The Application of Systems Science in Nutrition-Related Behaviors and Outcomes Implementation Research: A Scoping Review

Ayron E Walker, Rachel A Wattick, and Melissa D Olfert

Division of Animal and Nutritional Sciences, Davis College of Agriculture, Natural Resources and Design, West Virginia University, Morgantown, WV, USA

ABSTRACT

Use of systems science can improve the dissemination and implementation (D&I) process. However, little is known about use of systems science in nutrition D&I research. The purpose of this article is to synthesize the ways in which systems science methodology is applied in nutrition D&I research. Scoping review methodology involved searching 6 academic databases for full-text, peer-reviewed, English articles published between 1970 and 2020 that employed systems science within nutrition D&I research. Data extraction included intervention type, population, study aim, methods, theoretical approach, outcomes, and results. Descriptive statistics and qualitative thematic analysis followed. Thirty-four retained articles qualitatively identified benefits (successful planning and organization of complex interventions) and challenges (limited resources, trainings, and lack of knowledge) to utilizing systems science in nutrition D&I research. Future research should work toward building knowledge capacity among nutrition practitioners by increasing available trainings and resources to enhance the utilization of systems science in nutrition D&I research. *Curr Dev Nutr* 2021;5:nzab105.

Keywords: systems thinking, implementation science, nutrition, health behaviors, dissemination, science

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Supplemental Table 1 is available from the "Supplementary data" link in the online posting of the article and from the same link in the online table of contents at https://academic.oup.com/cdn/

Address correspondence to MDO (e-mail: Melissa.olfert@mail.wvu.edu).

Abbreviations used: ABM, agent-based modeling; D&I, dissemination and implementation; MeSH, medical subject headings; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; SDM, systems dynamic modeling; SNA, systems network analysis.

Introduction

Dietary patterns describe the frequency, proportions, variety, and combination of different foods, drinks, and nutrients in the human diet (1). The current dietary patterns in the United States are associated with 4 of the 10 leading causes of death: heart diseases, some types of cancer, stroke, and type 2 diabetes (2). For example, many American do not consume enough fruits and vegetables (3) and overconsume added sugars, saturated fats, and salt (4), which can increase the risk of obesity and carries with it an increased risk of these chronic diseases (4–7). Luckily, nutrition interventions including education, programs, and policies can lead to positive changes in an individual's dietary behaviors, which can lower the risk of chronic diseases and enhance health (2).

Nutrition interventions describe any combination of strategies designed to motivate and facilitate the adoption of nutrition-related behaviors that encourage health and well-being (2). Current research shows that nutrition interventions such as i-COOK 4-H (8, 9) and Homestyles (10–13), which address childhood nutrition, the Get-FRUVED (14, 15) intervention that encourages college student health behaviors (16–27), a mental health recovery and nutrition program, M4R2 (28, 29), and a culinary medicine educational program to improve health professional nutrition-related knowledge (30–32), can positively support healthy lifestyle changes. Despite the noted positive influences on health and well-being, current reviews evaluating the effectiveness of nutrition interventions on health behaviors have identified areas for improvement in implementation. There is a need to address the sustainability (33), replicability and adaptability (34) of interventions, methodological issues, lack of large-group interventions (35–37), and unclear identification or integration of the multiple interrelated factors that impact nutrition and dietary patterns (34, 38, 39).

Dissemination and implementation (D&I) research seeks to understand and overcome barriers to adoption, sustainability, and methodological issues of interventions that address complex problems (40). Health issues are increasingly recognized as complex problems embedded within our society, with multiple interacting components and undefined behaviors (40, 41). For example, implementation of a nutrition intervention to promote healthy dietary patterns in adults without consideration of the mix of factors that influence food consumption, including biological factors, cultural and social preferences, physical health, food access, and emotional and psychological well-being, can have limited impact. Solutions to complex problems often require intervening at many different levels, using multiple strategies, and engaging numerous actors and organizations (40), which can require new methodological approaches that address complexity with the implementation of nutrition interventions.

