applied to obesity prevention. These include agent-based modeling, system dynamics, group model building, and social network analysis, which have roots in disciplines such as engineering,<sup>39</sup> management,<sup>40</sup> evolutionary biology,<sup>41</sup> and social science.<sup>42</sup> These methods are gaining traction in obesity prevention research not only to help identify individual, social, and environmental determinants of obesity risk

as described above, but also to identify the characteristics of community interventions (e.g., local expertise, stakeholders’ networks, community assets) that may be the most successful and sustainable.<sup>43</sup> Collectively,

*Complex systems modeling methods are gaining traction in obesity prevention research.*

these approaches allow investigators and practitioners to evaluate the system, visualize and elucidate mental models and shared understanding among stakeholders, and identify key leverage points that will have the greatest impact.

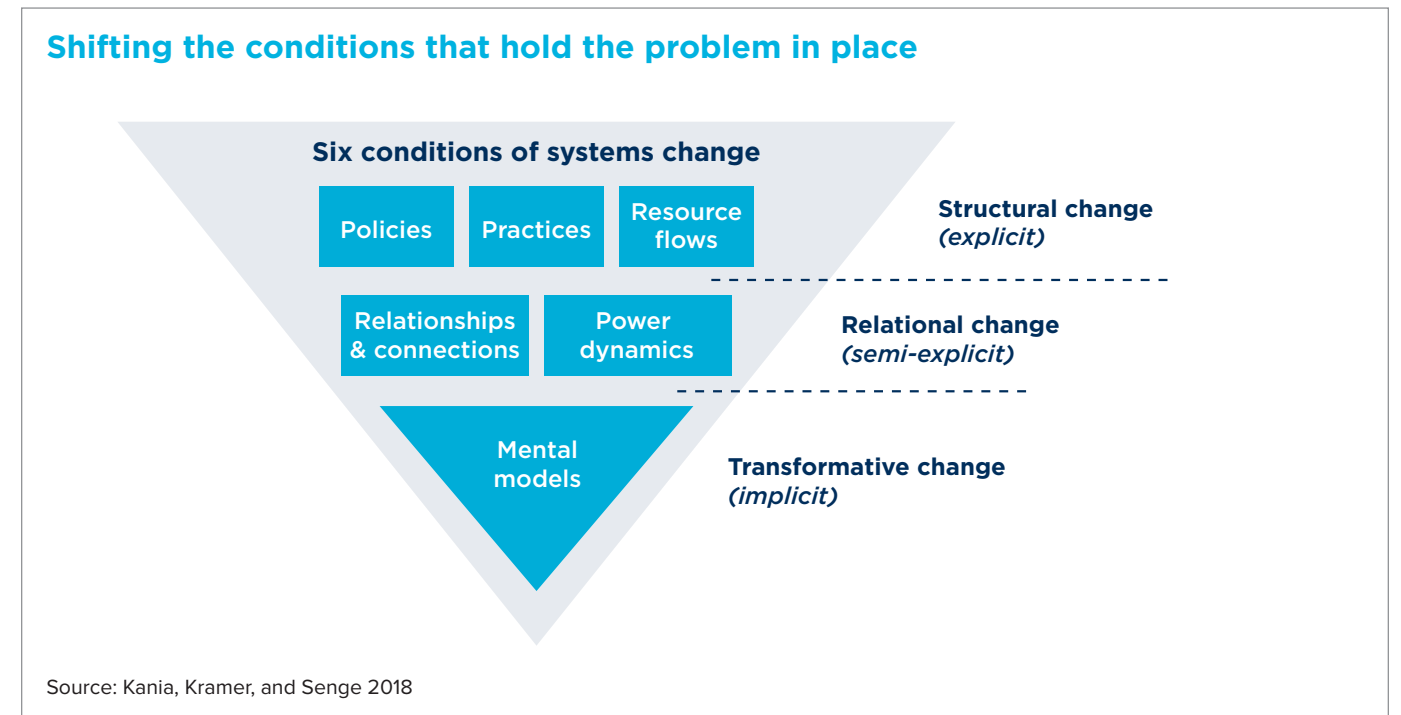
The integration of systems science into obesity prevention research has focused largely on identifying the factors causing obesity or simulating potential impacts of specific policy, practice, or environmental changes. This is because most obesity research has focused on these

