


BMJ Open Value of social network analysis for developing and evaluating complex healthcare interventions: a scoping review

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ABSTRACT

Objectives Most complex healthcare interventions target a network of healthcare professionals. Social network analysis (SNA) is a powerful technique to study how social relationships within a network are established and evolve. We identified in which phases of complex healthcare intervention research SNA is used and the value of SNA for developing and evaluating complex healthcare interventions.

Methods A scoping review was conducted using the Arksey and O'Malley methodological framework. We included complex healthcare intervention studies using SNA to identify the study characteristics, level of complexity of the healthcare interventions, reported strengths and limitations, and reported implications of SNA. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews 2018 was used to guide the reporting.

Results Among 2466 identified studies, 40 studies were selected for analysis. At first, the results showed that SNA seems underused in evaluating complex intervention research. Second, SNA was not used in the development phase of the included studies. Third, the reported implications in the evaluation and implementation phase reflect the value of SNA in addressing the implementation and population complexity. Fourth, pathway complexity and contextual complexity of the included interventions were unclear or unable to access. Fifth, the use of a mixed methods approach was reported as a strength, as the combination and integration of a quantitative and qualitative method clearly establishes the results.

Conclusion SNA is a widely applicable method that can be used in different phases of complex intervention research. SNA can be of value to disentangle and address the level of complexity of complex healthcare interventions. Furthermore, the routine use of SNA within a mixed method approach could yield actionable insights that would be useful in the transactional context of complex interventions.

INTRODUCTION

The development and evaluation of interventions in healthcare are often considered to be complex.¹ This complexity has been defined in various ways.^{2,3} A consolidated definition

Strengths and limitations of this study

- The Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews 2018 was used to ensure the quality of reporting.
- Two researchers worked independently during the selection of studies, data charting and synthesis of the results. All authors checked and confirmed the synthesis of the results.
- The literature search was conducted in four scientific databases, which is more than sufficient to include the central and relevant research evidence regarding complex intervention studies in healthcare.
- There is no sharp boundary between simple and complex healthcare interventions; therefore, the level of complexity was unravelled of all included studies based on the iCAT_SR.
- This study did not critically appraise the included studies.

for complex interventions was therefore formulated by Guise *et al*.⁴

All complex interventions have two common characteristics; they have multiple components (intervention complexity) and complicated/multiple causal pathways, feedback loops, synergies, and/or mediators and moderators of effect (pathway complexity). In addition, they may also have one or more of the following three additional characteristics; target multiple participants, groups, or organisational levels (population complexity); require multifaceted adoption, uptake, or integration strategies (implementation complexity); or work in a dynamic multidimensional environment (contextual complexity).⁴

Additionally, interventions can be conceptualised as having 'core components', that is, the essential and indispensable elements

of the intervention and an ‘adaptable periphery’, that is, adaptable elements, structures and systems related to the intervention and organisation into which it is being implemented.^{5 6}

The effectiveness of complex interventions is critically influenced by their contexts.^{7–9} Context is often used synonymously with setting and environment and includes static (eg, the physical environment) and dynamic aspects in terms of professionals, relationships or networks.⁸ Because of the heterogeneity of the contexts in which complex interventions are embedded, there is still no adequate translation of how to accommodate to the context in good clinical practice.^{8 10} Furthermore, most complex interventions in healthcare research target a network of different (healthcare) professionals from multiple sectors and disciplines that is commonly driven by interactions. Such networks form the backbone of a system (eg, hospital, general practice) by directing the collective power of diverse individuals and groups to achieve mutually relevant goals and objectives.¹¹ However, there is a lack of intervention studies exploring the underlying network structure and how this structure affects intervention outcomes as well as the contribution that different actors such as interventionists play in a network.¹²

Social network analysis (SNA) is a scientific method to study underlying network structures. SNA is a powerful technique that aims to characterise and study how social relationships within a network, for example, among persons, groups or organisations, are established and evolve.¹³ The use of SNA has been suggested for designing and evaluating complex interventions with the goal of understanding and examining complex interactions among or between networks.^{9 12 14–19} The aim of this scoping review was to identify and determine the value of SNA in studies that develop or evaluate complex interventions in healthcare research.

The research questions were as follows:

1. In which complex healthcare intervention research phases and level of complexity is SNA used?
2. What value do researchers report in the use of SNA for developing and evaluating complex healthcare interventions?

MATERIALS AND METHODS

A scoping review was conducted to report a wide search for evidence addressing our research questions without specific quality assessment which is common for scoping reviews.^{20 21} After identifying the research question, the following steps were conducted: identifying relevant studies; selecting studies based on predefined inclusion criteria; charting the data; and collating, summarising and reporting the results. Although presented as a series of stages, the process was iterative. Steps were repeated when needed to ensure that the literature was reviewed in a comprehensive way.²⁰ The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)

Box 1 Search strategy

PubMed

("intervention"[All Fields] OR program[All Fields] OR programme[All Fields] OR ("clinical trials as topic"[MeSH Terms] OR ("clinical"[All Fields] AND "trials"[All Fields] AND "topic"[All Fields]) OR "clinical trials as topic"[All Fields] OR "trial"[All Fields]) OR ("Evaluation"[Journal] OR "Evaluation (Lond)"[Journal] OR "evaluation"[All Fields])) AND ("social network analysis"[All Fields] OR "network analysis"[All Fields]) AND ("2004/01/01"[PDAT] : "2019/04/30"[PDAT])

PsychINFO

("intervention" OR program OR programme OR trial OR evaluation) AND ("social network analysis" OR "network analysis")

Embase

('intervention'/exp OR 'intervention' OR 'program'/exp OR program OR programme OR 'trial'/exp OR trial OR 'evaluation'/exp OR evaluation) AND ('social network analysis'/exp OR 'social network analysis' OR 'network analysis'/exp OR 'network analysis') AND (2004:py OR 2005:py OR 2006:py OR 2007:py OR 2008:py OR 2009:py OR 2010:py OR 2011:py OR 2012:py OR 2013:py OR 2014:py OR 2015:py OR 2016:py OR 2017:py OR 2018:py OR 2019:py) AND ('article'/it OR 'article in press'/it OR 'review'/it) AND [embase]/lim NOT ([embase]/lim AND [medline]/lim)

CINAHL

("intervention" OR program OR programme OR trial OR evaluation) AND ("social network analysis" OR "network analysis")

Extension for Scoping Reviews 2018 was used to guide the reporting.²² Ethical approval or patient consent was not required.

Search strategies

Intervention-based studies using SNA in the field of healthcare were identified through a systematic search using logical operator-based combinations of key terms to identify potentially relevant publications from the Embase, PsycINFO, CINAHL and PubMed databases. The search strategy included the use of a combination of key terms related to complex health interventions and keywords related to SNA (see [box 1](#)). For each database, we worked with a librarian from the healthcare discipline to develop a list of relevant keywords. The database searches were conducted from the third week of April 2019 to the end of April 2019. Reference lists of relevant reviews were hand searched.

Inclusion criteria

Complex healthcare intervention studies were defined as the earlier described consolidated definition for complex interventions by Guise *et al*.⁴ Only empirical studies were included when the healthcare intervention was targeted the individual or community level. Interventions targeting institutional networks (which may include federal agencies (eg, CDC), local government agencies (eg, city health departments), non-government organisations and private health organisations (eg, hospitals and healthcare providers) public and population healthcare programmes) were therefore excluded.²³ Additionally,

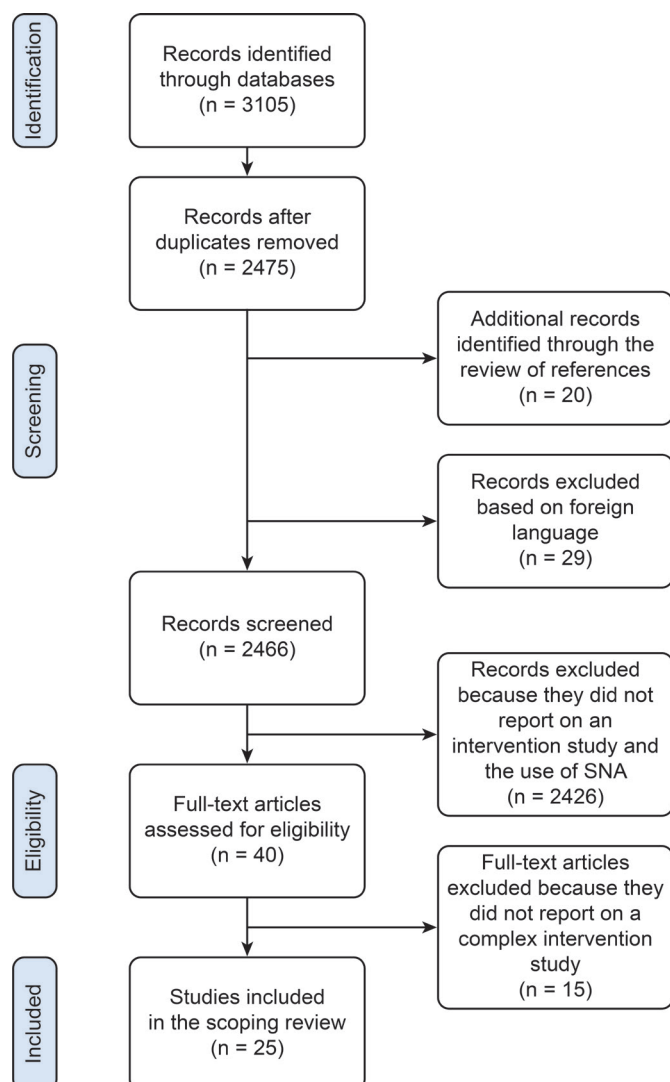


Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram.

studies had to report use of SNA in the design of the study, for example, social network mapping, assessment of network structure and properties, or analysis of network members. Studies were excluded if (1) social networks were mentioned, but the type of analysis was not reported; (2) the primary focus was social support, peer support, social capital or other related topics, but did not report an SNA. Studies published in any language other than English were excluded from the review. The search was limited to studies published between January 2004 and April 2019. This time period was carefully chosen with the goal of including relevant studies from the moment that the use of SNA in research was emerging.¹² If studies reported the same data in two or more journals, the second and subsequent submissions were excluded. While we did not include (systematic) reviews, we did check the references from these reviews to identify relevant and eligible articles to ensure that we were comprehensive in our search (figure 1). Furthermore, we did not use the study quality as an inclusion criterion.²⁰ All studies that met the inclusion criteria were uploaded into

Rayyan^R, a web application for systematic reviews that aims to offer researchers a one-stop dashboard to work through the details of their processes while also allowing their collaborators the ability to see each other's work.^{24 25}

Study selection

The study selection involved two steps. First, the list of study titles resulting from the various searches was reviewed by two reviewers (LS and JD) independently, and each reference was assigned a value of 'include', 'exclude' or 'maybe'. Second, the reviewers independently assessed the abstracts of the included titles for relevance. In both steps, disagreement between the two reviewers was resolved by consensus, with input from a third author (NB) when necessary.