Systems thinking is a perspective that aims to interpret how things are connected to each other and within a larger system (42). A system is a set of elements or factors that are organized and interconnected and ultimately produce complex and dynamic behaviors that can evolve over time (43). Dynamic, complex, and interrelated are key terms among these definitions that inform many components of systems thinking and systems science methods. Methods of systems science, including systems dynamic modeling (SDM), systems network analysis (SNA), agent-based modeling (ABM), soft-systems approaches, cognitive and concept mapping, and other simulations have been developed to understand and identify systems' structure and behavior over time (44). Systems science methods are increasingly used to explain or predict real-world outcomes of large-scale interventions (42). In recent years, public health practitioners have been applying systems science and thinking to identify the factors that influence intervention efficacy and real-world application (45). Further, D&I research utilizes systems science to understand complex factors influencing successful interventions and to identify challenges (44). Current research for systems science and D&I research predominantly focuses on patient safety and the medical field (46–54), tobacco research (55, 56), obesity with a focus on planning and quantifying interrelated factors (57–60), and policy change (61–65). Although current evidence provides positive insights from using systems science in D&I health research, little is known about the utilization within nutrition. However, interest in the use of systems science in nutrition implementation research is increasingly recognized. For example, recent calls have been made to organize knowledge and interest in implementation science in nutrition (66–68) including the development of the Society for Implementation Science in Nutrition (68), yet there is a lack of reviews of the current state of research. Therefore, more research is needed to inform nutrition practitioners in order to lead to a greater capacity for factors that influence complex issues and interventions to enhance the health and well-being of communities (1, 40). Thus, the purpose of this article is to synthesize the ways in which systems science methodology is applied in nutrition D&I research.

Methods

Scoping reviews formulate research questions of interest, based on what is known or not known from the literature (69). A scoping review is particularly useful when a topic has not yet been extensively reviewed or is a complex issue (70), making it an ideal approach to map the application of systems science in nutrition D&I research. The methodology of this scoping review followed the guided framework developed by Levac and colleagues (71) and adapted by Arksey and O'Malley (72), which identifies 6 key guidelines including: identifying the research question, identifying relevant studies, study selection, charting the data, collating, summarizing, and reporting results and consultation. Step 6 is optional and was not applied in the current review.

Step 1: identify the research questions

1. How are systems science methods and systems thinking applied to nutrition D&I research?
2. What are the benefits and challenges of systems science and systems thinking within nutrition D&I research?

Step 2: identify relevant literature

The search strategy was approved by 2 authors (AEW and MDO) and involved a search of peer-reviewed English literature that was completed in July 2020 within 6 primary literature databases: PubMed, CINAHL, Web of Science, ProQuest, Scopus, and Agricola. Medical subject headings (MeSH) and keywords that were mapped to subject headings were used to define the search's scope to best capture relevant articles. Because the language of D&I research and systems science is complex, keywords consisted of relevant concepts related to systems science or systems thinking, diffusion of innovation or dissemination, implementation or interventions, nutrition behaviors and outcomes, and food. A full electronic search strategy is presented in **Supplemental Table 1** for replicability.

Step 3: select the literature

Identified articles were screened for inclusion by 1 author (AEW). Inclusion criteria included full-text, peer-reviewed, English articles published between 1970 and 2020 describing studies that employed systems science within nutrition D&I research. Preliminary exclusion criteria sought to identify articles that were non-English articles, articles without an abstract or articles with only an abstract, and articles that did not address nutrition and nutrition-related D&I using systems science in some capacity through an intensive initial analysis of titles, keywords, and abstracts. Secondary exclusion primarily focused on whether an article did or did not mention systems science or thinking, systems analysis (i.e., network analysis, ABM, SDM, or conceptual modeling), or systems vocabulary (i.e., complexity, interrelated, and complex relations) within nutrition D&I research. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow chart guides were used to display the exclusion methodology and approved by a secondary reviewer (MDO) to ensure the search strategy was implemented with fidelity.

Step 4: chart the data

The primary researcher (AEW) extracted the data using a structured table adapted from Armstrong and colleagues (69) in accordance with the research questions identified in step 1. Study descriptions of interest included: title, authors, year of publication, study location, study population, organization of articles, systems methods and modeling or systems framing and language, aims, methodologies, context, theories, models or framework utilized, intervention type (i.e., planning, evaluation, implementation, dissemination), outcomes, and results to inform qualitative analysis. The final chart and study characteristics were reviewed collaboratively by the primary researcher (AEW) and a secondary researcher (RAW). Any discrepancies between the 2 researchers were identified and adaptations were mutually agreed.

Step 5: collate, summarize, and report results

Descriptive statistics including frequency counts of study description categories including: systems science methods, tools and ideologies, intervention types (i.e., planning, evaluation, implementation, dissemination), and explicitly mentioned theory, models, and frameworks used in the included articles' study designs were calculated using JMP Pro 14 (SAS Institute Inc). Qualitative data analysis, which is used to

