Why we need a complex systems model of evidence for public health

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Despite major investment in both research and policy, effective action to tackle pressing contemporary public health challenges remains elusive. To date, the evidence underpinning responses to these challenges has largely been generated using tools and methods that were developed to answer questions about the effectiveness of clinical interventions, grounded in linear models of cause and effect. Identifying, implementing and evaluating effective responses to major public health challenges requires a wider set of approaches (1, 2) and a focus on complex systems (3, 4).

A complex systems model of public health conceptualises poor health and health inequalities as interdependent elements within a connected whole that affect each other in sometimes subtle ways, with the impacts of changes potentially reverberating throughout the system (5). A complex systems approach uses a broad spectrum of methods to design, implement and evaluate interventions for changing these systems to improve public health.

Complex systems are defined by a number of properties including emergence, feedback, and adaptation (3). Emergence describes the properties of a complex system that cannot be directly predicted from the elements within it and are more than just the sum of its parts. For example, the changing distribution of obesity across the population can be conceptualised as an emergent property of the food, employment, transport, economic and other systems that shape an individual’s energy intake and expenditure. Feedback describes the situation where a change reinforces or balances further change. For example, banning smoking in public places reduces the visibility of smoking, making it less appealing to young people, fewer of whom then start smoking, further reducing its visibility, and so on in a reinforcing loop. Adaptation refers to adjustments in behaviour in response to interventions,
such as a tobacco company lowering the price of cigarettes in response to a public smoking ban.

Increasing rhetoric urging complex systems approaches to public health is only rarely operationalised in ways that generate relevant evidence or effective policies (1, 6). Public health problems that emerge as a property of a complex system cannot necessarily be ‘solved’ with a simple, single intervention, but the interacting factors within the system can potentially be reshaped to generate a more desirable set of outcomes (7, 8). Achieving meaningful impacts on complex multi-causal problems, such as obesity, requires more than single interventions such as traffic light food labelling or exercise on prescription, many of which require high levels of individual agency, have low reach and impact, and tend to widen health inequalities (9-11). It requires shifts within multiple elements across the many systems that influence obesity, some of which may only have small effects on individuals but can drive large changes when aggregated at population level (12).

While it is relatively straightforward to conduct a randomized controlled trial of individual-level interventions, it is usually impossible to randomise a population-level intervention such as the introduction of a national tax on sugar-sweetened beverages, or the multiple factors that support cycling, such as physical infrastructure, spatial planning and integration with public transport. Approaches to research that aim to understand single components within systems (13) or attempt to factor out the system context using randomisation and control are thus of limited use for identifying how to influence complex systems to achieve improved population health and wellbeing (14).

Despite this, research funding, research activity, and the published evidence base are all heavily skewed towards studies that attempt to identify simple, often short-term, individual-level health outcomes, rather than complex, multiple, upstream, population level actions and outcomes. This skew echoes the prioritisation by policymakers of simple interventions over system-level responses, in the face of broad recognition of the need to do the opposite - so-called ‘lifestyle drift’ (15). While it is important for public health policy to be guided by evidence, if this evidence predominantly supports individual-level interventions that have minimal reach and impact across populations, the benefits of being informed by the existing evidence base may be illusory (16). Research on systems needs to provide policy makers and
practitioners with robust and relevant evidence that takes adequate account of the real-world circumstances in which people live, policies are made, and interventions are implemented.

A shift in thinking is required, away from simple, linear, causal models, to consideration of the ways in which processes and outcomes at all points within the system drive change. Instead of asking whether or not an intervention ‘works’ to ‘fix’ a problem we should aim to identify if and how it contributes to reshaping a system in favourable ways. Public health actions often exert their effects over long time periods, so we need to track proximal, intermediate and distal processes and outcomes if we are to avoid mistakenly believing that interventions are ineffective when we have merely judged them on the wrong terms and over the wrong time frames. We must also be prepared to adapt interventions in response to observed changes in systems that may learn and adapt in ways that lead to dilution of the desired intervention effect, thus requiring further intervention.

Where complex systems approaches have been used in public health research, policy and practice they have tended to focus on describing or modelling systems. While this is essential, and echoes responses to other multifactorial, context-driven problems (17), we now need to build on these foundations to evaluate the potential effects of interventions on systems (for a current example, see Box 1). What is needed is the development of robust tools, using a broad, multidisciplinary suite of methods for both intervention research and evidence synthesis in order to support effective policy responses.