Data extraction

Data were extracted from the included studies using a structured format that enabled us to (1) describe the study characteristics, (2) describe the level of complexity of the healthcare interventions (3) report the strengths and limitations of the application of SNA, and (4) report the implications of using SNA in complex intervention-based studies. To describe the study characteristics, data regarding the author, date of publication, country of the study, type of intervention, target of the SNA in the intervention design, SNA purpose and the metrics used were extracted. To describe the level of complexity of the healthcare interventions, data were extracted based on the Complexity Assessment Tool for Systematic Reviews (iCAT_SR). Six core dimensions and two optional dimensions were assessed by defined criteria (see online supplemental appendix 1).²⁶ The eight dimensions covered the earlier described consolidated definition for complex interventions in which intervention complexity, implementation complexity, population complexity, pathway complexity and contextual complexity stood central. To describe the value of using SNA for developing and evaluating complex interventions, the strengths and limitations of the application of SNA were extracted from the included studies first. Next, the reported implications of using SNA were extracted. The data extraction process and format were initially piloted by the first two authors with five studies. In the next stage, each author independently extracted data from the remaining studies. After extraction, the data were compared, and differences were discussed between the two reviewers, with input from a third author (NB) when necessary, until agreement was reached.

Collating, summarising and reporting the results

Following data extraction, a narrative synthesis was created to describe the included studies in terms of the study characteristics, level of complexity of the healthcare interventions, the reported strengths and limitations of the application of SNA, and the reported implications of using SNA in the development and evaluation of complex

interventions. This narrative was intended to provide an overall description of the available evidence.²⁰

Patient and public involvement

No patients or public were involved in this study.

RESULTS

Studies identified

After removing the duplicates, we identified 2466 potentially relevant studies, 20 of which we identified by hand searching. After abstract screening, 40 full-text studies were assessed for eligibility, resulting in 25 studies being included in the review (see [figure 1](#)). The publication year of the included complex intervention studies ranged from 2009 to 2019. The countries of origin were diverse; however, 11 studies (44%) were conducted in the USA. As shown in [table 1](#), the application of SNA in developing and evaluating complex interventions differed. Most studies (60%) used SNA to evaluate (partially) the effectiveness of an intervention. No study used SNA when developing an intervention. In two studies, SNA findings were used to provide information on the feasibility of the complex intervention.^{27 28} The types of interventions, as well as the SNA purpose, were diverse. Most studies identified relationships between actors, while other studies collected data on the specific network type, such as knowledge exchange or patterns of collaboration ([table 1](#)) (see online supplemental appendix 2 for the extended study characteristics and online supplemental appendix 3 for the application of SNA in the included studies).

Level of complexity of included studies

The level of complexity of the included studies based on the iCAT_SR is shown in [table 2](#).²⁷ Regarding the intervention complexity, only two studies reported one component intervention^{29 30} while the other studies consisted of a multicomponent intervention whether or not offered as a bundle. Behaviour or actions of intervention recipients of the studies were diverse from single till dual or multiple target. The implementation complexity showed that the degree of tailoring the intervention was in 10 studies inflexible (40%), 11 studies moderate (44%) and in 4 studies highly flexible (16%). The level of skill required by those delivering the intervention was in most studies intermediate (84%) and for those receiving the intervention, was the level of skills required basic in most studies (88%). The population complexity was low in 16 studies (64%) as the interventions directed only at single category of individuals within the individual level (eg, professionals or patients), 5 studies (20%) were defined as multcategory as the interventions directed at 2 or more categories of individuals within the individual level (eg, primary care professionals and primary care patients), 4 studies (16%) were defined as multilevel as the intervention directed at 2 or more levels. The pathway

complexity was in 21 (84%) studies unclear or unable to assess, only 4 (16%) studies used a logic model to explain the nature of the causal pathway between the intervention and the outcome it is intended to effect. Three studies (12%) were defined as having a long variable pathway and one study (4%) having a short, linear path. Contextual complexity was, except for two studies (4%) which interventions could moderately dependent on individual-level factors, unclear or unable to assess.

Reported strengths and limitations of the application of SNA

[Table 3](#) provides an overview of the reported strengths and limitations. Of the included studies, 6 studies (24%) reported only strengths in the application of SNA for developing and evaluating complex interventions,^{31–36} 1 study (4%) reported a limitation,³⁷ 4 studies (16%) did not report any strength or limitation,^{38–41} and the remaining 14 studies (56%) reported strengths as well as limitations in the application of SNA. Reported limitations of the application of SNA were focused on the study design and data collection. Regarding the study design, the lack of a qualitative component and lack of control group were reported as limitations because they prevent more in-depth understanding of the results and contribute to lower methodological rigour than that of some other analysis methods, which inhibits authors from stating the causal effects of an intervention.^{27 28 36 42} A mixed-method approach was reported as a strength for gaining an in-depth understanding of the results.³¹ Reported limitations related to data collection were possible recall bias due to self-reported data, the challenge of obtaining responses, and non-respondent data.^{19 28–30 37 43–46} The absence of nonrespondent data may introduce potential bias and can therefore dramatically affect network representation.¹⁹ Reported strengths were that SNA data are easy to collect²⁸ and that data can be collected by various methods,¹⁹ including specific SNA tools (NET map, Social Network Diagnostic Tool and Partner Tool).^{31 40 47} Regarding analysis, the quantitative results that SNA yields can be combined with other statistical approaches.³⁴ In addition, sociometrics may have superior value for overcoming the shortcomings of ego network self-reported measures, but data collection from ego networks is more feasible and less expensive than sociometric network data collection.⁴⁴ SNA analysis is further strengthened because it is based on the number of relationships instead of only the number of individuals.⁴³ Additionally, the use of SNA programmes to analyse data was reported as a strength in terms of the ease of use but as a limitation in terms of the need for special training and experience.^{19 27 44} The visualisation of SNA results can strengthen the interpretation of the results.⁴⁴ However, a reported limitation was that complexity cannot be captured in simplified visuals.¹⁹ Additionally, the interpretation of the results was reported as strength, as SNA provides insights into the relationships, positions, structure and strength of a network.^{19 31 48}

Table 1 Study characteristics

	Target of SNA				Intervention type	SNA purpose	
	Pilot/feasibility phase		Evaluation phase		Implementation phase		
Study	Identification of Interventionists	Acceptability	Effectiveness	Process evaluation	Implementation	1=Educational 2=Network, peer, capacity building 3=Health promotion 4=E-health 5=Group based 6=Organisational 7=Environmental change 8=Disparity reduction 9=Theory based	1=Identify relationships 2=Identify persons 3=Identify knowledge exchange 4=Identify patterns of collaboration
Banbury <i>et al</i> ³⁷			×			4	1
Benton <i>et al</i> ²⁷	×					1	2
Bliuc <i>et al</i> ²⁹			×			2	1
Campbell <i>et al</i> ³²			×			4	3
Elreda <i>et al</i> ³⁴				×		5	1
Gesell <i>et al</i> ⁴⁷			×			3	3
Gesell <i>et al</i> ⁴¹			×			3	3
Held <i>et al</i> ⁴³			×			1	3
Jippes <i>et al</i> ⁵⁰			×			7	1
Katz <i>et al</i> ³³			×			1	4
Li <i>et al</i> ⁴⁴				×		2	1
Márquez-Serrano <i>et al</i> ⁴⁶			×			1	3
Masumoto <i>et al</i> ⁴⁰			×			3	4
McGlashan <i>et al</i> ⁴⁸				×		7	1
Millary <i>et al</i> ³⁵				×		2	1
Moses <i>et al</i> ³¹			×			1	1, 2
Nooraie <i>et al</i> ⁴²			×			6	3
Owen <i>et al</i> ³⁹			×			4	1
Phillips <i>et al</i> ⁴⁵			×			1	3, 4
Ramanadhan <i>et al</i> ³⁰					×	3	1, 3
Ramanadhan <i>et al</i> ⁴⁹					×	2	1, 3
Rice <i>et al</i> ²⁸		×				2	1
Rosas and Knight ¹⁹				×		3	4

Continued

Table 1 Continued

Target of SNA			Intervention type	SNA purpose
Pilot/feasibility phase	Evaluation phase	Implementation phase		
Spitzer-Shohat <i>et al</i> ³⁶		×	8	1
Yang <i>et al</i> ³⁸	×		9	1

However, the generalisability of SNA results is limited due to the unique nature of a network.^{48 49}

Reported implications and added value of SNA

Fifteen studies reported implications of using SNA in developing and evaluating complex interventions.^{19 27 28 30 31 33 35 36 43–46 48–51} Three studies reported the wider use of SNA in their topic of research, namely, inter-professional education, train-the-trainer programmes and the evaluation of nursing interventions.^{27 45 46} Figure 2 shows a graphical framework that summarises reported strengths of the application of SNA and reported implications, and connects their content to the dimensions of complexity. The graphical framework depicts the ways SNA can be used in the various phases of complex intervention research in healthcare, in connection to complexity of the intervention, implementation, population, pathway and context.

Regarding the development phase, the acceptability study by Rice *et al*²⁸ reported that SNA can provide essential information in the design of large-scale efficacy studies. For the pilot phase, the educational intervention by Benton *et al*²⁷ indicated that SNA offers an opportunity to introduce quantitative rigour to the selection of interventionists. Rice *et al*²⁸ suggested that the identified people can disseminate innovations. SNA results can also inform the design of feasibility trials.⁵⁰ In regard to the evaluation phase, five studies reported implications.^{30 33 35 43 44} One study that was characterised as an implementation study reported that SNA provides useful monitoring and evaluation data for both evaluation and implementation purposes.³⁰ The process evaluation study by Millery *et al*³⁵ suggested that SNA allows analysis of the network as a whole system and at the individual organisation level. Such analysis enables researchers to document systemic change beyond simple shifts in knowledge, attitudes and skills. Both levels were reported to be very useful for an evaluation framework in a transactional context.³⁵ Some authors reported that SNA can measure network structural factors beyond the intervention, which is necessary to understand the broader context.⁴⁴ Furthermore, the effectiveness study by Held *et al*⁴³ reported that SNA helps to identify points of leverage to create and improve targeted intervention strategies. For the implementation phase, the reported implications indicated that SNA provides an in-depth understanding of the barriers and/or facilitators of the diffusion and implementation of an

intervention. SNA also offers actionable insights into the network of interest, such as insights into skill transfer and team effectiveness, which can guide the implementation of large-scale efficacy studies.^{28 36}

DISCUSSION

This scoping review described the specific use of SNA in different phases of complex intervention research, in different level of intervention complexity, as well as the value of using SNA for developing and evaluating complex interventions. Five main conclusions can be drawn from this analysis. First, SNA seems underused in evaluating complex intervention research. Second, SNA was not used in the development phase of the included studies. Third, the reported implications in the evaluation and implementation phase reflect the value of SNA in addressing the implementation and population complexity. Fourth, pathway complexity and contextual complexity of the included interventions were unclear or unable to access. Fifth, the use of a mixed methods approach was reported as a strength, as the combination and integration of a quantitative and qualitative method clearly establish the results.

