

Review Article

A Realist Synthesis of Community-Based Interventions in Vector-Borne Diseases

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Abstract. Randomized control trials have provided evidence that some community-based interventions (CBIs) work in vector-borne diseases (VBDs). Conversely, there is limited evidence on how well those CBIs succeed in producing specific outcomes in different contexts. To conduct a realist synthesis for knowledge translation on this topic, we examined the extent to which realist concepts (context, mechanisms, and outcomes) and their relationships are present in the existing literature on CBIs for VBDs. Articles on CBIs were identified from prior scoping reviews of health interventions for VBDs. Content of the articles was extracted verbatim if it referred either to realist concepts or CBI features. The number of articles and the average number of words extracted per category per CBI were quantified. Content of the articles was scrutinized to inductively gather qualitative evidence on the interactions between realist concepts. We reviewed 41 articles on 17 CBIs from 12 countries. The average number of words used for mechanisms was much lower than those used for outcomes and context (309,474, and 836, respectively). The average number of words used for mechanisms increased when a CBI was described in three or more articles. There were more extensive accounts on CBI features than on mechanisms. It was difficult to gather evidence on the interactions among realist concepts from the content of the articles. Scarce reporting on mechanisms in published articles limits conducting a realist synthesis of CBIs in VBDs. More transdisciplinary research that goes beyond the biomedical paradigm is needed to boost the development of intervention mechanisms in this field.

INTRODUCTION

Vector-borne diseases (VBDs) pose a major and uncontrolled threat to global health.^{1,2} Community-based interventions (CBIs) are seen as a way forward to tackle the expansion and emergence of VBDs at national and international levels. Indeed, the WHO's *Global Vector Control Response 2017–2030* promotes community engagement and mobilization as one of the four pillars of action to achieve effective and locally adapted vector control and enhance protective behaviors among the population.¹ However, dissemination or large-scale implementation of effective CBIs in VBDs has some constraints.

Community-based interventions usually encompass multiple and diverse components or activities, among which at least one targets the community. Participation of its members can range from being merely recipients of technocratic control efforts to being involved in decision-making on control activities.³ Evidence that directly links community participation to health outcomes is weak and insufficient; and where links are found, they are deemed situation-specific and hardly generalizable.⁴ CBIs are sensitive to context or to any feature of the circumstances in which they are conceived, developed, implemented, and evaluated.⁵ As such, they cannot be studied in isolation from their contexts.⁶ Yet contextual elements essential for implementation processes and transferability are poorly described in VBD studies.⁷

Indeed, CBIs meet the criteria of complex interventions: they are theories or sets of theories; they involve actions of people; they consist of chains of nonlinear steps or processes involving negotiation and feedback; they are shaped by the

social system in which they are embedded; and they are likely to be modified during implementation.^{5,8} Randomized control trials (RCTs), which monopolized the field, have proved useful to provide evidence on effectiveness of some CBIs. However, such a study design does not explain how those CBIs succeeded (or not) in producing specific outcomes in different contexts.

Recent moves are being observed toward applying the realist lens,^{9,10} which is better suited to assess CBIs in global health.^{11,12} Nevertheless, the limited theoretical understanding of how community participation works challenges such efforts. The realist approach¹³ is particularly useful to provide not only empirical evidence but also theoretical understanding of a complex and heterogeneous body of research.

Realist synthesis is a model of knowledge synthesis rooted in the realist approach to evaluation. It is based on a generative understanding of causation, and thus, it is deemed to better account for the complexity of social interventions, such as CBIs. According to the realist approach, actors are the ones who make change happen or maintain the status quo through their actions, behaviors, and reactions to an intervention and its various activities. Such a social phenomenon/reasoning is conceptualized as a mechanism. Based on a scoping review, Lacouture and others¹⁴ define a mechanism as “an element of reasoning and reactions of agents in regard to the resources available in a given context to bring about changes through the implementation of an intervention, and evolves within an open space-time and social system of relationships.” Whether a mechanism is actually triggered depends on the context, including the characteristics of both the actors and the intervention settings.^{8,15,16}