Table 1

Examples of complex systems modeling methodologies in the context of obesity prevention		
Approach	Description	Example(s)
<b>Agent-based modeling</b>	Agent-based modeling is a computational tool that models the actions or interaction of “agents” and allows for the exploration of dynamic mechanisms that link individual behavior to overall outcomes among populations.	ChildObesity180
<b>System dynamics</b>	System dynamics is an approach to understanding the nonlinear behavior of complex systems over time using informal maps and formal models with computer simulation (stocks, flows, internal feedback loops, table functions, and time delays) to understand endogenous sources of system behavior.	Baltimore implementation model
<b>Group model building</b>	Group model building is a participatory approach widely used to build the capacity of practitioners to think in a systems way. Group model building improves understanding of the problem, increases engagement in systems thinking, builds confidence in the use of systems ideas, and creates consensus for action among diverse stakeholders.	Group model building in Australia
<b>Social network analysis</b>	Social network analysis is a way to map and measure the relationships between people (or groups, organizations, etc.). This analytic tool has recently been applied to the study of interventions, including obesity prevention interventions.	Shape Up Somerville and Romp & Chomp coalitions

Sources: Allender et al. 2015; Allender et al. 2016; Auchincloss and Diez Roux 2008; El-Sayed et al. 2013; Gesell, Barkin, and Valente 2013; Hammond 2009; Hennessy et al. 2016; Jalali et al. 2019; Marks et al. 2013; Marks et al. 2018; McGlashan et al. 2016; McGlashan et al. 2018; Rahmandad and Sterman 2008; Shoham et al. 2015; Siokou, Morgan, and Shiell 2014

Figure 2



areas. Yet when one considers the six conditions of systems change (figure 2) combined with the fuller suite of systems science tools available, the full potential of applying a systems approach becomes much clearer.

### Six conditions of systems change

In 2018 FSG, a mission-driven consulting firm, published a report entitled *The Water of Systems Change* that includes a framework of the “six conditions of systems change” organized into three interdependent levels: (1) structural change (explicit), (2) relational change

*We believe that integrating these six conditions into whole-of-community obesity prevention research could lead to a paradigm shift if the research community expands its focus beyond structural change.*

(semi-explicit), and (3) transformative change (implicit).<sup>44</sup> The framework “draws upon the extensive literature behind systems change and systems thinking.”<sup>45</sup> The intersection of these six conditions in the context of childhood obesity prevention research is described below. We believe that integrating these six conditions into whole-of-community obesity prevention research

could lead to a paradigm shift if the research community expands its focus beyond structural change. To date, very few studies or interventions have been designed to influence semi-explicit and implicit changes, yet transformation in these conditions is critically important to make impactful and sustainable change. Recent work in Australia studying how community network structure influences obesity prevention capacity<sup>46</sup> and from the COMPACT study<sup>47</sup> suggests a growing movement toward studying relational and transformative change.

### Structural change: Policies, practices, and resource flows

Efforts to optimize obesity-prevention *policies* (e.g., a school district wellness policy promoting healthy eating and opportunities for physical activity), *practices* (e.g., serving water instead of sugar-sweetened beverages at community events), and *resource flows* (e.g., the allocation and distribution of financial support to implement interventions) represent explicit, structural changes. The vast majority of community-level childhood obesity prevention efforts to date, particularly those that focus on policy and practice interventions, are structural.<sup>48</sup> For example, the Healthy Communities Study identified and assessed structural changes impacting children on a national scale (130 communities).<sup>49</sup> Associations between the “intensity” (defined by behavioral intervention strate-

gy, duration, and reach) of programs, policies, and environmental changes aiming to prevent childhood obesity and children's BMI indicated that children in communities with the highest intensity scores had significantly lower BMI (on average, a difference of 1.4 kg/m<sup>2</sup>) than those in communities with the lowest intensity scores.<sup>50</sup> Despite this observational relationship, further research is warranted to understand how intensity thresholds and different combinations of intervention strategies can favorably impact populations disproportionately affected by obesity and health inequities.

### **Relational change: Relationships & connections and power dynamics**

Structural changes can be difficult to achieve without the commitment of time, energy, and resources by community members, or “stakeholders,” to implement them. The *relationships, connections* and *power dynamics* among community stakeholders are critical to systems change.