This study showed that SNA seems underused in evaluating complex intervention research. A total of 25 complex healthcare intervention-based studies published in the last 10 years in the field of healthcare were found that used SNA. This number is comparable to the findings of a systematic review reporting the application of SNA in health behaviour intervention studies.⁵¹ SNA has developed only over the past 20 years from a niche discipline in sociology to an approach applied in many fields of the physical and biological sciences.⁵² SNA is focused on the structure of relationships and assumes that relationships are important.⁵³ Most complex interventions are embedded within a network of multiple (healthcare) professionals from multiple sectors and disciplines.¹¹ Recent studies, therefore, highlight the importance of understanding and examining networks and their interactions in complex intervention research.^{9 12 14–19}

Although SNA has been used in the pilot, evaluation and implementation phase, this study showed that no study used SNA in the development phase. Several frameworks are available for the development and evaluation of complex interventions.^{1 54–58} Optimising the development

Table 2 Complexity of included studies based on the Complexity Assessment Tool for Systematic Reviews (iCAT_SR)

	Intervention complexity			Implementation complexity			Population complexity	Pathway complexity	Contextual complexity
Studies	Active components included in the intervention, in relation to the comparison	Behaviour or actions of intervention recipients or participants to which the intervention is directed	The degree of tailoring intended or flexibility permitted across sites or individuals in applying or implementing the intervention	The level of skill those delivering the intervention in order to meet the objectives	The level of skill required for the targeted behaviour when entering the included studies by those receiving the intervention, in order to meet the intervention objectives	Organisational levels and categories targeted by the intervention	The nature of the causal pathway between the intervention and the outcome it is intended to effect	The degree to which the effects of the intervention are dependent on the context or setting in which it is implemented	
Banbury <i>et al</i> ³⁷	More than one component and delivered as a bundle	Multitarget	Moderately tailored/flexible	Intermediate-level skills	Basic skills	Single category	Unclear or unable to asses	Unclear or unable to asses	
Benton <i>et al</i> ²⁷	More than one component and delivered as a bundle	Multitarget	Moderately tailored/flexible	High-level skills	High-level skills	Single category	Unclear or unable to asses	Unclear or unable to asses	
Bliuc <i>et al</i> ²⁹	One component	Single target	Inflexible Intervention	Basic skills	Basic skills	Multicategory	Unclear or unable to asses	Unclear or unable to asses	
Campbell <i>et al</i> ³²	More than one component	Single target	Moderately tailored/flexible	Intermediate-level skills	Basic skills	Multilevel	Unclear or unable to asses	Unclear or unable to asses	
Molloy Elreda <i>et al</i> ³⁴	More than one component and delivered as a bundle	Multitarget	Inflexible Intervention	Intermediate-level skills	Basic skills	Multicategory	Unclear or unable to asses	Unclear or unable to asses	
Gesell <i>et al</i> ⁴⁷	More than one component and delivered as a bundle	Multitarget	Moderately tailored/flexible	Intermediate-level skills	Basic skills	Multicategory	Pathway linear, short	Unclear or unable to asses	
Gesell <i>et al</i> ⁴¹	More than one component and delivered as a bundle	Multitarget	Moderately tailored/flexible	Intermediate-level skills	Basic skills	Multicategory	Pathway linear, short	Unclear or unable to asses	
Held <i>et al</i> ⁴³	More than one component	Single target	Inflexible Intervention	Intermediate-level skills	Basic skills	Single category	Unclear or unable to asses	Unclear or unable to asses	

Continued

Table 2 Continued

	Intervention complexity	Implementation complexity	Population complexity	Pathway complexity	Contextual complexity
Jippes <i>et al</i> ⁵⁰	More than one component and delivered as a bundle	Single target	Inflexible Intervention	High-level skills	Intermediate-level skills
Katz <i>et al</i> ³³	More than one component and delivered as a bundle	Multitarget	Moderately tailored/flexible	Intermediate-level skills	Basic skills
Li <i>et al</i> ⁴⁴	More than one component and delivered as a bundle	Dual target	Highly tailored/flexible	Intermediate-level skills	Basic skills
Márquez-Serrano <i>et al</i> ⁴⁶	More than one component and delivered as a bundle	Multitarget	Highly tailored/flexible	Intermediate-level skills	Basic skills
Masumoto <i>et al</i> ⁴⁰	More than one component and delivered as a bundle	Dual target	Inflexible Intervention	Intermediate-level skills	Basic skills
McGlashan <i>et al</i> ⁴⁸	More than one component	Multitarget	Moderately tailored/flexible	Intermediate-level skills	Basic skills
Millary <i>et al</i> ³⁵	More than one component and delivered as a bundle	Multitarget	Moderately tailored/flexible	Intermediate-level skills	Basic skills
Moses <i>et al</i> ³¹	More than one component and delivered as a bundle	Multitarget	Moderately tailored/flexible	Intermediate-level skills	Intermediate-level skills
Yousefi-Nooraie <i>et al</i> ⁴²	More than one component and delivered as a bundle	Dual target	Moderately tailored/flexible	Intermediate-level skills	Basic skills

Continued

Table 2 Continued

	Intervention complexity			Implementation complexity			Population complexity	Pathway complexity	Contextual complexity
	More than one component and delivered as a bundle	Multitarget	Inflexible Intervention	Intermediate-level skills	Basic skills	Single category	Unclear or unable to asses	Unclear or unable to asses	Unclear or unable to asses
Owen <i>et al</i> ³⁹	More than one component and delivered as a bundle	Multitarget	Moderately tailored/flexible	Intermediate-level skills	Basic skills	Single category	Pathway variable, long	Moderately dependent on individual-level factors	Unclear or unable to asses
Phillips <i>et al</i> ⁴⁵	One component	Multitarget	Inflexible Intervention	Intermediate-level skills	Basic skills	Single category	Unclear or unable to asses	Unclear or unable to asses	Unclear or unable to asses
Ramanadhan <i>et al</i> ³⁰	More than one component and delivered as a bundle	Single target	Highly tailored/flexible	Intermediate-level skills	Basic skills	Single category	Unclear or unable to asses	Unclear or unable to asses	Unclear or unable to asses
Ramanadhan <i>et al</i> ⁴⁹	More than one component	Multitarget	Inflexible Intervention	Intermediate-level skills	Basic skills	Multicategory	Unclear or unable to asses	Unclear or unable to asses	Unclear or unable to asses
Rice <i>et al</i> ²⁸	More than one component and delivered as a bundle	Multitarget	Highly tailored/flexible	Intermediate-level skills	Basic skills	Multilevel	Pathway variable, long	Moderately dependent on individual-level factors	Unclear or unable to asses
Rosas and Knight ¹⁹	More than one component	Dual target	Inflexible Intervention	Intermediate-level skills	Basic skills	Single category	Unclear or unable to asses	Unclear or unable to asses	Unclear or unable to asses
Spitzer-Shohat <i>et al</i> ³⁶	More than one component and delivered as a bundle	Dual target	Inflexible Intervention	Basic skills	Basic skills	Single category	Unclear or unable to asses	Unclear or unable to asses	Unclear or unable to asses
Yang <i>et al</i> ³⁸	More than one component and delivered as a bundle	Dual target	Inflexible Intervention	Intermediate-level skills	Basic skills	Single category	Unclear or unable to asses	Unclear or unable to asses	Unclear or unable to asses

Table 3 Reported strengths and limitations in the application of social network analysis (SNA) in complex intervention research

Application component	Strengths	Limitations
Design		
SNA as a method ^{28 31 42 44 49}	<ul style="list-style-type: none"> ▶ SNA supports the conclusions from traditional analysis and generates new information. ▶ SNA reveals important intervention dynamics that would not be found with classical methods. ▶ SNA moves beyond individual-level effects and captures system-level effects. ▶ Longitudinal SNA can reveal underlying social processes after the implementation of the intervention. 	
Type of SNA method ^{27 29 36}	<ul style="list-style-type: none"> ▶ A mixed methods approach clearly establishes the results. 	<ul style="list-style-type: none"> ▶ The lack of a qualitative component results in a less comprehensive understanding of the results.
Control group ^{28 42}		<ul style="list-style-type: none"> ▶ Insight into the structure does not indicate causality. ▶ Due to the lack of a parallel control group, findings on the changes in social networks through the implementation of the intervention could simply be the result of natural tendencies in social networks over time and not the effect of the intervention per se.
Data		
Data collection ^{19 28–30 37 43–46}	<ul style="list-style-type: none"> ▶ Data are easily to collect. ▶ Primary data can be collected through several methods such as surveys, workshops or interviews. ▶ SNA is applicable to all kind of networks. 	<ul style="list-style-type: none"> ▶ The data collection method can be restrictive in examining relations involving more than two people. ▶ Self-reported data induce recall bias. ▶ There is a possibility for social desirability bias. ▶ Obtaining responses for (longitudinal) data collection can be challenging. ▶ The operationalisation of the network type of interest can be interpreted in multiple ways. ▶ Constructing sociometric network data requires outreach work and knowledge of the community. ▶ Egocentric network data collection is much more feasible and less expensive than sociometric network data collection.
SNA tools (NET map, Social Network Diagnostic Tool, Partner Tool) ^{32 35 47}	<ul style="list-style-type: none"> ▶ NET map is a tool for action research that yields visual quantitative and qualitative evaluation data; it enhances the sense of a shared purpose among network members. ▶ A social network diagnostic tool can monitor group programmes during implementation and can guide programme activities with the intent to build new social networks. ▶ The SNA Partner Tool produces a rich set of network metrics to describe the state of the network at baseline. 	<ul style="list-style-type: none"> ▶ The Social Network Diagnostic Tool is not sensitive to the measurement of different mechanisms explaining social influences.

Continued

Table 3 Continued

Application component	Strengths	Limitations
Non-respondent data ^{19 28 48}		<ul style="list-style-type: none"> ▶ The absence of non-respondent data may introduce potential bias, as non-respondents' positions in the network may lead to them being difficult to contact in retrospect. Alternatively, the occurrence of missing data may be random due to staff turnover and changing contact details between the end of the intervention and the data collection period. ▶ Missing or erroneous data can dramatically affect network representation.
Analysis		
Quantitative metrics ^{27 34}	<ul style="list-style-type: none"> ▶ SNA provides a wide range of tools for quantifying the structure and strengths of networks (of interest) during an intervention. ▶ SNA can support multiple analyses of effectiveness at the individual level. ▶ SNA can be combined with other statistical approaches. 	
Sociometrics ^{30 44}	<ul style="list-style-type: none"> ▶ Sociometrics have superior value in overcoming the shortcomings of ego network self-reported measures. ▶ Sociometrics strengthen studies. 	
Use of SNA programmes (eg, UCINET, NETDRAW) ^{19 27 44}	<ul style="list-style-type: none"> ▶ The use of programmes as UCINET and NETDRAW to analyze (and visualize) social network data is relatively easy, which makes SNA potentially attractive for routine use in programme evaluation. 	<ul style="list-style-type: none"> ▶ Network data analysis requires special training. ▶ SNA requires experience.
Number of respondents ⁴³	<ul style="list-style-type: none"> ▶ SNA is focused on relationships instead of individuals (the number of respondents), which establishes the basis for the quantitative analysis (power). 	
Results		
Visualisation ^{19 44}	<ul style="list-style-type: none"> ▶ Visuals are a resource for reflection about the structure and process. ▶ Visualisation may change the self-perceptions of actors. 	<ul style="list-style-type: none"> ▶ Results that are simply visualised do not take into account the actual complexity. ▶ The interpretation of visuals is sometimes difficult.
Interpretation of results ^{19 31 48}	<ul style="list-style-type: none"> ▶ SNA provides insight into the interactions that people have within an intervention. ▶ SNA is an informative approach to analysing changes in professionals' networks. ▶ The network map helps identify and act on individuals who leave the network. ▶ The positions and expansion of network actors can be understood. ▶ The structure and strength of the network can be characterised, which facilitates the examination of changes in the structure over time, whether the network becomes more sparse or cohesive, and whether there are changes in people's strategic positions (eg, central or peripheral). 	
Generalisability ^{48 49}		<ul style="list-style-type: none"> ▶ Limited or cautious generalisation of the findings to other networks.