Because actors' actions and behaviors occur at a certain moment, in a certain context, the realist approach aims to

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identify regularities in the process of the production of outcomes, rather than systematic patterns of the outcomes themselves. More precisely, its purpose is to explain how an intervention works, for whom, and under what circumstances, and exposes interactions among the intervention, the context (C), the mechanisms (M), and the outcomes (O). Such interactions are referred to as C–M–O configurations. Generalization of findings from a realist synthesis occurs through theories. Starting with a theory about how an intervention is supposed to affect the actors' reasoning, the research concludes with a refined and transferable theory which is more or less likely to work in certain respects, for particular subjects, in specific kinds of situations.¹⁷

To conduct a realist synthesis for knowledge translation, we examined the extent to which realist concepts and the relationships between them are present in the literature on CBIs in VDBs.

METHODS

Search for relevant papers. Articles were identified from two prior scoping reviews conducted by the VECtor boRne DiseaseAses (VERDAS) consortium.^{7,18} The VERDAS consortium conducted a series of scoping reviews to identify research gaps and priorities on urban health interventions for the prevention and control of vector-borne and other infectious diseases in the context of poverty. Several scientific and gray literature databases were systematically searched for peer-reviewed and gray literature published between 2000 and 2016. A detailed protocol of the VERDAS project has been published elsewhere.¹⁹ References from included articles were hand-searched to find additional relevant records.

Eligibility criteria. A CBI was defined as any complex intervention involving local institutions and community members in the planning, design, implementation, and/or evaluation stages.²⁰ Articles were not eligible if 1) the intervention described was not a CBI, 2) the community was only involved in one stage of the intervention, and 3) the involvement of the community was not clear. There was no restriction regarding the type of article nor study design.

Data extraction and analysis. The content of each article, except for the abstract, was examined. Partial or complete paragraphs were extracted verbatim if they referred to at least one of the aspects listed on the data extraction form and then coded/labeled deductively as such. The data extraction form was composed of three sections.

Section one encompassed characteristics of the articles, including publication year, type (e.g., original research, review, commentary, editorial, and short communication) and objective, study design, reporting guidelines, and scientific background of the first author, among others. The scientific background of the first author of each article was gathered by searching available curriculum vitae, scholarly biographies, or professional profiles on the author's institutional affiliation website, Google scholar profiles, and social networking websites for scientists, for example, ResearchGate. The rationale for including the scientific background of the first author was that social scientists would provide additional relevant information on the CBIs, their theoretical basis, and implementation contexts through different formats. Section two comprised characteristics of the CBIs such as country, city, type of intervention, and underlying theoretical or

methodological approach. Section three included the realist concept categories, namely, context, mechanisms, and outcomes. These categories were not mutually exclusive: data could be extracted and labeled as context, mechanisms, and outcomes at the same time. Information on CBI features, that is, content and processes, was also extracted in Section three.

The data were extracted into an Excel spreadsheet (Microsoft Office 2010) and then imported into NVivo 10 (QSR International Pty LTD, Melbourne, Australia) for quantitative and qualitative content analyses. The number of articles per CBI was quantified as well as the number of words extracted per article and the average number of words per category for each CBI. The aggregate number of words extracted in each category for all articles published on the same CBI was tabulated. Subsequently, the average number of words used to refer to context, mechanisms, outcomes, and features per CBI was calculated.

Inductive subcategories were created (e.g., context features and typology of mechanisms) by reading the extracted data. The whole content of each article was scrutinized to inductively gather evidence on the connections among context, mechanisms, and outcomes. NVivo-advanced coding queries using Boolean operators (e.g., AND, NEAR Content, and SURROUNDING Content) were run to explore such interactions. Results of the queries were recoded using a relationship node, that is, an NVivo record created by the researcher to quote and show how concepts were related.²¹

Two researchers (E. J. P. and D. P.) did the data extraction. A scholar on CBIs (P. L.) checked the data for consistency in coding/labeling. Debriefing activities during the analysis process were conducted with researchers with expertise on CBIs and/or realistic evaluation (V. V., E. R., and V. R.).