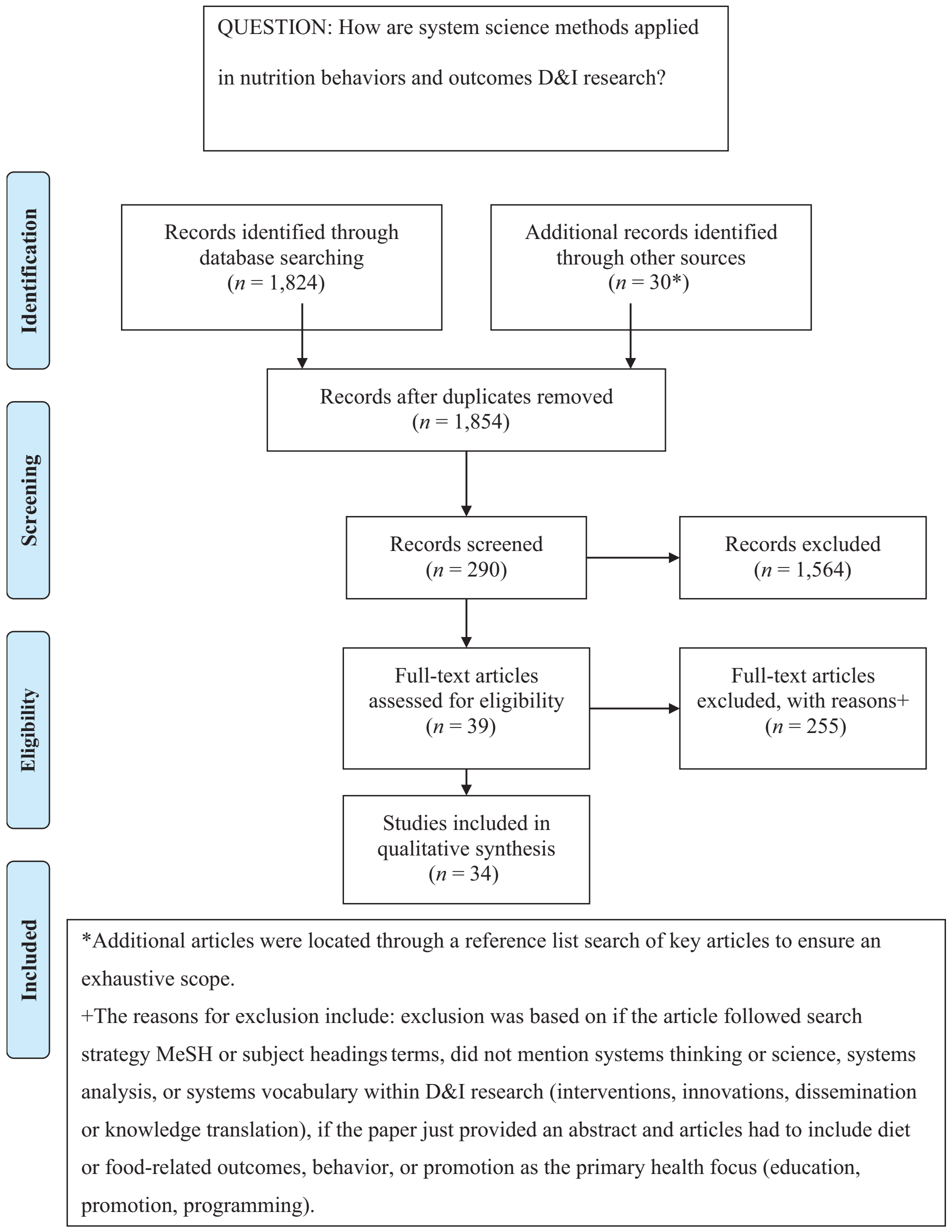

FIGURE 1 Flow diagram of the article screening process. D&I, dissemination and implementation.

examine themes or patterns to organize, describe, and interpret a dataset (73), was conducted to identify and interpret themes from the study description categories, including articles' aims, methods, outcomes, and results, using NVivo Pro 12 (QSR International). The benefits and challenges were assessed by analyzing specifically mentioned benefits and challenges by the authors of the included articles and independently identified by researchers. The qualitative data analysis was conducted by 2 trained researchers (AEW and RAW), one of whom generated initial codes that informed a coding dictionary and then developed themes to generate summative content. Then independent researchers discussed the coding dictionary to identify discrepancies and collectively agree upon themes.

Results

Publication and article characteristics

A total of 1854 articles were retrieved, of which 34 met inclusion criteria. **Figure 1** shows the PRISMA flow diagram (74) of included and excluded studies. Most of the included articles were published in 2015 (20%) and 2018 (20%). The data sets described in the 34 articles employed 7 different research designs, in which reviews, including systematic, literature, or scoping reviews (37%), and case study analyses (20%) were more prominent. Most studies conducted research in locations within the United States (55.9%) and 44.1% of research was conducted within a global lens (i.e., multiple locations at once including in

Africa, Europe, the United Kingdom, Australia, Canada, and low- and middle-income countries).