	Intervention complexity	Implementation complexity	Population complexity	Pathway complexity	Contextual complexity
Development phase	Mixed methods SNA data <ul style="list-style-type: none"> Monitoring data can guide the development of an intervention, design of feasibility trials and large-scale efficacy studies. SNA tools <ul style="list-style-type: none"> Describing the state of the network at baseline. 	Mixed methods SNA data <ul style="list-style-type: none"> Monitoring data can guide the development of an intervention, design of feasibility trials and large-scale efficacy studies. 	Mixed methods SNA data <ul style="list-style-type: none"> Understanding the positions and expansion of network actors. 	Mixed methods SNA data <ul style="list-style-type: none"> Understanding the barriers and facilitators of the diffusion of an intervention. Mixed methods SNA data <ul style="list-style-type: none"> Facilitating the examination of changes in the network structure over time. 	Mixed methods SNA data <ul style="list-style-type: none"> Understanding the broader context, and offering a visual understanding by measuring network structural factors beyond the intervention.
Pilot/feasibility phase	SNA tools <ul style="list-style-type: none"> Guiding program activities. Tool for action research that yields visual quantitative and qualitative evaluation data. Enhancing the sense of a shared purpose among network members. 	SNA data <ul style="list-style-type: none"> Identifying key individuals that can disseminate innovations or be interventionists. Bringing quantitative rigor to the selection of interventionists. 	SNA data <ul style="list-style-type: none"> Visualization of SNA data may change the self-perceptions of actors. Mixed methods SNA data <ul style="list-style-type: none"> Identifying and act on individuals who leave the network. 	Mixed methods SNA data. <ul style="list-style-type: none"> Identifying points of leverage to create targeted intervention strategies. 	Mixed methods SNA data <ul style="list-style-type: none"> Understanding the broader context, and offering a visual understanding by measuring network structural factors beyond the intervention.
Evaluation phase	Mixed methods SNA data <ul style="list-style-type: none"> SNA programs easy to use, attractive for routine use in program evaluation. Support multiple analyses of effectiveness at the individual level. Focusing on relationships instead of individuals, which establishes the basis for the quantitative analysis (power). Combining SNA with other statistical approaches. SNA data <ul style="list-style-type: none"> Documenting changes in networks of participants during program evaluation. 	SNA data <ul style="list-style-type: none"> Visualization of SNA data are a resource for reflection about the structure and process of networks of interests. Mixed methods SNA data <ul style="list-style-type: none"> Understanding the barriers and facilitators of the implementation of an intervention. Monitoring programs during implementation. 	Mixed methods SNA data <ul style="list-style-type: none"> Understanding the positions and expansion of network actors. Mixed methods SNA data <ul style="list-style-type: none"> Identifying and act on individuals who leave the network. SNA data <ul style="list-style-type: none"> Quantifying the structure and strengths of networks (of interest) during an intervention. 	Mixed methods SNA data. <ul style="list-style-type: none"> Identifying points of leverage to create targeted intervention strategies. SNA tools <ul style="list-style-type: none"> Tool for action research that yields visual quantitative and qualitative evaluation data. 	Mixed methods SNA data <ul style="list-style-type: none"> Documenting systemic change beyond simple shifts in knowledge, attitudes, and skills by measuring network as whole system and individual organization level. Both levels useful for an evaluation framework in a transactional context. Mixed methods SNA data <ul style="list-style-type: none"> Understanding the broader context, and offering a visual understanding by measuring network structural factors beyond the intervention.
Implementation phase	Mixed methods SNA data <ul style="list-style-type: none"> Guiding the implementation of large-scale efficacy studies. 	Mixed methods SNA data <ul style="list-style-type: none"> Understanding the barriers and facilitators of the implementation of an intervention. Monitoring programs during implementation. 	Mixed methods SNA data <ul style="list-style-type: none"> Identifying and act on individuals who leave the network. Mixed methods SNA data <ul style="list-style-type: none"> Examination of changes in the network structure over time, whether the network becomes more sparse or cohesive, and whether there are changes in people's strategic positions (e.g., central or peripheral). 	Mixed methods SNA data. <ul style="list-style-type: none"> Identifying points of leverage to create targeted intervention strategies. SNA tools <ul style="list-style-type: none"> Tool for action research that yields visual quantitative and qualitative evaluation data. 	Mixed methods SNA data <ul style="list-style-type: none"> Monitoring data can reveal underlying social processes after the implementation of the intervention.

Figure 2 Graphical framework. SNA, social network analysis.

of a complex intervention will enhance the intervention design, increase value and minimise the risk of subjects being exposed to ineffective interventions. A gap between the intervention and the implementation context often results in suboptimal treatment success⁵⁹ and SNA may contribute to bridge the gap and to understand the implementation context. During the development phase, SNA can provide strategies to consider the social context of programme delivery, determine the appropriate methods and communication needs, and identify particular change agents and opinion leaders in the network to focus on.^{60–62} This suggests that SNA can be of great value when developing, complex interventions.

This study shows a significant potential of using SNA in addressing the implementation and population complexity in various ways. Although frameworks highlight the importance of a systematic development and evaluation of complex interventions, an iterative rather than linear process is recommended.^{1 54–58} An iterative process allows researchers to consider the implementation complexity and population complexity prior to the implementation. When addressing implementation complexity, SNA could focus (1) on the skills required by the intervention providers who deliver the intervention and (2) the tailoring carried out by the intervention providers, regarding the receiver or context, in applying

or implementing the intervention.²⁶ By addressing the population complexity, SNA can highlight the structures of the organisational levels and categories targeted by the intervention.²⁶ Since interventions itself might alter networks and since networks are dynamic and likely to change over time, researchers are therefore encouraged to collect network and outcome data of interest longitudinally (eg, monitoring data) and cross-sectionally.^{43 51} Furthermore, the use of monitoring SNA data can identify points of leverage to create and improve targeted intervention strategies.⁴³ Valente *et al*⁶⁰ published a practical overview of how to use SNA for programme implementation to understand which social network can be created, maintained and accomplished.

This study showed that the pathway complexity and contextual complexity of most interventions were unclear or unable to access. The limited reporting regarding the use of a logic model which describe the nature of the causal pathway between the intervention and its effect, and contextual factors which can influence the effectiveness of an intervention, was also observed by Smit *et al*¹⁰ that examined complex primary healthcare interventions.¹⁰ SNA could be of value in addressing the contextual complexity as the degree to which the effects of the intervention are dependent on the context or setting in which it is implemented.²⁶ The Consolidated Framework

for Implementation Research (CFIR) comprises 39 constructs organised across five major domains (eg, intervention, outer setting, inner setting, characteristics of individuals and process), all of which interact to influence implementation and implementation effectiveness.⁵ The study of Kirk *et al*⁶ provide a broad overview of CFIR constructs used in literature which can be directory in disentangling and addressing contextual complexity. In general, the graphic framework, introduced in this study, is a first step and can be used in future research in this area. Additionally, more research is needed to assess the optimal way to use SNA in complex intervention research in healthcare, especially in relation to the five dimensions of complexity.

The included studies reported the use of a mixed methods approach to be a strength, as the combination and integration of a quantitative and qualitative method clearly establishes the results. All included studies were quantitative studies, consistent with their use of SNA, which is quantitative in nature. A strong reliance on quantitative methods was criticised. Adding a qualitative approach alongside quantitative procedures can be a solution to generate an in-depth understanding of the results.^{63 64} SNA increasingly relies on both quantitative and qualitative approaches for data collection and analysis.⁶⁵ The development and evaluation of complex interventions often require multiple research questions which reflect the number of behaviours or actions that the intervention focuses on as part of the intervention complexity.²⁶ The use of mixed methods social network analysis (MMSNA) can be an appropriate means to answer these research questions in which the '13-step model' of Schooneboom (2018) can guide researchers.⁶⁶ Although the use of MMSNA is recommended, MMSNA still lacks conceptual clarity as, as the 'when', 'how' and 'why' of a mixed methods approach are rarely described.⁶⁷ However, MMSNA seems promising, and a mixed-method approach is consistent with the multiphase model of complex intervention development and evaluation.

Strengths and limitations

This study has several strengths. First, the data collection and data management processes were thorough. Two researchers selected the studies in accordance with the inclusion and exclusion criteria, which were determined beforehand. In addition, the data charting and synthesis of the results were also conducted by two researchers (LS and JD) working independently. The synthesis of the results was checked and confirmed by all authors to ensure the validity of the findings. Second, the literature search was conducted in four scientific databases, which is more than sufficient to include the central and relevant research evidence in healthcare.⁶⁸ In addition, the reference lists of the reviews in our search were hand searched to identify studies that otherwise potentially would have been missed. Third, the review process followed a universally agreed protocol (PRISMA Extension for Scoping Reviews 2018) to ensure the quality of reporting.²²

Additionally, in the analysis, the authors' original expressions were used without any interpretations.

This review has some limitations. First, there is no sharp boundary between simple and complex healthcare interventions.¹ To overcome this limitation, the level of complexity was unravelled of all included studies based on the Icat_SR.²⁶ Second, this study did not critically appraise the included studies. However, the literature states that scoping reviews cannot identify gaps in the literature related to the low quality of research.^{69 70} By not addressing the issues of quality appraisal, this study was able to include a larger range of study designs and methodologies than would have been included in a systematic review⁷¹; thus, the emphasis of a scoping study is on comprehensive coverage rather than a particular standard of evidence.⁷²

CONCLUSION

Based on the application of SNA in 25 studies, we conclude that SNA is a valuable method to apply, but currently underused. SNA has been applied in the pilot, evaluation and implementation phases of complex intervention research. Although there is an absence of studies applying SNA in the development of complex interventions, the included studies reported the potential value of SNA in the development phase. Furthermore, SNA can be of value to disentangle and address the five dimensions of complexity of complex healthcare interventions. The routine use of SNA within a mixed-method approach for developing and evaluating complex interventions could yield actionable insights that would be useful in the trans-actional context of complex interventions.

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Appendix A. Dimensions, assessment and criteria to extract complexity of the health care interventions based on the Complexity Assessment Tool for Systematic Reviews (iCAT_SR) (Lewin, 2017).