RESULTS

Search findings. There were 86 records retrieved from the two prior VERDAS scoping reviews,^{7,18} of which 46 were excluded for different reasons (e.g., duplicates and not fulfilling inclusion criteria). Eleven citations were added after hand-searching the reference lists of included records. A total of 41 articles were retained for the review. Figure 1 shows the PRISMA flowchart of the published articles' selection process.

Description of included articles and CBIs. Table 1 shows the descriptive characteristics of the articles included in this review. Publication year ranged from 2004 to 2017. More than a half of the articles ($n = 25$; 61%) resulted from multi-trial initiatives.^{22–46} Studies were conducted in 12 Asian and Latin American countries: India, Thailand, Indonesia, Myanmar, Sri Lanka, Mexico, Nicaragua, Ecuador, Brazil, Uruguay, Cuba, and Colombia. Nine articles (22%) reported on more than one country.^{22–24,28,29,38–40,44}

Original research predominated ($n = 32$; 78%). According to the objective as stated, nine (24.3%) studies evaluated efficacy/effectiveness/cost-effectiveness exclusively; 10 (24.4%) assessed effectiveness combined with other CBI aspects, for example, processes, feasibility, and acceptability; six (16.2%) provided formative research results; and five (13.5%) described the intervention and reported on implementation outcomes. Two articles (5.4%) conducted secondary analysis of trial data. Study designs included 12 (29%) cluster-randomized controlled trials,^{22,35–38,41–43,45–48} seven (21.9%) quasi-experimental designs,^{49–55} five (15.6%) surveys^{26,30,31,34,40}

