One Health 15 (2022) 100444

Contents lists available at ScienceDirect

One Health

journal homepage: www.elsevier.com/locate/onehlt

Prevention of exposure to zoonoses in rural Latin America: Social ecological factors in a diverse regional context

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ARTICLE INFO

Keywords:
Exposure to zoonoses
Rural Latin America
Social ecological model
Prevention
One health

ABSTRACT

Zoonotic diseases have serious impacts on human health and well-being, but they are often overlooked in rural Latin America. The design of effective preventive interventions is complex and requires an integrative approach from evidence-based information analyzed through robust theoretical frameworks. We conducted a systematized literature review and qualitative framework-guided thematic analysis to identify social ecological factors affecting the prevention and exposure to zoonotic diseases. Although resources for research are limited in Latin America, we found several studies with relevant results. We extracted and interpreted 8 themes as factors affecting the prevention, transmission, and exposure to zoonosis. These themes included knowledge and misconceptions, low risk perception, gaps in knowledge and communication, psychological effect of diseases, culture and traditions, inequality, disarticulated prevention programs, and organizational responsibility. Alongside this, we compiled and present the recommendations for actions to reduce the impact of zoonoses in these populations. The factors and recommendations here presented can be adapted to inform the design and improvement of preventive programs, focused on One Health and aiming to reduce the impact of zoonotic diseases in rural settings.

1. Introduction

The World Health Organization (WHO) defines zoonotic diseases as "any diseases or infections that are naturally transmitted between vertebrate animals and humans." Nearly 60% of known pathogens are zoonoses, and from livestock, almost 40% can infect humans [1]. For such diseases as anthrax, bovine TB, brucellosis, neurocysticercosis by *T. solium*, cystic echinococcosis, rabies, and many others, the close contact between animal production and humans play a central role in the epidemiology of these important diseases [2]. Farming is one of the occupations with an increased risk of zoonotic infections due to close contact with potentially infected animals. Many of the rural populations in developing countries depend on breeding livestock and other animals as an extra source of subsistence. These populations live in close contact with their livestock and poultry and the conditions of this close human-animal interaction interface increase the risks of exposure and transmission to zoonotic diseases [3]. Additionally, workers in related occupations that carry an increased risk include veterinary services, meat processing, and handling, and disposal of animal waste [4].

The design and implementation of interventions for the prevention of transmission of infectious diseases are challenging due to the diversity and complexity of the Latin American rural settings [5]. Sustainable prevention in low and middle-income countries (LMIC) requires cross-sectoral, integrated, participatory, and socially and culturally compelling evidence-based interventions; especially in contexts of social and health inequality [6]. Specifically, it has been reported that the Latin American and Caribbean (LAC) region is the most unequal in the world. Of the 14 countries with the highest inequality in the world, 6 are in Latin America [7]. The rate of rural poverty in LAC is 46.2%, affecting 60 million rural people, and this is considerably higher than the rate of urban poverty calculated at 23.8 % [8]. Rural workers face lower levels of i. per capita income, ii. access to education, iii. access to health services and coverage and iv. security of land tenure which makes them disproportionately affected and vulnerable to health challenges. In this

Abbreviations: WHO, World Health Organization; LMIC, Low and Middle Income Countries; LAC, Latin America and the Caribbean; SEM, Social Ecological Model.

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https://doi.org/10.1016/j.onehlt.2022.100444
Received 10 June 2022; Received in revised form 29 September 2022; Accepted 9 October 2022
Available online 11 October 2022

study, we focused our attention on the rural Latin American workers' landscape because we are aware of the heterogeneity of the region's rural social determinants and factors influencing zoonotic emerging and endemic disease prevention at community level. Also, we acknowledge the gap of understanding on how the inclusion and engagement of communities and marginalized voices, as those living and working in rural areas of Latin America, could shape One Health implementation in the Region.

A robust theoretical framework that can be applied for elucidating this complexity and the potential factors that drive prevention is the Social-Ecological Model (SEM) [9]. The SEM is a theoretical framework that has been successfully used for the development and improvement of disease prevention programs [10,11]. The SEM was developed to understand drivers of human behavior based on the hierarchical interactions of biological systems that are conceptualized as a multi-level hierarchical organization of systems centered on the individual [12].