Core dimensions	Assessment and criteria
Active components included in the intervention, in relation to the comparison	<ul style="list-style-type: none"> • More than one component and delivered as a bundle = The intervention includes more than one component and some or all of these components need to be delivered as a bundle. • More than one component= The intervention includes more than one component. These components may be integrated into a package. • One component= The intervention includes one component only. • Varies= Varies across interventions to be considered for/ included in the review.
Behaviour or actions of intervention recipients or participants to which the intervention is directed	<ul style="list-style-type: none"> • Multi-target= Intervention directed at three or more behaviours or actions. • Dual target= Intervention directed at two behaviours or actions. • Single target= Intervention directed at one behaviour or action only. • Varies= Varies across interventions to be considered for/ included in the review.
The degree of tailoring intended or flexibility permitted across sites or individuals in applying or implementing the intervention	<ul style="list-style-type: none"> • Highly tailored/flexible= High degree of variation in implementation from site to site permitted and/or intervention designed to tailor to individuals or specific implementation settings. • Moderately tailored/flexible = Some variation in implementation from site to site permitted (i.e. some components of the intervention are tailored/flexible while others are not). • Inflexible Intervention= implementation highly standardised with minimal variation from site to site. • Varies= Varies across interventions to be considered for/ included in the review
The level of skill required by those delivering the intervention in order to meet the intervention objectives	<ul style="list-style-type: none"> • High level skills= Extensive specialised skills required, i.e. new skills in addition to expected existing skills AND/OR the extension of existing skills to a highly specialised area AND/OR skills requiring extensive additional training. • Intermediate level skills = Some specialised skills required, i.e. a small extension to the expected existing skills of professionals, decision makers or consumers. • Basic skills= No specialised skills required. • Varies= Varies across interventions to be considered for/included in the review.
The level of skill required for the targeted behaviour when entering the included studies by those receiving the intervention, in order to meet the intervention objectives	<ul style="list-style-type: none"> • High level skills= Extensive specialised skills required. • Intermediate level skills= Some specialised skills required. • Basic skills = No specialised skills required. • Varies= Varies across interventions to be considered for/ included in the review.

Organisational levels and categories targeted by the intervention	<ul style="list-style-type: none"> • Multi-level = Intervention directed at two or more levels. • Multi-category= Intervention directed at two or more categories of individuals within the individual level (e.g. primary care professionals and primary care patients). • Single category= Intervention directed only at single category of individuals within the individual level (e.g. professionals or patients or policy makers).
Optional dimensions	
The nature of the causal pathway between the intervention and the outcome it is intended to effect	<ul style="list-style-type: none"> • Pathway variable, long= The causal pathway includes three or more steps between intervention and outcome or occurs over a long time period; is not linear, or is variable; and/or more than one causal pathway has been proposed. • Pathway linear, long= The causal pathway is linear but there are three or more steps between intervention and outcome. • Pathway linear, short= The causal pathway is clear, short (only one or two steps), direct, linear. • Varies= Varies across interventions to be considered for/included in the review. • Unclear or unable to assess
The degree to which the effects of the intervention are dependent on the context or setting in which it is implemented	<ul style="list-style-type: none"> • Highly dependent on individual-level Factors= The effects of the intervention are modified by both recipient and provider factors. • Moderately dependent on individual-level factors= The effects of the intervention are modified by one of recipient or provider factors. • Largely independent of individual level Factors= The effects of the intervention are not modified substantially by recipient or provider factors. • Varies= Varies across interventions to be considered for/included in the review. • Unclear or unable to assess

Appendix B. Extended study characteristics of the included studies.

Authors/year	Study Objective	Population/sample	Type of intervention	Intervention description
Banbury, 2017 [37]	This study examined the relationship between changes in social support networks for older people living in a regional area following weekly videoconference groups delivered to the home.	Coffs Harbour , New South Wales, Australia. Participants were recruited via community events and health professional referrals. aged 50 years and over with at least one LTC and the cognitive ability and the physical ability to use the videoconference equipment. A total of 44 videoconference meetings with 9 groups took place lasting between 45 minutes to 1.5 hours each. The mean number of participants in each meeting was 4.2	Tele health intervention	Telehealth Literacy Project was nested within a non-randomized, non-controlled vital signs remote monitoring project, My Health Clinic at Home. The THLP study consisted of five weekly group meetings by videoconference followed by a further week for feedback and evaluation. At the aged care provider premises, one facilitator, who is an experienced health promotion professional, ran the group meetings with support from an IT specialist who was also in the room. Participants were situated in their homes and once connected to a virtual room by the IT specialist, they could see and hear other group members and the facilitator in real time. Meetings started with introductions and the facilitator highlighting videoconference etiquette and confidentiality. Health information using slides and videos was provided. However, and more importantly, didactic teaching was minimal, and a facilitation method was employed whereby participants were highly encouraged to share anecdotes about their week and discuss their experiences, knowledge and opinions on health issues.
Benton et al., 2015 [27]	To explore whether social network analysis metrics may be useful in identifying candidates for the LFC train the trainers' programme. Instead of individuals identified by the traditional expert-opinion approach to train the trainer selection	A country in the Middle East. Participants in the study consisted of the inaugural Leadership for Change cohort. 32 participants were enrolled in the SNA	Educational	The Leadership For Change Programme utilizes five major elements; workshops that deliver core knowledge and provide opportunities for skills development; mentoring that offers students a means of addressing particular gaps in the leadership competencies; a team project that requires sub-cohorts to work together on a major policy or change issue; the completion and pursuit of individual development plans; and the opportunity to participate in learning activities such as visits to television or radio studios and media centers. The LFC programme uses an action learning methodology and from the initial cohort of thirty students trained by either the programme director, one of the regional trainers or the ICN chief executive approximately one third of the group go on to become in-country trainers

Bliuc, 2016 [29]	This study examines how online participation in a community of recovery contributes to personal journeys of recovery. It investigates whether recovery capital building as indicated by increased levels and quality of online social interactions and markers of positive identity development predict retention in a recovery program designed around fostering community involvement for early stage recovery addicts.	The study population (total N 609) consisted of all participants in the online JFH Facebook community. This community includes JFH program participants (N ¼ 23), JFH staff (N ¼ 5), and community members (N ¼ 581) who contributed to the online discussions over a period of eight months since the establishment of the JFH Facebook page	Network intervention	Jobs, Friends and Houses (JFH), a social enterprise that engages addicts in early recovery in apprenticeships in building professions while working on the renovation and construction of recovery housing in the north of England town of Blackpool. Participants in the program are actively involved in employment and training and are provided with recovery housing; as a part of a lifestyle change program, many of them also attend recovery mutual aid group meetings. As part of the building of the recovery community, JFH introduced a Facebook page to perform two primary functions: (1) to provide a recovery-supportive online community for participants; and (2) to allow the outside world (including a range of community stakeholders) to engage with JFH.
Campbell, 2014 [32]	Describes the mobile health intervention of the K4Health Malawi project and explores the effects of the intervention on knowledge exchange, focusing particularly on the qualitative and quantitative data collected through a participatory action research methodology called Net-Map.	Malawi, Nkhosokota and Salima Districts. In total 638 community health workers (CHWs) were included by given them phones etc. Participants were selected based on their membership in key stakeholder groups related to the technical focus of their work in HIV/AIDS and family planning/reproductive health in Malawi. A limit of 15 participants per workshop was necessary to ensure substantive discussions and output.	M health intervention	The project trained and provided mobile phones, solar chargers, and airtime to 253 CHWs in Nkhosokota and Salima Districts—30% of all CHWs in the 2 districts combined. An additional 385 CHWs received phones, chargers, and training during a second distribution in November 2010, bringing SMS coverage to 77% of health workers in both districts, targeting those whose homes were farthest away from health centers. In addition to providing new channels for communication (mobile phones and the SMS Hub), the system also filled these channels with essential technical information. The communication flow encompassed requests from health workers as well as prompt replies from district supervisors and coordinators. When clients approached health workers with urgent questions, or when workers needed to restock contraceptives, the workers could use their mobile phones to send a text message to the Hub, where a district coordinator or supervisor would be assigned to read and respond to messages. Alternately, a worker could reach a specific supervisor directly by using defined keywords, which the Hub would recognize and forward to the phone of the supervisor. The CHW could also use the system to contact a fellow worker within the network to ask a question or make a request. One of the reasons that the project chose this mHealth intervention was because of its low cost. NET-MAP intervention was included as evaluation method. Consisting of 5 steps: 1) Identifying the actors in the network. 2) Linking the actors 3) Mapping the influence 4) Facilitating the discussion. 5) Comparing the maps.

Elreda, 2016 [34]	The present study examines group process among parents and early adolescents in an efficacy trial of a mindfulness-based adaptation of the Strengthening Families Program (MSFP)	Central Pennsylvania. In total, participants for this study were 120 parents	Group based intervention	MSFP; in which participants were assigned to either SFP or the MSFP adaptation. SFP is a universal, evidence-based behavioral intervention for parents and youth ages 10–14 delivered in seven weekly sessions to groups of families, targeting a range of outcomes related to parenting, quality of the parent-youth relationship, and various parent and youth behavioral and psychological functioning outcomes. Each session begins with a one-hour parenting skills course and an adolescence life skills course (for which parents and teens are separated). MSFP followed an identical delivery structure, but integrated mindfulness activities into the parent skills portion. Group process within the separate parent and teen groups is the focus of the present study. We integrate SNA and IEV methods to provide for precise tracking of group structural features and individuals' positions in the groups, their change over time, and their associations with between-person differences in program benefits accrued to members.
Gesell, 2013 [47]	We hypothesized (H1) that by week twelve, after weekly 90-minute group skills-building group sessions, we will observe a moderate increase in network structure and perceived cohesion among participants.	Eleven pilot study participants enrolled in a twelve week intervention designed to teach healthy lifestyles in a group format.	Network intervention	GROW is an ongoing group-level behavioral intervention to prevent childhood obesity. It occurs at public community recreation centers for high-risk parent preschool child (ages three to five years) dyads. GROW is based on a conceptual model that childhood growth patterns are affected over time at sensitive windows of development by both micro- and macro-level systems. The micro-level system includes personal characteristics ranging from genetic profiles to individual attitudes and behaviors; whereas the macro-level system ranges from social networks to public policies. The GROW intervention focuses on the family, recruiting an index parent-child dyad, and connecting that dyad to the larger built environment. This built environment serves as a community-centered location to build healthy lifestyle skills (both routine physical activity and nutritional habits). During the first (intensive) phase of the intervention, families attend skills-building sessions together in small groups for twelve weeks.
Gesell, 2016 [41]	This article examined the relationship between social network ties and group cohesion in a group-based intervention to prevent obesity in children.	Davidson County Tennessee. Six-hundred and eleven adult-child pairs were enrolled in the GROW trial. Of those, 305 pairs were assigned to the intervention designed to teach healthy lifestyles in a group format. Social network data were	Group intervention	GROW is an ongoing group-level behavioral intervention to prevent childhood obesity. It occurs at public community recreation centers for high-risk parent-preschool child (ages 3-6 years) dyads. GROW is based on a conceptual model that childhood growth patterns are affected over time at sensitive windows of development by both micro- and macro-level systems. The micro-level system includes personal characteristics ranging from genetic profiles to individual