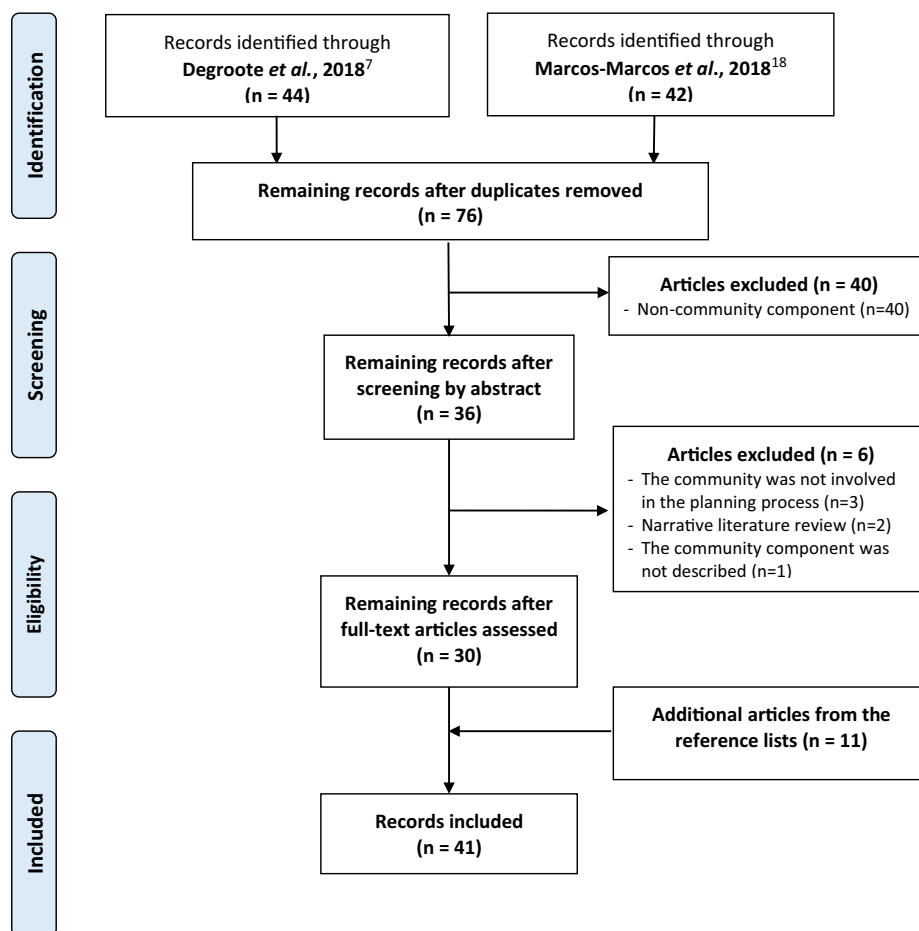


FIGURE 1. PRISMA flowchart of the selection process of the studies.

and mixed-methods designs,^{27,56–59} three (9.4%) qualitative research studies,^{44,60,61} and one (3.1%) observational study.⁶²

Guidelines or checklists available in the literature to improve reporting on the development of interventions were rarely used. Two articles (4.9%)^{25,28} used the Template for Intervention Description and Replication (TIDieR) published in 2014.⁶³

Most of the first authors had a medical sciences background ($n = 16$; 61.5%). Only three (11.5%) were social scientists, and background information could not be retrieved for five authors (19.2%).

There were 17 CBIs that focused on dengue prevention and/or *Aedes aegypti* control. With few exceptions,^{47,54,55} there was more than one article available per CBI (Table 2). The CBIs assessed through multi-trial initiatives were of flexible design so they could be tailored to different implementation contexts, as seen with *Camino Verde* (the Green Way)^{22–32} and the Eco-bio-social CBIs from Asia^{40–46} and Latin America.^{33–39} Despite their similarities, these CBIs are differentiated by country in this study. Eleven CBIs included exclusively community-based activities such as training and organizing local stakeholders for vector control, raising population knowledge and awareness on disease transmission through social communication, and clean-up campaigns. The six remaining CBIs also involved the community in the application or use of biological, mechanical, and chemical control tools, insecticide-treated materials, and nonchemical tools.

The underlying theoretical frameworks and/or methodological approaches were described for all 17 CBIs. The frameworks were used either for providing theoretical and operational definitions of “participation,” as methodological guidance for community involvement, or as an evaluation tool.

Word count and content on realist concepts. We hypothesized that the journal’s audience, scope, and word count limit would influence authors’ decisions on what would be considered relevant content for their article. Word counts of extracted data could show the extent to which each realist concept (i.e., context, mechanisms, and outcomes) is present in the reviewed articles, and which concept is emphasized as compared with the others.

Figure 2 shows the average number of words coded per realist concept among the CBIs by the number of published articles. There are more words used to describe CBIs’ context and outcomes than mechanisms (836, 474, and 309, respectively). Although there is not a linear relation overall between the number of articles and the number of words coded as mechanisms, the average number of words used for mechanisms increased when there were three or more publications on a CBI. The average number of words used for each of the realist concepts tended to be more balanced for those CBIs with eight publications. In such cases, authors have more opportunity to provide accounts on the mechanisms.

The number of articles published on CBIs that met the study criteria generally increased each year over time. The average

TABLE 1
Characteristics of the articles included in the review (n = 41)

Characteristics of the articles	n (%)
Source	
Multi-trial initiative	25 (61.0)
Single trial	16 (39.0)
Report on	
One CBI	32 (78.0)
More than one CBI	9 (22.0)
Type	
Original research	32 (78.0)
Review	4 (9.8)
Short communication	2 (4.9)
Study protocol	1 (2.4)
Commentary	1 (2.4)
Editorial	1 (2.4)
Objectives as stated	
Effectiveness and other aspects	10 (24.4)
Efficacy/effectiveness/cost-effectiveness exclusively	9 (24.3)
Formative research/baseline assessment	6 (16.2)
Description of intervention	5 (13.5)
Implementation processes and outcomes	5 (13.5)
Secondary analysis of trial data	2 (5.4)
Other	4 (10.8)
Design of original research articles	
Cluster-randomized controlled trial	12 (29.3)
Quasi-experimental	7 (21.9)
Mixed methods	5 (15.6)
Survey	5 (15.6)
Qualitative descriptive	3 (9.4)
Observational	1 (3.1)
Not original research	8 (25.0)
Reporting guidelines or checklist	
Not declared	39 (95.1)
Declared	2 (4.9)
Scientific background of the first author*	
Medical sciences	16 (61.5)
Social sciences	3 (11.5)
Statistician	2 (7.7)
Unknown	5 (19.2)

CBI = community-based intervention.