Articles were grouped into 2 categories based on their utilization of systems science. Systems modeling (44.1%) included articles that employed systems dynamics, network analysis, or ABM. Systems framing and language (55.9%) described articles that depicted and identified elements of systems thinking including complexity, interrelations, and systems-related frameworks. Additionally, articles were sorted into their D&I intervention type or process including planning and organizing (29.4%), scope of implementation (29.4%), utilization and adoption of an intervention (20.6%), knowledge translation or dissemination (17.6%), training or curriculum development and implementation (2.94%), and implementation evaluation (2.94%). Lastly, articles were reviewed and classified for their nutrition topics including: 23.5% nutrition-related behaviors and outcomes (i.e., hypertension, smoking, physical activity, obesity, diabetes, BMI); 11.7% food, health, and nutrition policy; 11.7% health and nutrition education; 38.2% knowledge translation; 8.82% described intervention methods; and 5.88% health and food access. **Table 1** provides a summary of these results.

Qualitative analysis

Eight key themes emerged from the deductive qualitative thematic analysis of the 34 included articles that describe how systems science methods and framing were applied in nutrition D&I research. Each theme will be defined and highlight key aspects of systems science that should be addressed by individuals that are involved in nutrition implementation science. Further, the benefits and challenges and future research were analyzed from the qualitative data.

1. *Engagement and leadership* are defined as having strong strategic support to provide appropriate leadership that will promote nutrition and health-related partnerships and to enhance engagement with key community members that will be a part of the intervention. Engagement and leadership were key themes in 8 articles analyzed in this scoping review (57, 75–81). Six articles (57, 77–81) expressed that the involvement of key leadership encouraged the commitment and empowerment of other key stakeholders, which contributed to the success of systems science methods and framing in the analyzed articles.
2. *Strategies for sustainable interventions* are defined as practices that explicitly set out to improve nutrition behaviors and outcomes by outlining clear strategies and goals. Several (9 of 34) articles demonstrated that applying systems science to nutrition implementation had an effect on program effectiveness (82), the planning and organizing process (83), wide-scale adoption and scalability of interventions (84), evaluation and assessment (63), and organizational relationship building (76), and assisted in developing complex interventions (57, 60, 85).
3. *Conceptualizing systems components* is the recognition of the complex nature of nutrition D&I research including the acknowledgment of the interacting and evolving elements of the complex adaptive system. Articles (18 of 34) clearly conceptualized and discussed the systems components within their research. Many articles identified and employed a systems-approach methodology, which improved the recognition that nutrition and diet-related interventions are complex and dynamic (59, 77, 83, 86–90). Other articles acknowledged that linear ways of thinking hinder the nutrition implementation process, and that systems science demonstrates complexities, structure, and interrelations, which are important aspects in intervention design (91–93).
4. *Interaction and dynamic relationships* are methods or actions of specific activities to develop and maintain relationships among individuals and organizations. Articles identified relationship factors that influence implementation by applying systems science methods. Acknowledged factors included: contextual and organizational structures, and intervention and individual behavioral characteristics that impact nutrition D&I goals, plans, and sustainability (59, 83, 87, 92, 94–97).
5. *Innovation and education* defines systems science approaches to support and encourage the development of strategies to address complex nutrition behaviors and outcomes in D&I research. Articles identified that situating education and innovations within systems-oriented frameworks or theories assists stakeholders with design, evaluation, and self-efficacy in nutrition D&I research (59, 83, 96). Furthermore, the development of more trainings and curriculums that focus on applying systems science in nutrition D&I research is needed to enhance knowledge capacity and educational support among practitioners to increase utilization (76, 81, 84, 90, 92, 98, 99). The capacity-building theme elaborates more on increasing available resources and information for innovation and education.
6. *Capacity building* is increasing nutrition resources, education, support, and information within a system to encourage change among communities and organizations. Many articles discussed the need for capacity building among organizations to utilize systems science in nutrition D&I research (82, 87, 90, 92–94, 100). Likewise, articles identified that insufficient capacity was a major barrier to systems-oriented nutrition D&I research (63, 75, 77, 79, 90). Other articles referenced the need to address knowledge capacity gaps to increase self-efficacy in systems science and nutrition D&I research (57, 79, 82, 90, 101). Further, the communication and knowledge translation theme below elaborates on additional capacity-building barriers that influence self-efficacy in systems science and nutrition D&I research.
7. *Communication and knowledge translation* are mechanisms and processes that support communication of evidence-based information and practice among stakeholders within the system. Twelve articles reported the importance of effective communication (86) and community engagement (77, 100) in nutrition implementation research. Further, the application of systems science resulted in articles identifying the differences in knowledge translation among diverse populations (81, 88, 101). Lastly, articles noted minimal translation and understanding of systems science and D&I theories, models, or frameworks in different settings, which resulted in low self-efficacy and ultimately persistence

TABLE 1 Characteristics of included studies[1]