		collected from 304 intervention group adults (in 30 groups) and included in the analysis.		attitudes and behaviors, whereas the macro-level system ranges from social networks to public policies. The GROW intervention focuses on the family, recruiting an index parent–child dyad, and connecting that dyad to the larger built environment. This built environment serves as a community-centered location to build healthy lifestyle skills (both routine physical activity and nutritional habits). During the first (intensive) phase of the intervention, families attended skills-building sessions together in small groups for 12 weeks. Parents met in consistent groups of approximately 8 to 10 parents for 2 hours each week for group sessions. Transportation and child care for siblings was offered to all study participants to overcome the most frequently cited barriers to study participation (Eakin et al., 2007). Participants did not receive remuneration for attending sessions. All sessions for each group were conducted in English or Spanish by the same group leader, who was trained to facilitate group discussion rather than lecture. All sessions involved a parent only skills building component and a parent–child applied learning component to build healthy lifestyle skills (nutrition, physical activity). Integrated within the intervention was the intentional building of new social networks described in detail elsewhere (Gesell, Barkin, & Valente, 2013). By design, participants who could not attend group sessions were given the opportunity to receive the intervention via phone call coaching depending on their weekly circumstances.
Held, 2019 [43]	In this study we use the novel methodology of social network analysis to explore important aspects of learning of allied health professional (AHP) students in a rural community-based program.	Australia, Broken Hill. An entire cohort of ten students (6 speech therapy and 4 OT students) was invited to participate during the final week of their placement. They had spent 6–8 weeks at Broken Hill University Department of Rural Health (BHUDRH). They came from the same university and were in the final year of their undergraduate degrees. Nine were female, one was male.	Educational	For the cohort of AHP students in our study (occupational therapy (OT) and Speech therapy) the program included regular classes and workshops at BHUDRH, and the students’ main role was to conduct lessons in local primary schools and kindergartens to further the children’s lingual and motor development. In teams of two or three students had to plan, prepare, conduct and evaluate classes. Team membership was fixed for each school for the duration of the placement, but different combinations of students teamed up in different schools. School teachers were present during each of their classes. Students lived in shared housing facilities with students of other disciplines during their placement. In this context, we asked the research question “What are the important social relations of AHP students within a community-based rural clinical placement regarding what and from whom the students learn?”

Jippes, 2010 [50]	We examined the effect that following an intensive Teach-the-Teacher training had on the dissemination of a new structured competency-based feedback technique of assessing clinical competencies among medical specialists in the Netherlands.	The Netherlands. The total sample consisted of 105 gynecologists and pediatricians and 86 residents in Obstetrics & Gynecology and Pediatrics.	Organizational	Many medical specialists in our sample had followed a Teach-the-Teacher course which was aimed at improving the didactic skills or teaching abilities of the participants. The training consisted of three sequential two-day courses. Registration for the second and third courses was dependent upon successful completion of the first course. The introductory course comprised training in structured feedback, training in the Mini-CEX, and the basics of adult learning. The second course comprised training in daily educational practice, which includes organizing day-to-day training for residents and adapting the training to the learning styles of the residents. The third course included training in periodic interviews for the formative and summative assessment of residents. Participants in the courses were medical specialists from different specialties and hospitals in the Netherlands; among these participants were the gynecologists and pediatricians in our sample.
Katz, 2012 [33]	Cancer education seminars for appalachian populations were conducted to: (1) increase knowledge of existing cancer disparities, (2) disseminate findings from Appalachian community based participatory research (CBPR) projects, and (3) foster CBPR capacity building among community members by promoting social networking.	USA. Participants (n=335) attending the four seminars	Educational	The seminar series consisted of three regional and one national seminar. The educational objectives of the seminars were to increase knowledge of existing cancer disparities in Appalachia and to disseminate research findings from CBPR projects conducted in Appalachia. An additional objective of the national seminar was to foster capacity building among Appalachian community members for CBPR by promoting networking at the seminars. The seminars were designed to draw attention to the cancer disparities that exist in Appalachia and to highlight the CBPR projects and evidence-based educational programs being conducted by academic and community partnerships in Appalachia. Each seminar used a common agenda format including speakers who were academic researchers, junior investigators, and community members from local cancer coalitions. Panel discussions were featured to facilitate sharing ideas with the members of the audience. In addition to presentations directed at cancer disparities and interventions to reduce cancer, the seminars also addressed Appalachian identity, the impact of culture and heritage on cancer disparities in Appalachia, and the importance of storytelling in Appalachia. Although the content of all seminars was comparable, the regional seminars featured local researchers and community members compared to the national seminar which featured researchers,

				community members, and cancer-related issues associated with the entire Appalachian region.
Li, 2012 [44]		We conducted a study called the Risk Avoidance Partnership (RAP) in which we tracked network relationships and dynamics in the course of implementing an innovative peer intervention to measure efficacy of this program to change group behavior. This paper uses ego and sociometric network analysis to test the RAP intervention diffusion process and effect based on diffusion theory, in order to illustrate the key processes of social change driven by drug users as community change agents within the networks of their peers.	The survey sample includes two primary participant groups related to peer intervention diffusion. The first was 112 PHAs who completed 5 or more of the 10-session training curriculum. The second participant group was 411 contacts, comprising primarily contact referrals the trained PHAs brought into the study for the baseline and 6-month surveys, plus PHA candidates who did not finish the training and their network referrals.	Peer intervention
		The RAP PHA Curriculum was a 10-session, theoretically driven interactive training program modeled after a similar one tested in Baltimore, Maryland, adding a significant staff-PHA partnered community component based on community empowerment theory to emphasize advocacy action. Content of the training and intervention was modified on the basis of local ethnography (Weeks, et al., 2001) and PHA input during the pilot (Weeks, et al., 2006). The first 5 training sessions were conducted in-office for two hours each on consecutive days, using both didactic and interactive methods to provide information, model peer intervention activities, and role play delivery of the RAP Peer Intervention to other drug users in the community. The RAP Peer intervention was a harm reduction approach to reducing risky drug use and sexual practices and promoting general prevention and health enhancement. Up to 5 additional staff-accompanied field sessions were conducted in the community over the next 10 weeks at the convenience of the PHA and his or her staff partner in a variety of community locations chosen by the PHA, including in some of the PHAs' drug-use sites. Field sessions allowed PHAs to practice effective communication and demonstration of prevention strategies in community situations where they could be expected to continue to apply them in the absence of project staff. Ongoing support for PHAs included monthly Community Advocacy Group (CAG) meetings to plan, organize, and implement activities to advocate for and promote drug users' health and well-being at the community level, and to reinforce their new role as interventionists for peer and community change. PHAs received monetary compensation of \$20 for participation in each of the 2-hour training sessions, and also received \$10 for each CAG meeting they attended. However, they received no monetary incentives to deliver intervention to their peers.		
Márquez-Serrano, [46]	2012	To explore the impact of an educational intervention for self-care of elders on their knowledge of acute respiratory infections and its incidence within their social networks.	Mexico. 10 older people included in intervention. 94 people including participants and family (their social network) included in SNA.	Educational
				The educational strategy was based on the meaningful learning principles by Ausubel, which indicate that learning should be based on prior knowledge. The experience included the following four stages: (1) activation of knowledge, (2) acquisition of knowledge, (3) practice of knowledge, and (4) application and evaluation of knowledge. Thus, the participating elders first

	<p>indicated what they knew about acute respiratory infections. Second, they acquired new knowledge during seven sessions. They then modified some of their hygienic habits, including washing their hands with the correct technique before each meal, covering their mouths when coughing or sneezing, and, finally, producing the liquid soap, handkerchief, and towel that they used for the prevention of acute respiratory infections. The sessions combined information to acquire the knowledge needed for self-care and the development of skills—such as making low-cost liquid soap, correctly using a thermometer and masks—and to participate in recreational activities such as making a handkerchief and a towel. A central theme of all the sessions was the strengthening of self-esteem so that the elders could change from being receivers of care to being promoters of their own health and that of their families. Seven educational sessions were held for approximately 70 min each, from September to December 2009. The first two sessions corresponded to the first stage in the Ausubel learning cycle, with the objective of activating the elders' prior knowledge of acute respiratory infections. The method used was discussion among the participants. The second stage in the learning cycle was conducted during Sessions 3, 4, and 5, with the objective of broadening the elders' knowledge of acute respiratory infections. The method used in these sessions was the presentation of recreational activities by the facilitator. The objective of the third stage (Sessions 6 and 7) was for the elders to expand and modify their practices. This was accomplished using the active method, in which each elder applied and adapted the knowledge that he or she had learned and maintained. The objective of the last stage in the learning cycle was for the elders to self-discover their own knowledge, making it personal and replicating it with events and/or activities within their social networks.</p>
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Masumoto, 2017 [40]	The present study was designed to quantitatively measure and visualize face-to-face interactions among elderly participants in an exercise program. We also examined relationships among interactional variables, personality and interest in community involvement, including interactions with the local community.	Kobe City , Japan. 27 participants (10 men and 17 women; mean age 73.41 years) were recruited on the condition that they were expected to participate in all four sessions of the exercise program. However, just eight could participate in all the sessions as a result of ill health or unexpected schedule changes. Of the remaining 19 participants, 11 attended three sessions, five attended two sessions and three attended one session.	Exercise intervention	In this study, participants were led in the DK Elder System (Daiichikoshō, Tokyo, Japan) by professional instructors. The DK Elder System consists of a program combining exercise, music and video images, aiming at preventive care and health maintenance. The programs are delivered using the karaoke-on-demand system. In the present study, images were projected on a screen (H180 cm × W240 cm) set in front of the participants. Two instructors demonstrated exercises on both sides of the screen, and another instructor accordingly gave advice while observing the condition of the participants. The programs included exercises using rubber bands and dumbbells for preventing falls, stretching exercises and rhythmic exercises, by moving the body to music. Each session of the exercise program lasted 90 min, and four sessions were carried out with the same participants over a 2-month period.
McGlashan, 2017 [48]	This paper presents a quantitative analysis of the interpersonal network structures within a sub-sample of stakeholders from two past successful childhood obesity prevention interventions.	USA & Australia	Community-based environmental change intervention & community capacity building approach	Two interventions: the Shape Up Somerville (SUS) and Romp & Chomp (R&C) CBIs resulted in significant reduction in BMI z-score for children in the intervention areas. Both SUS and R&C investigators retrospectively hypothesized that the SC networks comprising strong partnerships and engagement of community stakeholders were key contributors to the interventions' results. SUS (2003-2005) was a community-based environmental change intervention in Somerville, MA, USA that targeted the school, home and community settings of early elementary school children. The SC included individuals from schools, food service, community organizations, academia and local health leaders. The 'on-going group cohesion and consistent