* Authors, n = 26.

number of words coded for CBI features and mechanisms followed an increasing trend (Figure 3). However, the gap observed between the two data series (curves) reveals that there are much more extensive accounts on CBI features than the details provided on mechanisms.

The kind of outcomes, context features, and mechanisms coded inductively varied. The outcomes expressed changes in population attitudes, knowledge and practices, community involvement, entomological indices, and disease transmission, indistinctly. Likewise, context features referred, in turn, to the epidemiological situation, health organization services, and sociopolitical and sociocultural aspects. The typology of mechanisms was particularly wide, and the number of reviewed articles referring to each kind of mechanism ranged from one to nine (Table 3). The mechanisms emerged from specific underlying theoretical and methodological frameworks of some of the CBIs, assumptions noted in the articles, and theoretical developments from different areas of the social sciences. The following quotations (italics) illustrate the inspiration of adherence and responsiveness mechanism for the Eco-health approach in Fortaleza, Brazil, and Camino Verde in Guerrero, Mexico.

... Partnerships were developed with schools on dengue control and solid waste management under the assumption that these spaces naturally inspire the adherence of social actors and enable the understanding that health is the responsibility of different sectors of society. ... Caprara et al.³⁶: CBI; Eco-health approach: Fortaleza, Brazil; led by a social scientist.

... Evidence plays a fundamental role in SEPA (Socialization of Evidence for Participatory Action) as a tool for rational persuasion [...]. In a community context, evidence can stimulate reflection and dialogue, leading to new collective interpretations and consensus for action. Just as people tend to be more open to evidence when they see its subject as something that affects their own situation, their responsiveness increases when this evidence is actionable... Ledogar et al.²⁸: CBI; Camino Verde: Guerrero, Mexico; led by the first author's scientific background unknown.

Interactions context-mechanisms-outcomes. The whole content of each article was scrutinized to inductively gather evidence on the connections among the context, mechanisms, and outcomes. Data labeled as context-mechanisms-outcomes relationships were found exclusively in three articles: Cáceres-Manrique et al.⁵⁴ Mitchell-Foster et al.³⁷ and Morales-Perez et al.³² All such quotations were extracted from the Discussion section:

... Besides, population mobility is very common. The majority of the residents are not house owners, and they change housing and neighborhoods very frequently [CONTEXT]. This reduces population's sense of ownership [MECHANISM]. Community participation is difficult and it does not allow completing the sequence of changes of the strategy cycle [OUTCOME]... Cáceres-Manrique et al.⁵⁴: CBI; Empowerment in dengue control: Bucaramanga, Colombia; led by a biomedical scientist.

... IIS (integrated intervention strategy) implementation was very successful in cluster 14 [...] with high community enthusiasm and sustained involvement [MECHANISM]. This, along with the effects of localized flooding in 2012 and a very dry season in 2013 [CONTEXT], resulted in a significant reduction of PPI (pupa per person index) [OUTCOME]... Mitchell-Foster et al.³⁷: CBI; Eco-bio-social: Machala, Ecuador; led by a biomedical scientist.

... In the exceptionally difficult and dangerous field conditions of Mexico's Guerrero state [CONTEXT], it was community authorship and subsequent ownership of the intervention [MECHANISM] that had an impact [OUTCOME]. Reproducing our success elsewhere will require building that authorship and ownership, rather than simply copying the specific preventive activities the communities opted to do ... Morales-Perez et al.³²: CBI; Camino Verde: Guerrero, Mexico; led by the first author's scientific background unknown.