First author, year (reference number)	Study aims	Category	Intervention type	Nutrition topic	Data collection	Theoretical perspective
Shelton RC, 2018 (94)	To examine and discuss conceptual and methodological issues in studying sustainability	Systems framing or language	Scope of Implementation	Intervention methods	Review	Dynamic sustainability framework
Stave KA, 2015 (95)	To explain and demonstrate the system dynamics approach for examining food systems closely	Systems modeling (SDM)	Planning and organizing interventions	Agriculture policy, nutrition education, communication, and behavior	Modeling	Whole systems approach
Brownson RC, 2018 (90)	To aid practitioners in building organizational-level capacity and assist researchers in conducting participatory research	Systems framing or language	Planning and organizing interventions	Methods to translate health information	Review	n/a
Erasmus E, 2016 (63)	To investigate the scope of health and systems education among partners in the organization	Systems framing or language	Scope of implementation	Food and health policy and systems	Cross-sectional	Social science theory
Yamey G, 2012 (75)	To understand how to scale up health tools in low- to middle-income countries	Systems framing or language	Scope of implementation	Health and food access	Qualitative Study	Diffusion of innovation
Glegg SMN, 2019 (104)	To comprehensively map ways social network analysis are used in D&I	Systems modeling (SNA)	Dissemination	Methods to translate health knowl-edge/information	Review	Whole systems approach
Hammer JM, 2010 (76)	To improve the understanding about what reasonably to expect from large group interventions and how best to design them	Systems framing or language	Planning and organizing interventions	Health and nutrition education	Case study	Large group intervention theory
Hitziger M, 2018 (97)	To improve the integration, governance, and coordination of implementing the One Health framework into practice	Systems framing or language	Utilization/adoption of evidence-based practices (EBPs)	Methods to translate health knowl-edge/information	Case study	One Health framework
Zhang J, 2015 (91)	To build an agent-based model (ABM) of adolescent BMI and test the impact of social influence on combined overweight and obesity prevalence in the population	Systems modeling (ABM)	Planning and organizing interventions	BMI and obesity (nutrition-related)	Secondary data analysis	Social learning theory

(Continued)

TABLE 1 (*Continued*)

First author, year (reference number)	Study aims	Category	Intervention type	Nutrition topic	Data collection	Theoretical perspective
Kalim K, 2006 (86)	To describe systems thinking and illustrate its value in understanding the complexity of the diabetes national service framework	Systems modeling (SDM)	Planning and organizing interventions	Diabetes (nutrition-related disease)	Qualitative study	Systems thinking/systems theory
Johnston LM, 2014 (59)	To explore the utility of the intervention-level framework	Systems framing or language	Planning and organizing interventions	Obesity policy	Review	Intervention-level framework
Limbani F, 2019 (87)	To report the relationships, benefits, and challenges of process evaluation and complex interventions	Systems framing or language	Utilization/adoption of an EBP	Hypertension (nutrition-related disease)	Case study	n/a
Loyo HK, 2013 (77)	To align prevention efforts and maximize the effect of limited resources; to pioneer an innovative, systems-oriented approach to understand the dynamic dimensions of health protection policies	Systems modeling (SDM)	Planning and organizing interventions	Chronic disease/obesity policy (nutrition-related diseases)	Modeling	Whole systems approach
Luig T, 2018 (57)	To explore implementation strategies using the interactive systems framework	Systems framing or language	Utilization/adoption of an EBP	Methods to translate health knowl-edge/information	Qualitative study	Interactive systems framework
McGlashan J, 2016 (60)	To explore the application of network analysis to a community-developed causal-loop diagram (CLD) to advance understanding of the system drivers of obesity to plan for interventions	Systems modeling (SNA and SDM)	Planning and organizing interventions	Obesity (nutrition-related)	Modeling	Whole systems approach
Widener MJ, 2013 (85)	To contribute to the current discourse on food deserts by presenting an agent-based model (ABM) that tests several spatial and aspatial interventions	Systems modeling (ABM)	Planning and organizing interventions	Health and food access	Modeling	Whole systems approach

(*Continued*)

TABLE 1 (*Continued*)