As an example, the Shape Up Somerville study made structural and relational changes. Utilizing a community-based participatory research approach, Shape

*Investigators attribute the success of the Shape Up Somerville study to diverse community partnerships that designed, implemented, evaluated, and sustained changes to promote healthy behaviors throughout the children's entire day.*

Up Somerville focused on policy and environmental changes to prevent obesity, which were designed and diffused through a community coalition.<sup>51</sup> The study demonstrated that children living in the intervention community had a significant decrease in BMI z-scores (the number of standard deviations from the mean) by 0.10 and 0.06 kg/m<sup>2</sup> one year and two years, respectively, after the intervention began compared to control groups.<sup>52</sup> Favorable shifts in dietary and physical activity were documented.<sup>53</sup> Investigators attribute the success to diverse community partnerships (including parents, teachers, school food service providers, healthcare professionals, after-school programs, local government, restaurants, and the media) that designed, implemented, evaluated, and sustained practice, policy, and environmental changes to promote healthy behaviors throughout the children's entire day. Because of this measurable

success and the corresponding enthusiasm in the community, Shape Up Somerville is a community-wide program to this day and has inspired communities across the world to adopt similar models of change.<sup>54</sup>

Research in fields such as community psychology, community-based participatory research, implementation science, and organizational theory provides important insights into how stakeholders convene and organize to impact population health. Creating community coalitions, steering committees, task forces, and so forth (hereafter referred to as “coalitions”) is a common strategy due to the ability to collaborate with diverse stakeholders, share critical information and resources specific to local contexts, build capacity, plan tailored interventions, and put those interventions in place.<sup>55</sup>

In 2009 the Centers for Disease Control and Prevention (CDC) recommended using coalitions as a strategy to organize obesity prevention efforts.<sup>56</sup> Yet little research has documented and characterized the processes and dynamics that drive success. To address this gap, our team led a mixed methods systematic review to understand how coalitions engage in community-based obesity prevention efforts.<sup>57</sup> Only 13 studies met our review criteria, and the majority of these described coalitions' involvement in intervention design and planning (n = 11), implementation (n = 12), and sustainability (n = 10). Beyond the coalitions' impact on these more structural change processes related to the intervention (“the what”), study investigators shared insights on coalition members' relational dynamics (“the how”). Several key themes emerged: the importance of uniting stakeholders from multiple sectors, strengthening existing relationships within the community, strategically creating new relationships, and creating space for positive group dynamics so that information and ideas can be exchanged.<sup>58</sup>

### **Transformative change: Mental models**

At the bottom of the inverted triangle of systems change are implicit *mental models* representing perhaps the most difficult yet impactful target for transformative change. Mental models are the relatively enduring internal abstraction of an external system to aid and govern activity.<sup>59</sup> They are the deeply held beliefs and assumptions of how something works that influences how we think, what we do, and how we talk.<sup>60</sup> Mental models are important because they inform our decision-making processes and actions. However, if our mental models are not made *explicit*, stakeholders may end up with

different perspectives, beliefs, and assumptions about a given problem such as obesity and develop disparate and siloed solutions. Complex systems modeling techniques such as group model building<sup>61</sup> are promising approaches to share and visualize mental models leading to transformative change. Group model building, grounded in system dynamics, is a participatory method led by trained facilitators following scripted, group exercises.<sup>62</sup> The process helps diverse stakeholders visualize a complex and dynamic system, develop and prioritize action steps, and view connections across time and scale.<sup>63</sup> It can be useful for stakeholders working together over time in a specific community and has been cited as a promising approach for designing and adapting intervention strategies that take the inherent complexities into account.<sup>64</sup>

### **Whole-of-community obesity prevention interventions**

A pandemic as paramount and complex as obesity requires systems-wide societal changes that target a range of influences and behaviors starting early in life. While community-level interventions such as those in school settings have had varying degrees of success in impacting individual biology and behavior as well as