TABLE 2
General information on CBLs included on the review

CBL: city, country	No. papers references	Theoretical or methodological approach	Type of intervention
Camino Verde: Guerrero, Mexico	8 ^{22–24,28–32}	SEPA	Combined with biological control (i.e., tilapia and crustaceans like crayfish)
Camino Verde: Managua, Nicaragua	8 ^{22–29}	SEPA	Exclusively community-based
Environmental management: Santiago de Cuba, Cuba	5 ^{50–52,59,62}	Rifkin's framework for community participation in health programs Shediac-Rizkallah & Bone's framework of sustainability	Exclusively community-based
Intersectoral coordination and empowerment: Havana, Cuba	5 ^{49,53,56,60,61}	Popular education theory	Exclusively community-based
Eco-bio-social: Girardot, Colombia	4 ^{33,34,38,39}	Eco-bio-social approach	Combined with long-lasting insecticide-treated materials (i.e., window and door curtains alone or in combination with water container covers)
Community empowerment: Havana, Cuba	3 ^{48,57,58}	Popular education theory	Exclusively community-based
Eco-bio-social: Chachoengsao, Thailand	3 ^{40,43,44}	Eco-bio-social approach	Combined with eco-friendly tools (i.e., copepods, and <i>Bacillus thuringiensis</i> var. <i>israelensis</i> toxins (Bti sacs)
Eco-bio-social: Machala, Ecuador	3 ^{34,37,39}	Eco-bio-social eco-health-style approach	Exclusively community-based
Ecohealth approach: Fortaleza, Brazil	3 ^{34,36,39}	Eco-health approach (ecosystem)	Exclusively community-based
Eco-health methods: Chennai, India	3 ^{40,42,44}	Eco-bio-social approach	Combined with non-insecticide-treated water container covers
Ecosystem management: Salto, Uruguay	3 ^{34,35,39}	Eco-bio-social approach	Combined with non-chemical tools (i.e., plastic collecting bags and plastic mesh covers)
Ecosystem management: Yogyakarta, Indonesia	3 ^{40,44,45}	Eco-bio-social approach. Framework for assessing community participation in health programs	Exclusively community-based
Partnership-driven ecosystem management: Yangon, Myanmar	3 ^{40,44,46}	Eco-bio-social approach	Combined with waste collection bags and integrated vector management approach (i.e., biological (dragon fly nymphs), mechanical (lid covers and cotton-net sweepers) or chemical (pyriproxyphen) control.
Waste management: Gampaha, Sri Lanka	3 ^{40,41,44}	Eco-bio-social approach	Exclusively community-based
Empowerment in dengue control: Bucaramanga, Colombia	1 ⁵⁴	Empowerment. Communication for behavioral impact, COMBI	Exclusively community-based
Environmental management: Guantánamo, Cuba	1 ⁴⁷	Framework for assessing community participation in health programs	Exclusively community-based
Family leader empowerment: Chachoengsao, Thailand	1 ⁵⁵	Bishop's five-step learning process for empowerment	Exclusively community-based

SEPA = socialization of Evidence for Participatory Action.

From the content of the reviewed articles, it was difficult to gather evidence on the interactions among the realist concepts to further draw potential interactions among the CBLs, the context, the mechanisms, and the outcomes (i.e., C–M–O configuration).

DISCUSSION

CBLs are complex, and not one size fits all interventions. A realist approach can be applied to build a theory that better explains the observed outcomes of CBLs across different contexts and actors. This is in line with efforts that have been made in the last few years to identify proven and context-relevant interventions in view of setting public health policy priorities for VBD prevention and control.⁶⁴ Our findings show that the three realist concepts are present in the literature on CBLs in VBDs. However, accounts on mechanisms are scarce when compared with the details provided on context and outcomes. Likewise, it was difficult to gather evidence on the interactions among the context, mechanisms, and outcomes

through which a middle-range theory for the fight against VBDs could be developed.