First author, year (reference number)	Study aims	Category	Intervention type	Nutrition topic	Data collection	Theoretical perspective
Nianogo RA, 2015 (88)	To review studies that used agent-based modeling (ABM) to study noncommunicable diseases as well as their risk factors in the context of public health	Systems science modeling (ABM)	Scope of implementation	Physical activity, diet, and diabetes (nutrition-related)	Review	Whole systems approach
Buchthal OV, 2015 (103)	To identify communication and collaboration patterns among organizations involved in nutrition education within a diverse community	Systems modeling (SNA)	Dissemination	Methods to translate health knowl-edge/information	Qualitative study	Whole systems approach
Peterson H, 2018 (82)	To describe the importance of implementation science in health	Systems framing or language	Scope of implementation	Methods to translate health knowl-edge/information	Review	Active implementation frame-work/interactive and synergistic framework
Phillips W, 2006 (102)	To investigate multilevel networks and their impact on diffusion of innovation	Systems framing or language	Dissemination	Methods to translate health knowl-edge/information	Case study	Systems of innovation
Ramaswamy R, 2019 (98)	To develop an interdisciplinary practice-focused curriculum to teach Master of Public Health (MPH) students D&I	Systems framing or language	Curriculum development	Health and nutrition education	Review	Kirkpatrick model of learning evaluation
Resnicow K, 2008 (92)	To provide a summary on chaos and complex adaptive systems (CAS) use in public health	Systems framing or language	Scope of implementation	Intervention methods	Review	Chaos theory/complex adaptive systems
Riley B, 2012 (78)	To integrate the lessons emerging from the literature with those of identified leaders in public health; to begin to identify useful principles to help public health better understand, assess, and shape the creation and use of EBP	Systems framing or language	Utilization/adoption of EBP	Methods to translate health knowl-edge/information	Review	Complex adaptive systems

(*Continued*)

TABLE 1 (*Continued*)

First author, year (reference number)	Study aims	Category	Intervention type	Nutrition topic	Data collection	Theoretical perspective
Hammond R, 2014 (96)	Re-examine a "follow the average" hypothesis to test whether the central insight from the original model holds and explore what new insights can be gained from a more detailed and complex model	Systems modeling (ABM)	Planning and organizing interventions	BMI (nutrition-related)	Modeling	Whole systems approach
Smith T, 2016 (100)	To explore how communities translate evidence-based and promising health practices to rural contexts	Systems framing or language	Utilization/adoption of EBP	Methods to translate health knowl-edge/information	Case study	Interactive systems framework
Theobald S, 2018 (89)	To provide key features in implementation research in low-/middle-income countries	Systems framing or language	Scope of implementation	Methods to translate health knowl-edge/information	Case study	n/a
Wang Y, 2015 (93)	To review current strategies used to model health-related issues by using systems science	Systems modeling (SDM)	Scope of implementation	Obesity and non-communicable chronic diseases (nutrition-related)	Review	Systems thinking/systems theory
Williams J, 2010 (83)	To explore how systems thinking might be used to guide state officials in developing a research-based evaluation plan for training programs and improve the understanding of the relationships and dependencies among units in an organization	Systems framing or language	Utilization/adoption of EBP	Health and nutrition education	Review	ABCD model approach inquiry: Phase A—Where do we want to be? Phase B—How will we know when we reached it? Phase C—Where are we now? Phase D—How do we get from here to our desired place? During the process, researchers continously consider the ongoing changes to the environment

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TABLE 1 (*Continued*)

First author, year (reference number)	Study aims	Category	Intervention type	Nutrition topic	Data collection	Theoretical perspective
Woltering L, 2019 (84)	To demonstrate the problems underlining successful scalability of the sustainable development goals	Systems framing or language	Scope of implementation	Intervention methods	Review	n/a
Li Y, 2015 (79)	To use ABM to help understand the potential impact of implementing lifestyle interventions	Systems modeling (ABM)	Utilization/adoption of EBP	Lifestyle intervention (smoking, overweight, diet, and physical activity)	Qualitative study	Whole systems approach
Yousefi-Nooraie R, 2015 (80)	Tested whether engagement of staff in the intervention and their behavior were associated with being chosen as information source	Systems modeling (SNA)	Dissemination	Methods to translate health knowl-edge/information	Longitudinal	Transactive memory principles/whole systems approach
Yousefi-Nooraie R, 2012 (101)	A quantitative social network analysis designed to understand how the staff of a health department in Canada turned to peers to seek information regarding research evidence to inform practice-based decisions	Systems modeling (SNA)	Dissemination	Methods to translate health knowl-edge/information	Cross-sectional	Whole systems approach/social capital theory/social influence theory
Yousefi-Nooraie R, 2014 (81)	To model how managers and professional consultants seek information to inform evidence-informed decisions in a public health department in Canada	Systems modeling (SNA)	Dissemination	Methods to translate health knowl-edge/information	Cross-sectional	Whole systems approach
Zenni E, 2006 (99)	To implement and evaluate the effectiveness of scenario-based learning in enhancing medical residents' competencies of systems thinking to address patients	Systems framing or language	Evaluation	Health and nutrition education	Case study	Systems thinking/systems theory/adult learning theory

[1]ABM, agent-based modeling; CAS, complex adaptive system; CLD, causal-loop diagram; D&I, dissemination and implementation; EBP, evidence-based practice; n/a, not available; SDM, systems dynamic modeling; SNA, systems network analysis.

of the evidence-based information practice gap in health (75, 100).