					leadership' were regarded as the most critical factors of the intervention for the effectiveness of the intervention. R&C (2004-2008) used a community capacity building approach to improve healthy eating and active play among 12,000 children aged 0 to 5 years in Geelong, Australia. The intervention consisted of multiple changes to environments in early-childhood care and educational settings. It was led by a SC with representation from local government, early childhood settings, health services and academia. R&C stakeholders documented their perceptions of what contributed to the intervention's positive results, reporting that partnerships and relationships were a critical factor of success; for example, engagement of major community stakeholders
Millary, [35]	2017	This study present a framework for evaluating the process and outcomes of a CEHI platform designed to improve connectivity among community health resources.	New York City 28 organizations; with a 61% response rate	Network intervention	GetHealthyHeights.org CEHI platform (GHH). The mission of GHH was collectively defined by the GHH Steering Committee as "an online community that engages people and organizations in Washington Heights-Inwood to discover, connect, and share resources to get healthy". The platform include a community calendar, a local service directory, posting of multiple types of content (e.g., articles, videos, and links), the ability to comment and rate content, integration of social media for content sharing, use of Google Translate (especially for Spanish translation of content), creation of pages for local organizations and the ability to form groups that other users can join. Community organizations have an essential role in creating and disseminating content through GHH.
Moses, [31]	2009	The purpose of this study was threefold. First, we wanted to determine if participation in the Teaching Scholars Program (TSP), a longitudinal faculty development program at our institution, resulted in a larger network of colleagues interested in education. If so, we also wanted to determine what types of colleagues—departmental, campus-wide, administrators, national contacts—were involved. Second, we wanted to identify themes related to building this network through TSP. Finally, we wanted to determine if an increase in participants' educational networks was	Arkansas. Interviews with individuals who completed the TSP at the University of Arkansas for Medical Sciences from 1998 to 2004 Thirty-six of the 43 (88%) eligible TSP graduates completed interviews.	Educational	The TSP sought to improve the teaching skills of faculty in five health professions colleges and to nurture the development of a group of faculty who actively engage in the scholarship of teaching. The format included three components: nine monthly 3-hr workshops on topics related to teaching and educational research; approximately four annual lectures by nationally known health professions educators; and completion of a project in the subsequent two years. During the 1st year, the program was available to College of Medicine faculty only; since then, the program has also included participants from the Colleges of Nursing, Pharmacy, Health-Related Professions, and Public Health.

	associated with increased productivity as measured with a curriculum vita (CV) analysis		
Nooraie, 2015 [42]	<p>We studied the evolution of information-seeking networks over a 2-year period during which an organization-wide intervention was implemented to promote evidence-informed decision-making (EIDM). We tested whether engagement of staff in the intervention and their EIDM behavior were associated with being chosen as information source and how the trend of inter-divisional communications and the dominance of experts evolved over time</p>	<p>Canada</p> <p>The three public health units enrolled in the study differed. Unit A served a large urban population (>1.5 million). At the time the study commenced, unit A had in place many trained project specialists assigned to practice-based teams, with responsibility for conducting literature reviews to address practice issues. Also, more than 100 staff members, mainly managers and project specialists, had attended a weeklong workshop on EIDM. The “highly engaged” staff frequently met at progress meetings and critical appraisal clubs to share their problems and progress with other review teams. At the end of the project, completed reviews were presented in department-wide research events and other local meetings. Unit B was the largest health unit in the study, serving a large urban population area (>1.5 million). Thirteen staff members (1.2 % of 1068) were highly engaged in the intervention. Unit C served a smaller mixed urban-rural community (~600,000 population). At unit C, public health nurses had the responsibility for searching and applying evidence to practice, along with carrying out their daily public health duties under the supervision of program managers. Much similar to unit B, a few divisions of unit C participated in the intervention, and nurses were assigned to small groups to conduct summary evidence reviews. There were 18 highly engaged staff members (9 % of 202).</p>	<p>Organizational</p> <p>Three public health units in Ontario, Canada, participated in a 22-month multi-faceted and site-tailored intervention to promote EIDM among public health professionals. Senior management from each health unit helped in tailoring the intervention to their unit’s goals for EIDM and available resources. The intervention consisted of an introductory workshop introducing the study and the concept of EIDM, and face-to-face mentoring of small groups of staff through the EIDM process by a professional knowledge broker (KB). More details about the capabilities and responsibilities of the KB are provided elsewhere. In each public health unit, a group of staff was recruited by local managers to get engaged in the development of summary evidence reviews to address local public health problems, while the majority of their peers had very limited contact with the intervention. Local managers chose these individuals because their roles were already (or were planning to be) associated with EIDM. The KB interacted with this “highly engaged” staff either one-on-one (through consultations) or as members of project-specific teams to develop summary evidence reviews. During and after the intervention, “highly engaged” staff continually communicated with their peers, through which they had the opportunity to share their experience and accomplishment and get recognized by the staff as EIDM experts.</p>

Owen, 2016 [39]	This study (a) evaluates social network characteristics of four distinct communication channels (discussion board, chat, e-mail, and blog) in a large social networking intervention, (b) predicts membership in online communities, and (c) evaluates whether community membership impacts engagement.	Southern California Participants were 299 cancer survivors with significant distress using the 12-week health-space.net intervention. Participants (n = 299) were derived from a larger study of the effect of a web-based social networking intervention for cancer survivors experiencing significant distress (healthspace.net). Eligibility criteria included having a previous diagnosis of cancer, reporting distress q4 on the Distress Thermometer, 29 having reliable access to the Internet, and being willing to complete baseline and follow up surveys.	Health-space net intervention	The health-space intervention included access to a confidential community of other cancer survivor participants and professional facilitators and a structured, 12-week coping skills training intervention. The intervention provided opportunities for participants to interact in four distinct social networking channels: asynchronous discussion board, personal pages and blogs, confidential web-based mail messages, and a real-time, 90-minute weekly chat (Fig. 1). Additional details about each social networking channel and engagement with each of the channels are provided by Owen et al. ³⁰ All dyadic interactions between participants (i.e., "actors" in the social networking analysis) were recorded by time stamp and activity on the study server. Participants' identities were held in strict confidence, so participants did not have any opportunity to interact with one another outside the health-space study Web site.
Phillips et al., 2016 [45]	This study evaluates the impact of "Mind the Gap", an Australian interprofessional continuing education program about management of dual illnesses, on practitioners' knowledge, use of psychological strategies and collaborative practice.	Of the 837 workshop participants, 645 enrolled in the evaluation (54 % GPs, 16 % nurses, 14 % mental health professionals, response rate 77 %). Other allied health practitioners who attended were occupational therapists, pharmacists, physiotherapists, podiatrists and social workers.	Educational	Mind the Gap was an advanced learning module which aimed to develop participants' skills and knowledge to work singly or interprofessionally with patients with comorbid psychological and physical illnesses. Aims, content and educational strategies are summarised in Table 1. The module was delivered in one six-hour workshop, or two three-hour workshops, facilitated by a local clinician with expertise in psychological care. All facilitators received a facilitator's guide and a presentation, with speaking notes. The program was delivered through the Medicare Locals, primary care support organisations, which at the time of the study had 61 regional offices across Australia. As this program was funded by the Department of Veterans' Affairs, one of the referral pathways covered was to the Veterans and Veterans Families Counselling Service (VVCS), an Australian Government funded service providing counselling and support for war and defence service-related mental health conditions.
Ramanadhan, 2010 [30]	This study was interested in ways that a staff network might serve as a resource for informal training to strengthen practitioner skills and, ultimately, the implementation of a health promotion program. We had three goals: (1) to	USA. All 91 staff members at program sites who participated directly in childcare and who were on the staff roster on November 1, 2007 were eligible to participate in the study. A total of 80 staff members took the survey, which yielded a response rate of 88%.	Health promotion intervention	The iPLAY program helped staff create environmental changes that support child health in four areas: physical activity, nutrition, time spent with television and videos, and staff connections with children and parents/guardians. Staff members were also encouraged to use data-driven decision making and experimentation to improve program offerings as part of the learning organization movement. The program placed explicit

	describe the network of staff implementing a health promotion program; (2) to describe perceived skill transfer within the staff network; and (3) to examine the relationship between staffprogram-related connections and perceived skill transfer.			emphasis on peer knowledge sharing as a means of enhancing implementation. To this end, coordinators (i.e., staff members responsible for spearheading implementation) received mandatory quarterly training sessions and were expected to share information informally (i.e., no formal training mandated) with colleagues at their sites. Technical assistance was provided by the program director, an individual hired to support this program.
Ramanadhan, 2017 [49]	This study brings together a unique focus on CBO-based practitioners; a goal of creating sustainable, community-based networks; and the use of a participatory approach to create a viable solution. We sought to answer the following question: Is network engagement associated with EBP use among trainees in a capacity-building program for CBO staff members?	USA. 125 trainees from diverse organizations, ranging from health-focused nonprofits to housing authorities to schools.	Capacity building programs	PLANET MassCONNECT, a project that used participatory approaches to build capacity for systematic program planning among a diverse range of CBOs working with the underserved in three Massachusetts communities. The intervention included a number of components to support the goal of repeated engagement with trainees over time. These components included the following: (1) a skill-building workshop, typically delivered over two half-days, which focused on using data, finding partners, exploring intervention approaches, selecting/adapting an EBP, and evaluating the EBP; (2) a tool kit including a customized web portal, a training manual with handouts, and case studies; (3) networking events for additional training and to support the development of a network of dissemination specialists;(4) mini-grants to provide opportunities to apply the systematic approach to program planning; and (5) technical assistance provided by staff members. The training emphasized the use of key national resources, including the CDC community guide, which provides systematic reviews related to health promotion intervention strategies and the NCI Cancer Control P.L.A.N.E.T., a web-based resource that supports the data and EBPs for cancer control. Trainees were enrolled on a rolling basis to allow for small class sizes (15–20 trainees per session) and to support interaction among trainees and between trainees and trainers. Additional details about the intervention are provided elsewhere
Rice et al., 2012 [28]	The objective of the study is to use social network analysis to examine the acceptability study of a youth-led, hybrid face-to-face and online social	Three different categories of participants were included in the pilot study: peer leaders (PL) (n = 7), face-to-face youth (F2F) (n = 53) and online youth (OY) (n = 103).	Social networking intervention	The intervention included psychosocial training and skill building for PL, as is typical of most effective HIV prevention interventions. For PL and F2F, engagement in the creation of youth-conceptualized and youth-produced digital media was based on

		networking HIV prevention program for homeless youth			theories of community mobilization and empowerment via participatory community theater models. For all participants, dissemination of online media and the accompanying HIV prevention dialog utilized the Diffusion of Innovations, which has successfully been employed in face-to-face HIV prevention strategies.
Rosas Knight, [19]	and 2019	This study described an evaluation that embraced systems thinking and complexity science to examine a complex intervention designed to promote the healthy development of adolescents. In doing so, we apply several systems principles and concepts, and describe how multiple systems methods enabled us to address systems-oriented evaluation questions and draw conclusions about the intervention.	USA IM40 targeted approximately 45,000 youth ages 12–15 across the state; however, the council decided that the initiative should start in three communities and gradually spread statewide. Using social, economic, and health data, planners identified communities with particularly high levels of poverty and indicators of disadvantage, such as low high school graduation rates and high percentages of single parent households, as well as other factors associated with youth risk. One community in each of DE's three counties was identified, resulting in a total of 7200 youth ages 12–15, who comprised the initial target population.	Health promotion intervention	IM40 sought to increase or strengthen youth developmental assets according to the Search Institute's 40 Developmental Assets® framework, enabling youth to foster greater resilience to negative influences and engage in healthier behaviors.
Spitzer-Shohat, 2018 [36]		This study investigated how the organizational structure and social relations among primary-care-clinic team members were associated with their perceptions of effectiveness in leading and implementing disparity reduction interventions to improve the care of disadvantaged populations they serve	Israel Participants were members of the interdisciplinary managerial teams (medical, nursing, and administrative directors) of the 26 clinics of 4 of the organization's regions. Additionally, the clinics' associated managerial levels (sub regional management for each 2–4 clinics and each region's headquarters) were included. Clinic teams comprised 26 physicians, 26 nurses, 20 administrative heads, five pharmacists and one clinic quality- improvement coordinator (n = 78). The 10 mid-level management, sub regional managerial teams included 10 medical directors, seven nursing directors and two administrative directors (n = 19). The four regional	large-scale disparity reduction intervention	An organization-wide QI program aimed at reducing gaps between low-performing clinics serving mostly low socioeconomic and minority populations and the general Clalit member population, in a composite measure of seven health and health care indicators: diabetes, hypertension, and lipid control; anemia prevention in infants; and performance of mammography and occult blood tests and of influenza immunizations for the chronically ill. The program targeted 55 primary care clinics serving approximately 400,000 people (10% of Clalit's population), of mainly economically disadvantaged and minority groups, who were identified as performing poorly on the composite indicators measure. Although the overall organizational goals for disparity reduction and the measurement scheme were set by the central Clalit management, the interventions formulated and their implementation strategy were developed locally at the regional, sub regional, and primary-care clinic levels.