Some methodological choices made by the authors of the present review could have biased the findings, such as the process for selecting the articles, extracting the content from the articles mainly through a deductive and not exhaustive categories system, and using the word count of extracted data in each category (i.e., context, mechanisms, and outcomes) as an analytical method. Not including articles from 2017 to 2019 could also be considered as a limitation of the review. However, the likelihood that publications' content in this field has changed radically in the last 2 years is very low.

Overall, this review provides a global picture of the level of contribution of the available literature to each of the three realist concepts for a knowledge synthesis of CBLs in VBDs. Our finding on the limited number of accounts on mechanisms might have several explanations. Some could be related to certain characteristics of the articles included in the review. Most of the articles were empirical studies focused on effectiveness/efficacy assessments rather than on describing

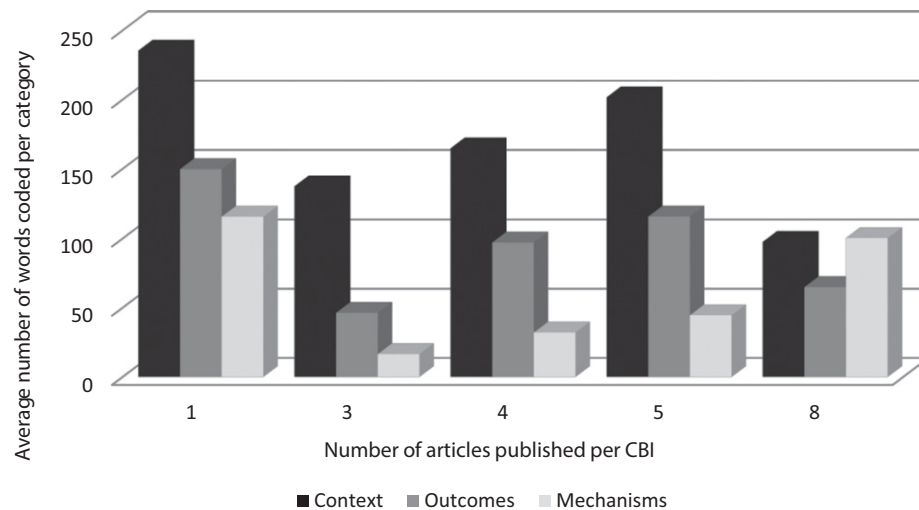


FIGURE 2. The average number of words coded for context, outcomes, and mechanisms among community-based interventions (CBIs).

the nature, processes, and implementation of CBIs. A high proportion (61.5%) of the first authors had biomedical or epidemiology backgrounds, so may have been less skilled using or generating explanatory theories and conceptual frameworks that explain human behaviors.^{65,66} Another explanation could be that the word count limit established by scientific journals does not provide room for extended qualitative and descriptive details.

An increased pattern of the number of accounts on CBI features, implementation processes, and setting characteristics over time does not necessarily mean there is a move toward providing more information on CBI mechanisms. This could be a result of an increase in the quality of reporting of intervention research, as claimed by some authors.^{63,67} Reporting gaps are not intrinsic to the nature of CBIs and the way they are dealt with in VBD studies.^{4,68} A growing number of guidelines and templates are now available for better

reporting of interventions in different fields.^{63,67,69,70} Nonetheless, these templates are not specifically designed for complex interventions and do not suggest the inclusion of details about interventions' theory of change. Two recent guidelines include the criteria for reporting on the development of interventions (e.g., theoretical basis and empirical evidence from different settings): the Criteria for Reporting the Development and Evaluation of Complex Interventions in healthcare⁷⁰ and, more recently, the TiDieR adapted for Population Health and Policy interventions (TiDieR-PHP).⁷¹

A lack of understanding on what mechanisms are and the difficulties differentiating them from activities and specific intervention resources has also been reported in the literature.^{14,72,73} However, investigators do not necessarily need an understanding of mechanisms to conduct research that actually identifies mechanisms. Despite the limited accounts on mechanisms in the reviewed articles, findings from