8. *Monitoring and evaluation* describes articulated methods to provide continuous feedback into the system to enhance effectiveness of nutrition D&I research. Articles cited utilizing systems science approaches to monitor and evaluate nutrition D&I research including process evaluation (87), SDM (77), network analysis (93), conceptual models (83), and ABM (79). However, many researchers cited the gap in the current literature for monitoring and evaluating nutrition D&I research including: designing and planning systems-oriented interventions (76); addressing scale-up approaches (75, 84); developing distinct health systems monitoring and evaluation methods (63, 94); development and evaluation of effective systems science competencies and tools (78, 82, 90, 98, 99); and fidelity of nutrition D&I interventions (57, 82, 83, 100, 102).

Benefits and challenges of systems science in nutrition D&I interventions

The 34 included articles were analyzed for the benefits and challenges, specifically stated by the authors and synthesized by the research team, of utilizing systems science in nutrition and diet-related behavior D&I research, as briefly described below. **Table 2** provides a simple summary of the benefits and challenges from the qualitative analysis. Articles identified systems science methods as useful tools to strengthen D&I planning and predicting, organizing, communicating and knowledge translation, design, and implementation (76, 77, 83–86, 90, 92, 93, 95–98, 101, 103, 104). Many key challenges included capacity and resources for complex interventions (57, 82, 93), especially in rural contexts (100), and lack of training in systems science and nutrition D&I research (88–90, 93). Articles concluded that future research needs to focus predominantly on educating nutrition researchers and practitioners through trainings and curriculums to enhance systems science in nutrition D&I research (57, 89, 93, 95, 98).

Discussion

Relatively few articles examined systems science in D&I research that focused on addressing nutrition behaviors and intervention methods, and most are recent; therefore, these results suggest an emerging area that deserves more attention. Furthermore, most articles identified by the inclusion process were reviews, which included commentaries, calls for application, or systematic reviews, but did not use systems methodologies. Additionally, the categorical analysis highlighted that systems science is more likely to be theoretically framed rather than utilized within research methodology, which mirrors findings from another systematic review (105), and suggests that prevention science, which includes nutrition interventions, has yet to take full advantage of these analytic approaches (106).

However, the articles that did use systems science methodologies and framing to implement an intervention, highlighted numerous key benefits in applying systems science to nutrition implementation including: planning and organizing potential policies and programs; predicting behavioral outcomes; and visualizing complexity of implementation. These findings reflect previous research by Burke and colleagues (44), which discusses the many implementation successes of 3 case studies that utilized the different models of systems science methods (SNA, SDM, and ABM). Furthermore, the qualitative findings from this review suggest that systems science framing and methods improved key aspects of nutrition D&I process and research such as conceptualizing systems components, methods of monitoring and evaluating, strategies for interventions, and relationships and leadership, echoing similar positive implications outlined by Riley and colleagues (40) and Luke and colleagues (107).

Although current research supports that systems science improves many aspects of health D&I research (40, 44, 107), our review found capacity-building barriers for systems science in nutrition implementation, including knowledge translation of D&I theories, models, and frameworks, as well as limited available educational trainings for nutrition researchers hindering systems science application in the field of nutrition D&I research. Therefore, the remainder of this discussion will reflect more deeply on how to build capacity among nutrition D&I researchers to apply systems science in the implementation process.

Current nutrition implementation researchers emphasize the importance of utilizing implementation science in nutrition interventions (66, 68, 108–111). Koorts and colleagues (112) reported a strong consensus among nutrition and physical activity academics that D&I research was important to reduce the research–practice gap in patients and communities and increase real-world implications of their own research. Nonetheless, a lack of D&I training and expertise, and misunderstanding of how to achieve real-world impact with D&I science hindered individuals' involvement (112). To achieve desired real-world changes, Warren and colleagues (68) suggest that nutrition strategies need to invoke systems thinking during the implementation process. Similarly, Burke and colleagues (44) argue that successful health implementation cannot take place without acknowledging the complexity of real-world situations and that the tools from systems science are needed to model these interrelated factors. However, to utilize systems science in nutrition interventions, capacity building, including increasing resources and knowledge, is needed (113), which reflects the findings of our review. Additionally, research suggests that a lack of training and expertise in D&I science among nutrition researchers is a barrier to utilization (68, 112), again reflecting the present study's findings.