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policy and environmental changes to reduce obesity risk,<sup>65</sup> growing evidence supports a whole-of-community approach. Whole-of-community interventions—those that are multilevel, multifaceted, and implemented holistically throughout an entire community—show promise for preventing obesity, especially when combined with a community-based participatory approach and the involvement of a coalition.<sup>66</sup> These interventions are more likely to be successful and sustained because of their focus on all six conditions of systems change. Examples of successful whole-of-community interventions include Shape Up Somerville and the Romp & Chomp Project.<sup>67</sup>

Whole-of-community interventions have the potential to be effective and equitable, especially when they

focus on structural components, when intervention strategies target a variety of contexts, and when there is engagement with the community.<sup>68</sup> Interventions that are contextual and culturally appropriate are needed to address persistent health disparities across the globe. However, the social determinants of health need to be taken into consideration if obesity prevention interventions are to be effectively embedded within communities. While work in this area is ongoing, there has been an effort to develop frameworks to guide research and action. One specific framework developed by Dr. Shiriki Kumanyika illustrates an equity-oriented obesity prevention action framework.<sup>69</sup> This framework consists of four “process categories”: increase healthy options, reduce deterrents to healthy behaviors, improve social and economic resources, and build community capacity, which should be considered across all settings important for obesity prevention such as schools, healthcare, workforce, etc.<sup>70</sup>

While the evidence supporting whole-of-community obesity prevention interventions is strong and growing, there are challenges. First, the current epidemiologic toolbox and design of whole-of-community interventions do not identify which components of the intervention are most effective. However, from a systems science perspective one could argue that the “whole” of a whole-of-community intervention trial is greater than the sum of its parts. A more useful strategy would be to more clearly study the implementation of whole-of-community interventions and apply complex systems modeling approaches to evaluate potential synergies between the multiple components. Yet this points to another challenge for whole-of-community interventions: the assessment of implementation processes and outcomes. A recent systematic review of whole-of-community trials found that few studies reported on aspects such as fidelity or other implementation metrics and that further research is needed in this area. Questions remain about how to scale these approaches across communities.<sup>71</sup>

### **A call to integrate systems approaches with whole-of-community obesity prevention interventions**

So far we have described two parallel movements in childhood obesity research: the application of systems science and whole-of-community interventions.

Whole-of-community interventions are not inherently systems approaches in their design, implementation, or evaluation. However, combining the two—systems science and whole-of-community interventions—can be especially useful and powerful for a number of reasons.

First, a systems approach to whole-of-community interventions allows one to better understand the context of the intervention and can ultimately result in a more targeted intervention. Second, systems approaches help uncover the true nature of the problem and why it is particularly hard to shift. This can be achieved by working collaboratively with key stakeholders to elicit their mental models—either formally through group model building or informally through interviews and discussions. However, the formal approach may be especially valuable. Working collectively creates a shared understanding that is difficult to achieve through other methods. In relation to the six conditions of sys-

*Integrating systems approaches with whole-of-community interventions greatly expands the toolbox with which we evaluate these interventions.*

tems change, this has the potential to lead to transformative change through the shifting of mental models.

Third, by applying systems approaches, the interconnections (direct and feedback) can become clearer, which may shift the nature of the intervention. While the focus for many interventions to date has been on the “what” (i.e., what evidence-based components or strategies to utilize), a systems approach also focuses on the “how” (i.e., how the evidence-based components or strategies are disseminated and implemented through the community). Fourth, a systems approach can uncover deeper system insights and the importance of social networks, the information that flows through them, and the characteristics of people within them. This is akin to relational change within the six conditions of systems change. In order to shift the system, we must focus on the relationships and connections along with the power dynamics. Lastly, integrating systems approaches with whole-of-community interventions greatly expands the toolbox with which we evaluate these interventions. Traditional epidemiological tools need not be abandoned but should be used in conjunction with complex systems methodologies illustrated in table 1.

Two ongoing studies illustrate how combining systems science and whole-of-community interventions can make a difference in addressing obesity.

### Shape Up Under 5 in Somerville, Massachusetts (2015–17)

As part of the NIH-funded COMPACT study, Shape Up Under 5 was a whole-of-community systems intervention pilot aimed at preventing obesity among children from birth to age five in Somerville, Massachusetts. This was one of the first obesity prevention studies that (a) intervened across the six conditions of systems change by engaging a multisector coalition of community stakeholders and employing a stakeholder-driven design to elicit structural, relational, and transformative change and (b) was designed and evaluated using complex systems modeling methodologies. Coalition members met approximately every month over the two-year study period and participated in a series of group model building activities designed to promote shared understanding of the problem and each other’s roles in the community. Analyses are under way using agent-based models and social network analysis to understand how coalition members’ efforts were diffused and disseminated throughout the community.