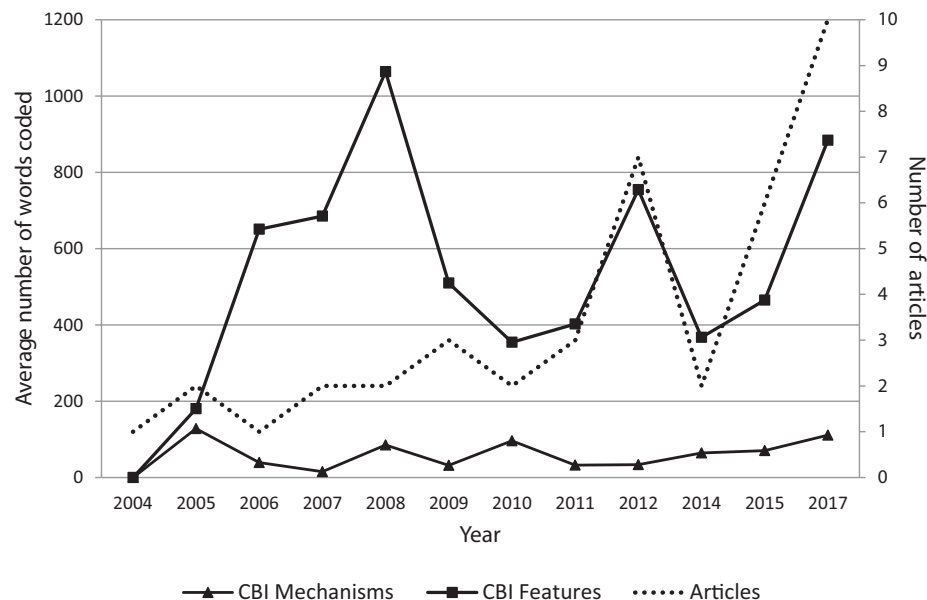


FIGURE 3. The number of articles published and the average number of words coded for features and mechanisms of community-based interventions (CBIs) over time.

TABLE 3

Number of reviewed articles referring to each kind of mechanisms inductively identified from the extracted data ($n = 41$ articles)

Kind of mechanism	Number of papers references
Mutual trust and respect	9 ^{25,27–29,32,33,46,54,61}
Social awareness	9 ^{28,32,36,43,46,52,57,59,61}
Co-responsibility	8 ^{25,33,36,46,51,54,57,59}
Intrinsic and extrinsic motivation	7 ^{27,32,36,43,47,54,59}
Sense of ownership and authorship	7 ^{28,32,33,36,48,50,54}
Self-reliance	6 ^{25,27,29,35,45,55}
Collective enthusiasm	4 ^{27,35,37,61}
Inspiration of adherence and responsiveness	4 ^{28,36,54,57}
Solidarity	4 ^{25,28,29,36}
Team work spirit	3 ^{42,43,45}
Values	2 ^{36,49}
Bounded rationality	1 ²⁷
Feeling of being listened	1 ³³
Social norms	1 ²⁷

our inductive analysis suggest there is potential to improve on the development and reporting of CBI mechanisms. On the one hand, the examples provided in Table 3 and the quotations from the articles might help other researchers to better understand what mechanisms are and how to look for them. On the other hand, they could also be useful as candidate mechanisms for CBIs to be confirmed through further empirical studies.

Conducting a knowledge synthesis using a realist approach will not bring further understanding of how, for whom, and under what circumstances CBIs in VBDs work, given the lack of reporting on mechanisms, which is the cornerstone of the realist approach.¹³ Hence, we urge investigators to conduct prospective studies with a realist lens. A mechanism-oriented approach to causality of CBIs in VBDs would benefit from conducting theory-based research, which is more focused on explaining, rather than describing social reality. Training biomedical scientists, allocating funding for such research, and including complexity, mechanisms, and theories when reporting findings could contribute to this field. Social science researchers are better equipped to put into practice available concepts and theories,⁷⁴ which could provide significant insights for CBI development. More transdisciplinary research that goes beyond the biomedical paradigm is needed to boost our understanding of the mechanisms of CBIs in VBDs.

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