Existing evidence demonstrates effectiveness of D&I trainings among graduate students, postgraduates, and professionals in public health fields including mental health and cancer. These studies reported significant increases in knowledge of D&I skills (114), demonstrated capability to incorporate D&I into research practice (98), improved understanding of implementation challenges in health care (115), and enhanced understanding of relevant D&I theoretical approaches (115). These results suggest that D&I trainings for graduates, postgraduates, and professionals positively influence knowledge and understanding of D&I science, which has important implications when addressing our review results of current capacity barriers among nutrition researchers and practitioners. Likewise, an NIH-convened panel recognized that D&I trainings should teach trainees to employ methods and strategies from the field and equip them to draw on methods from other areas such as systems science (116). Our results reflect this emerging viewpoint of incorporating other disciplinary methods, such as systems

TABLE 2 Benefits and challenges to systems science methods in nutrition D&I[1]

Benefits	Challenges
Provides methods for D&I planning and predicting	Methodological and conceptual challenges of measuring sustainability
Provides frameworks and models to organize and design implementation	Inconsistent knowledge translation in nutrition and diet research
Helps to understand and predict knowledge and communication patterns	Capacity building and resources to implement complex interventions
Systems science assisted in visualizing and modeling the complexities of nutrition D&I research	Limited "real-world" interventions and implications
Useful in understanding barriers for nutrition education and interventions	Inconsistent and varying language within D&I and systems science

[1]D&I, dissemination and implementation.

science, within implementation science. Therefore, a nutrition-specific D&I training that incorporates systems science modeling and perspectives would benefit current and future nutrition researchers' and practitioners' implementation self-efficacy, skills, and motivations for real-world intervention effectiveness.

With regard to the structure of the proposed nutrition-specific D&I training, current higher-education institutions systems science curriculums in health show positive adult learning outcomes through active learning strategies (83, 98, 99, 117). Active learning techniques ask participants to engage by practicing skills, solving problems to complex programs, proposing solutions, and explaining ideas (118). Current research demonstrates advantages of active learning strategies, such as scenario-based case studies, in teaching systems science in health implementation research, including: an increased understanding of barriers to care (99); improved knowledge and skills of systems science in health (117); and acquisition of knowledge to apply systems science frameworks and theory to frame the implementation process (83, 98). Additionally, many researchers discuss the need for mentorship (114) and faculty engagement (98) to act as translators when simulating active learning techniques, which is similar to a collaborative learning approach (119). A collaborative learning approach describes the joint intellectual effort by students and teachers to acquire knowledge (120). Current curriculums teaching systems science employing collaborative teaching strategies report that students are able to critically examine the complex challenges within food, nutrition, and health programs (121). Chambers and colleagues (122) encourage implementation science training programs moving toward problem-solving and activity style learning. Thus, enhancement of learning outcomes among current and future adult nutrition researchers and practitioners should incorporate active learning strategies and collaborative learning approaches to the acquisition of knowledge and skills in the application of systems science in implementation.

In terms of population for the proposed capacity-building training, it is important to start to train future nutrition researchers and practitioners. Highly selective training programs limit the amount and type of people able to receive the education (116). Additionally, training should be available for people in a variety of implementation roles, including predoctoral, early career, and experienced practitioners (116). Therefore, the proposed curriculum should be available to a variety of nutrition practitioners including university nutrition and public health students, registered dietitians, and established researchers. To incentivize current students and future registered dietitians to complete the proposed curriculum, course developers should build courses from previously identified D&I competencies (123) and from the Society of Nutrition Education competencies (124) to help with validation and to institutionalize the proposed curriculum for future nutrition degree recipients. Lastly, additional incentives could include awarding continuous educational credits, for Registered Dietitians to maintain their licensure, for completion of such courses, and for funders to highlight emerging issues such as capacity building in nutrition through targeted strategies (e.g., funding announcements, training programs, or support for new research teams) (125).

Limitations

This study is not without limitations. First, only 1 author was involved in the screening process. Whereas the search strategy, inclusion/exclusion criteria, and data analysis were reviewed and approved collaboratively, the screening process was done during the initial COVID-19 pandemic lockdown, which made collaborating for the inclusion process challenging. Although the researcher who led the inclusion process is proficient in nutrition D&I research and systems thinking, the article screen process was done independently, which is a limitation of this scoping review. Further, the inconsistencies and adapting language surrounding the interdisciplinary fields of D&I and systems science challenged the development of key terms and inclusion criteria, and influenced the databases chosen. Given these challenges, this review aimed to be exhaustive; however, the complex nature of this subject matter might have excluded some research. Furthermore, not all databases used MeSH terms, key terms, or subject headings, which could influence the types of articles retrieved. Lastly, indexing of articles sometimes takes up to a year, which could have potentially impacted article retrieval and inclusion analysis.

Conclusions

This study demonstrates that systems science provides positive implementation approaches to design and translate nutrition behaviors and knowledge into practice. However, capacity-building barriers for systems science in nutrition implementation, including limited available educational trainings for nutrition researchers, hinder systems science application in the field of nutrition D&I research. Therefore, our results suggest that an active and collaborative teaching method for a nutrition-specific D&I curriculum for university nutrition and public health students, registered dietitians, and established researchers is likely to enhance systems science skills, which aligns well with current literature implications. It is also important to note that capacity needs to be built at a higher level (e.g., funding announcements, training programs, or support for new research teams) as well as to support the development of said curriculums and to incentivize participation.

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