It will be important for research funders to rebalance the distribution of projects that they sponsor, with increased support for evaluations of public health interventions that take account of complexity and systems (18). Researchers will have to develop knowledge and skills to match, requiring considerable capacity building over a prolonged period (1). A number of methods already exist that can be used to evaluate interventions within complex contexts (19-26). For example, the Medical Research Council has produced guidance on natural experimental evaluations (27): studies in which the differences between the experimental and control contexts are determined not by the researchers but result from
policy or other interventions outside their control. Statistical methods, such as interrupted time series analysis, can be used effectively to evaluate the impacts of such interventions over time (28), while simulation approaches such as agent-based modelling can integrate diverse evidence sources, allow for non-independence and feedback, and simulate emergence (19, 29). The art and science of system level evaluation needs to be developed considerably using these and other methods. There is also a need to adopt and adapt techniques from other disciplines that are more advanced in complex systems methodologies, such as economics, climate change and urban science (30, 31).

Building capacity and funding research on evaluating interventions in complex systems will need to be supported by a favourable environment for publishing such research, including methodological developments. Medical, health science and public health journals will need to equip themselves with editors and reviewers familiar with the emerging science of complex systems for population health.

A complex systems approach can overcome the frustration of having ‘the right answers to the wrong questions’ (32) for persistent public health problems. It will help to answer the recent call from the Academy of Medical Sciences to reorganize the research environment to generate compelling, functional evidence for public health improvement (1), and provides a promising way to achieve this while engaging with diverse disciplines, including the social sciences, economics and urban planning (33).

Achieving this kind of shift from a linear paradigm to one that embraces complexity (34) will require considerable changes to the ways in which research is funded and conducted, academic work is valued, and policy is formulated. Unless we engage appropriately and meaningfully with these complex realities many of the major public health challenges we face, from emerging infections to non-communicable diseases, will remain intractable. Over-simplifying these problems to fit inappropriate models of research and practice dooms us to repeated failure. Existing approaches to the generation and use of evidence remain vitally necessary, but are not sufficient. It is understandable that funders are wary of supporting, and journals wary of publishing, alternative kinds of research that answer novel types of questions, but it is imperative that we generate and disseminate more, and more robust,
evidence on population-level interventions and their system impacts.

There is no single pathway to reaching this goal; changing the mechanisms and infrastructure that underpin public health evidence and action is itself a complex system challenge. However, reshaping public health research, policy and practice to incorporate complex systems approaches will be essential for improving population health and reducing health inequalities.

**Contributions**

HR had the initial idea for this paper, which was the subject of a workshop in September 2016, attended by most of the co-authors. HR wrote the first draft and all authors contributed to the development of the ideas, writing the manuscript, commenting on drafts, responding to the helpful suggestions from peer reviewers, and approved the final version.

**Declaration of interests**

The authors have no competing interests to declare.

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**References**

Box 1: Evaluation of the UK Soft Drinks Industry Levy: a systems perspective

In March 2016, the UK Chancellor of the Exchequer announced a Soft Drinks Industry Levy (SDIL) to be introduced by April 2018, aiming to prompt industry reformulation to reduce sugar content. The SDIL represents a potentially major perturbation in complex and interlinked social, health and economic systems, likely to trigger multiple reactions by stakeholders, potentially resulting in important impacts on diet and health. A comprehensive, system level, natural experimental evaluation of the SDIL has therefore been planned.

A concept mapping workshop with experts from a range of academic disciplines led to generation and structuring of an initial system map, guided by predefined questions and iterative consensus building. A modified online Delphi survey refined the map, with representation from academia, public health professionals, government, civil society and industry. Analysis identified the varying levels of agreement with the components of the map and their and connections, and led to a revised version.

Data sources were identified to allow identification of impacts across a range of domains using interrupted time series analyses, including price, formulation, purchases, consumption, preferences, diet and health. Qualitative enquiry, including analysis of public, media and professional discourses, will further illuminate observed changes. Triangulation between data sources will explore the extent to which they provide a consistent interpretation and conclusions about the impacts of the SDIL, thus strengthening causal inferences. The evaluation will use these and other approaches to the evaluation of complex systems to gain knowledge that it would not be possible to identify using traditional approaches.

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