		management teams included four medical directors, four nursing directors, and two quality-improvement coordinators (n = 10).		
Yang 2012 [38]	This study described the training effect in a single ward.	Taiwan En Chu Kong Hospital. The total bed number is 44 with 80% occupancy rate. All of the 20 nurses working in the 13th ward were voluntary to participate in this study	Theoretical based intervention program	Theoretical based intervention program was applied from May to October in 2010. First a needs assessment was carried out. Then, key persons were interviewed and group discussions were held. Subsequently, the results were translated into specific objectives and used in intervention development for the 13th ward's staff. Strengthening professional commitment and harmonic interaction was defined as objectives. And 16-hour training sessions were designed. The training sessions included courses, conferences and workshops. According to Frans' themes, the content of sessions included facilitation skills, standards of service, developing self-esteem and assertiveness, realize your potential, discovering the secrets of self-confidence, smart thinking and smarter working, effective communication, and essentials of personal development.

Appendix C. Application SNA in included studies

Author/Year	Single, Multi-, or mixed method*	SNA purpose	Target Intervention research	SNA metrics
Banbury, 2017 [37]	A mixed methods design combining a social network analysis tool, semi-structured interviews, focus groups and a course journal was used. The course journal was maintained by the facilitator throughout the programme and recorded details of meeting attendance, IT difficulties, group dynamics, processes and other observations.	The social network analysis focused on mapping egocentric networks, using a single 'name generator' Tool. Participants were asked pre and post-intervention 'Who do you think is most important to you in managing your condition/s?'	Effectiveness	Outdegree
Benton et al., 2015 [27]	Single method.	To explore whether social network analysis metrics may be useful in identifying candidates for the LFC train the trainers' programme.	Identifying interventionists	Indegree, outdegree, degree connectedness, closeness centrality, betweenness
Bliuc, 2016 [29]	A mixed methods design combining a social network analysis (to map how participants interact online), computerised linguistic analyses that evaluated sentiment of the textual data (to capture social identity markers), and in-depth interviews with participants to explore personal experiences of engagement in the online community of group members who have undergone the most significant changes since joining the community.	To measure the quality of participation in the online community, as centrality network coefficients derived from conducting social network analysis (SNA) by mapping the linkages between members of the online network through their online interactions.	Effectiveness	Degree-centrality, betweenness' - centrality.
Campbell, 2014 [32]	Qualitative and quantitative methodologies, including Net-Map research, Lot Quality Assurance Sampling (LQAS), and focus group discussions were used. The study did not specified their design by name as being a mixed methods.	To explore the effects of the intervention on knowledge exchange of the K4Health Malawi project	Effectiveness	Indegree, outdegree, degree centrality
Elreda, 2016 [34]	A multi-methods design was used. The study integrated SNA and "intra-entity variability" methods which are both quantitative in nature.	To provide for precise tracking of group structural features and individuals' positions in the groups, their change over time, and their associations with between-person differences in program benefits accrued to members.	Process Evaluation	Indegree - centrality, outdegree centrality, connectedness

Gesell, 2013 [47]	Single method.	A social network survey was developed to assess change in social relationships (specifically, advice networks and discussion networks) over the course of the study period by capturing the presence and absence of ties at mid-point and completion of the intervention	Effectiveness	Isolates, degree, reciprocity, sub-groups, density, centralization, transitivity, and cohesion
Gesell, 2016 [41]	Single method.	A social network survey was developed to assess change in social relationships (specifically, advice networks and discussion networks) over the course of the three weeks by capturing the presence and absence of ties at various stages of the intervention	Effectiveness	Outdegree, cohesion
Held, 2019 [43]	Single method.	We conducted a social learning network survey in four domains of learning (clinical knowledge, procedural skills, professional development, and complex determinants of health) to explore learning relationships (ties) with other people (alters) that students (egos) formed during their placement. We quantified how different roles (supervisors, health professionals, administrators, peers, schoolteachers, and clients) contributed to the students' learning in each of the four domains. We used exponential random graph models (ERGMs) to test which relational processes contributed to the structure of the observed learning networks.	Effectiveness	Density Attractiveness (including homophily) reciprocity
Jippes, 2010 [50]	Single method.	In this paper we will examine the effects of an intensive Teach-the- Teacher training course versus the effect that the structure of the social network has on the adoptive behavior of medical health care professionals. More specifically, we will look at the effect of network tie strength on the dissemination of a new structured feedback technique among medical specialists.	Effectiveness	Degree centrality betweenness centrality closeness centrality
Katz, 2012 [33]	A multi-methods design was used. Pre-post surveys were added with a social network component.	A social network analysis was conducted among the participants prior to and at the end of the meeting to evaluate potentially new patterns of collaboration for future community-based participatory research (CBPR).	Effectiveness	Out degree

Li, 2012 [44]	Single method.	Was it the RAP intervention or something else that caused the risk behavior norm change? To answer this question, methods other than over time risk assessment comparisons are needed in order to reveal the RAP intervention diffusion process, and to determine the relationship between RAP intervention diffusion and its possible effects on risk behavior change.	Process evaluation	Indegree, outdegree, degree centrality,
Márquez-Serrano, 2012 [46]	Single method.	To evaluate the impact of an educational strategy focused on the self-care of elders. Especially in the dissemination of knowledge from the intervention into the social network of participants.	Effectiveness	Density Out degree
Masumoto, 2017 [40]	A multi-methods design was used. A device with wearable sensor technology was used to measure face-to-face interactions. Psychological variables and interest in interacting with local community residents and community involvement were asked.	The aim of the program was to quantitatively assess participants' communication networks and changes in these networks by using wearable sensors that automatically collected face-to-face interactional data of participants.	Effectiveness	Network density, outdegree.
McGlashan, 2017 [48]	Single method.	The objective of this study was to use social network analysis to retrospectively analyze the structure of the networks present within the SCs of two successful childhood obesity CBIs	Process evaluation	degree; (out-degree); EI index, network density, reciprocity, clustering, coefficients, and centralization
Millary, 2017 [35]	Single method.	Context information at baseline of community bases organizations. The baseline results of the social network survey of CBOs, using the PARTNERtool, demonstrate that the survey methodology produces a rich set of network metrics for describing the state of the CBO network at baseline. They used an adapted version of the validated PARTNERtool. The PARTNERtool was designed to collect network interaction data from public health collaborations.	Process evaluation	Density, degree centrality, trust
Moses, 2009 [31]	Single method.	We wanted to determine if participation in the Teaching Scholars Program (TSP), a longitudinal faculty development program at our institution, resulted in a larger network of colleagues interested in education. If	Effectiveness	Outdegree isolated members and cut points.

		so, we also wanted to determine what types of colleagues—departmental, campus-wide, administrators, national contacts—were involved.		
Nooraie, 2015 [42]	Single method.	The study tested whether engagement of staff in the intervention and their EIDM behavior were associated with being chosen as information source and how the trend of inter-divisional communications and the dominance of experts evolved over time	Effectiveness	Measures of network connectivity (density, reciprocity, E-I index, and Krackhardt's hierarchy index) in-degree centrality of actors, and Freeman's centralization.
Owen, 2016 [39]	Single method.	This study (a) evaluates social network characteristics of four distinct communication channels (discussion board, chat, e-mail, and blog) in a large social networking intervention, (b) predicts membership in online communities, and (c) evaluates whether community membership impacts engagement	Effectiveness	Density, clustering, path length, average degree, and connectedness
Phillips et al., 2016 [45]	A mixed methods design combining a social network analysis, observations and surveys were used.	Exploring the size and structure of the individual's networks with other health professionals before and after the program.	Effectiveness	Defined as network characteristics
Ramanadhan, 2010 [30]	Single method.	To describe the network of staff implementing a health promotion program; and to examine the relationship between staff program-related connections and perceived skill transfer.	Implementation context	Network Density, In/Out Degree, out degree
Ramanadhan, 2017 [49]	A multi-methods design was used. Post-test surveys were added by a social network analysis.	Is network engagement associated with EBP use among trainees in a capacity-building program for CBO staff members?	Implementation context	Network density, Network centralization
Rice et al., 2012 [28]	Single method.	The objective of the study is to use social network analysis to examine the acceptability of a youth-led, hybrid face-to-face and online social networking HIV prevention program for homeless youth	Examine acceptability	Density, centralization, between-centrality ,

				eigen- centrality, degree- centrality, homophily
Rosas and Knight, 2019 [19]	A multi-methods design was defined by the authors as being used. The study however used qualitative methods, observations and social network survey	How were the collaborative <i>relationships</i> among IM40 stakeholders manifest – we employed network analysis to examine shifts in the relationships among organizational actors in the IM40 system.	Process evaluation	Average degree Average weighted degree Density Modularity Communities Average path length
Spitzer-Shohat, 2018 [36]	A mixed-methods design was used combining qualitative and quantitative methods in a convergent design. Semi-structured in-depth interviews, self-rated questionnaires and SNA.	To investigate the implementation of Clalit's disparity reduction program in which the types and strength of ties between network members were characterized.	Implementation context	Density, network centralization, group centrality, and group betweenness centrality
Yang 2012 [38]	Single method.	A quasi-experimental design was used in which one pre-intervention survey and one post-intervention survey was used to collect data from the participants. The most important parameters of the overall data collection were the change in the job satisfaction, professional commitment, and social networks. The collected data was analyzed in both individual and organizational levels.	Effectiveness	Outdegree, indegree.

* Multi-method studies collect and analyze multiple types of qualitative or quantitative data , mixed-methods studies collect and analyze both qualitative and quantitative data as quoted in Creswell's chapter in the 2nd edition of the Handbook of Mixed Methods Research.