### The Early Ages Healthy Stages Coalition in Cuyahoga County, Ohio

Following the completion of Shape Up Under 5, a new study intended to replicate the whole-of-community systems intervention approach was conducted in Cuyahoga County, Ohio. The Early Ages Healthy Stages Coalition, a multisector group of stakeholders, brought together community partners to improve environments, practices, and policies to ensure that all children in the county had the opportunity to grow and thrive in good health. Using the same participatory research method as above applied over the course of one year, a systems map/causal loop diagram was created to visualize the factors driving early childhood obesity in the community. Using the causal loop diagram, the group identified an ambitious and potentially transformative long-term vision to strengthen the systemwide connections between early childhood health and education focused on monitoring, evaluation, landscape mapping and coordination, and advocacy.

Box 2

## Definitions

### Body mass index (BMI)

BMI is a screening measure used to determine an individual’s weight status. BMI does not measure body fat or adiposity directly, but research has shown that BMI correlates with other measures of adiposity, such as skinfold thickness and body composition. BMI is calculated by dividing an individual’s weight in kilograms by the square of his or her height in meters (kg/m<sup>2</sup>). Since children are growing and there are differences by sex, BMI is age- and sex-specific. Weight status categories are defined based on BMI percentiles relative to a child’s age and sex based on a reference population.

### BMI z-score

The number of standard deviations from the population’s mean BMI.

### Obesity

Obesity is the excess accumulation of body fat with the potential to impair health. For adults, obesity is defined as a BMI at or above 30 kg/m<sup>2</sup>. For children, obesity is defined as a BMI at or above the 95th percentile. This means that the child’s BMI is greater than the BMI of 95 percent of other children in the reference population of the same age and sex.

### Energy balance

Energy balance is the state in which energy intake (from food and beverages) is equal to energy expenditure (largely from physical activity and basal metabolism [an individual’s minimum energy needs to maintain vital functions at rest]). Positive energy balance occurs when energy intake exceeds energy expenditure, typically resulting in weight gain.

### Systems science

The study of complex systems (natural and social), often through the use of methodologies such as agent-based modeling, system dynamics modeling, and network analysis (see table 1).

### Implementation science

An interdisciplinary body of theory, knowledge, frameworks, tools, and approaches to ensure that interventions are strong, impactful, and sustainable.

### Whole-of-community intervention

An intervention that is multilevel, multifaceted, and implemented holistically throughout multiple community sectors and settings.

### Community coalition

An organized group of leaders and stakeholders, often representing diverse sectors and settings within a community, that works together to achieve a common objective (may also be referred to as a steering committee, task force, etc.).

### Definitions from Kania, Kramer, and Senge, *The Water of Systems Change*, 2018 (see figure 2):

#### Policies

Government, institutional, and organizational rules, regulations, and priorities that guide the entity’s own and others’ actions.

#### Practices

Espoused activities of institutions, coalitions, networks, and other entities targeted to improving social and environmental progress. Also, within the entity, the procedures, guidelines, or informal shared habits that compose their work.

#### Resource flows

How money, people, knowledge, information, and other assets such as infrastructure are allocated and distributed.

#### Relationships & connections

Quality of connections and communication occurring among actors in the system, especially among those with differing histories and viewpoints.

#### Power dynamics

The distribution of decision-making power, authority, and formal and informal influence among individuals and organizations.

#### Mental models

Habits of thought—deeply held beliefs and assumptions and taken-for-granted ways of operating that influence how we think, what we do, and how we talk.

Sources: Luke and Stamatakis 2012; Tumilowicz et al. 2019; Kania, Kramer, and Senge 2018

## Recommendations and action steps

Several key areas need to be addressed to advance whole-of-community systems approaches and transform the field. These areas are highlighted in table 2 and offer innovative ways for different sectors to apply systems thinking and systems approaches to obesity prevention. This list is meant to be illustrative, not exhaustive. Recommendations for achieving (a) explicit and implicit change, (b) health equity, (c) training and capacity-building, and (d) funding within government, philanthropy, nonprofit and community-based organizations, academia, and the private sector are included.

For example, we recommend that government entities consider structural changes in research funding to accommodate the additional time and resources necessary to build relationships with community part-

ners. While there has recently been a strong focus on achieving health equity across many sectors, more can be done. The private sector, for example, may consider how communications, marketing, and advertising impact socially disadvantaged populations.

All sectors can invest more resources in training and capacity building for systems thinking and systems approaches. Further, none of this work would be possible without funding. A diversity of funding sources across government, philanthropy, nonprofits, academia, and the private sector is required for innovation given the scale and interdisciplinary nature of the approach. As research evolves, efforts must be made to develop the science of scale, including the development of effectiveness metrics, measurement of dose and impact, and connection of upstream policy changes to downstream behavioral and health outcomes, to name a few.

## Conclusion

Obesity is a growing global pandemic that affects every age group, with entrenched differences based on geography and sociodemographic groups. Interventions aimed at prevention have focused largely on structural changes—changes to policies, practices, and resource flows—and have had limited success in curbing the obesity pandemic. While structural change is important and needs to be continued, a sole focus on this fails to address all of the factors required to achieve true systems change.

Systems science is well suited to address the complexity of the obesity epidemic and to guide the design and evaluation of whole-of-community obesity prevention efforts. Interventions based on systems science have been shown to be promising and enduring solutions to the epidemic. Integrating systems approaches

with whole-of-community obesity prevention interventions is needed to advance the field and to create a paradigm shift. This would result in a comprehensive approach that involves all three levels of systems change—shifting the mental models of diverse community stakeholders; leveraging relationships and social network connections and addressing power dynamics; and changing obesity-related policies, practices, and resource flows based on the previous two levels.

Action is required across government, philanthropy, nonprofit and community-based organizations, academia, and the private sector and must include a focus on health equity, funding to support systems change, and training and capacity building of practitioners and scientists in systems science. Such efforts could help reduce the enormous economic, social, and health costs of this global pandemic and improve the lives of hundreds of millions of people around the world.

Table 2

### Recommendations and action steps to integrate systems approaches with whole-of-community childhood obesity prevention efforts

Recommendations and action steps	Government	Philanthropy
<b>Explicit/implicit levels of change</b>	Consider structural changes in grant mechanisms that acknowledge the need for relationship building	Share network information to advance best practices
<b>Health equity</b>	Build more training and capacity-building opportunities for researchers at all levels  Consider resources (time and money) required to impact socially disadvantaged communities	Recognize the profound impacts of social determinants on health and build them into the requirements
<b>Training and capacity building</b>	Support systems science training programs across professional levels (research, policy, practice)	Support systems science training for grantees
<b>Funding</b>	Increase funding for systems change research, including systems science methods and dissemination and implementation (D&I) research  Develop flexible, innovative mechanisms that support whole-of-community interventions  Create new mechanisms to better support systems change research efforts (e.g., longer funding duration or higher allowable direct costs)	Coordinate efforts to maximize impact  Bring together interdisciplinary experts (scientists and practitioners)  Assess the mental models of stakeholders within their own organizations and investigate internal conditions that may help or hinder external aspirations

Some action steps are adapted from Kania, Kramer, and Senae 2018.

Nonprofit and community-based organizations	Academia	Private sector
Shift mental models by activating and engaging community stakeholders and leadership from backbone organizations  Build social networks	Address silos/structures that limit collaboration  Build transparency into communications  Develop interdisciplinary networks of scholars	
Adopt equity-oriented practices and models	Generate research on equity-oriented interventions  Work with priority populations to design	Consider how communications, marketing, and advertising impact socially disadvantaged populations  Develop equity-oriented training, hiring, and capacity building internally
Train stakeholders on how to apply systems thinking and systems-oriented approaches	Train future leaders in systems thinking and complex systems modeling through enhanced curriculum/degree offerings	Invest in social impact internally and externally
Scale and sustain efforts  Adopt/implement equity-oriented, evidence-based interventions  Assess the mental models of stakeholders within their own organizations  Raise attention to shift power dynamics at play in communities	Build community partnerships with integrity  Maximize institutional collaboration	See above

# Endnotes

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