Many efforts to reduce the risk of potentially serious diseases have been attempted in particular settings. However, many of those interventions faced diverse and complex implementation barriers [13]. The social ecology of the transmission of zoonotic diseases has not been addressed integrally in Latin America. This social ecology varies in every social ecosystem, so it is imperative to identify the factors that might affect prevention in specific settings such as the rural populations of Latin America.

The goal of this research was to elicit all potential Social Ecological factors affecting the exposure, prevention, and transmission of zoonotic diseases in rural populations of Latin America from the published literature. To achieve this aim, we conducted a comprehensive literature review followed by a qualitative SEM-guided thematic analysis to identify factors and recommendations with the potential to inform the design and implementation of interventions to prevent and control emerging and endemic zoonoses with regional benefits in Latin America.

2. Methods

2.1. Literature review

A systematized review as described in Grant and Booth [14] was utilized. This type of review shares the advantage of using an exhaustive search method but allows a flexible approach to analyzing the data extracted.

2.2. Search string

The research question was established by the convergence of concepts after iterative discussion sessions among the co-authors agreeing on the following:

Population: Rural inhabitants of Latin America that are in close contact with livestock, other production animals (poultry, fish, pork/swine), and contact with wildlife (hunting, bush meat processing, wildlife farming) by husbandry, ownership, work, or personal consumption or benefit.

Exposure: Social-ecological factors, determinants, items, themes, or levels related to the exposure, prevention, and transmission of zoonotic diseases.

Outcome: Risk of exposure to zoonotic diseases (direct contact, foodborne, vector-borne) from livestock, other production animals, and contact with wildlife via husbandry, ownership, work, or personal consumption or benefit.

The resulting search strings are presented as supplementary material in Appendix A.

2.3. Databases search strategy

The following databases were searched in two phases: EBSCO, Scopus, Pubmed, Web of Science, and Scielo. The first phase string was searched from May and July 2020. The second phase was conducted between August and October of 2021. In the second phase, the search formula was adjusted including specific location, adding other production animals and wildlife contact, and adding specific terms about the use of production animals for husbandry, ownership, work, or personal consumption or benefit.

2.4. Selection of relevant documents

Rayyan QCRI platform was used for the deduplication and screening of titles and abstracts. The inclusion criteria for title and abstract screening were: published in English, Spanish, or Portuguese; only rural populations located in Latin America or the Caribbean; only exposure to zoonotic diseases from activities such as husbandry, ownership, work, or personal consumption or benefit. The screening of titles and abstracts was performed by three independent reviewers (AM, SR, JP), and differences were discussed and resolved. The preliminary included documents underwent a full-text review conducted by all the coauthors with the following inclusion criteria: Containing any mention of the factors, components, variables, concepts, items, or levels, that aligned with the Social Ecological Model. Additional exclusion criteria included: being a review.

2.5. Data extraction and framework-guided thematic analysis

From the full-text review, data were extracted and inputted into a spreadsheet table for further data analysis. These data included title, objectives, general methods, population, location, and type of zoonosis. Additionally, text excerpts were extracted when indicating any social ecological component and its context. The information extracted from the articles was analyzed using a framework-guided thematic analysis (thematic synthesis) as described by Braun and Clarke [15].

The Social Ecological Model is based on the systems approach where multiple levels of interaction around the individual are set to explain complex ecological interactions. Fig. 1 shows a graphical representation and description of the levels of the SEM. The intrapersonal level is the most internal level and contains intrinsic and extrinsic factors such as skills, motivations, self-efficacy, knowledge, and others. The next level is the interpersonal level which comprehends the closest social relationships and interactions of the individual. At this level, we can find peer pressure, social interactions, communication skills, etc. The community and organizational levels are parallel to each other and can be interchangeable depending on the context. Here we can find community interactions, access to resources, education, and health care. The outermost level is the enabling level, usually called the policy level, which contains regulations, policies, allocation of resources, and decisions that affect the internal levels. The complexity of the social-ecological factors for disease prevention would need the specification of SEMs for each cultural niche.

The information extracted from the articles was independently open-coded by two researchers. A secondary axial coding was then conducted to establish connections and relationships between codes. Finally, a deductive categorization of the codes was used to group them into themes and sub-themes that correspond to social-ecological components and levels. The final step of the process consisted of an open discussion and interpretation of the obtained themes.

3. Results

After removing duplicates, a total of 4052 unique records underwent title and abstract screening, of which 93 papers were retained (Fig. 2). After a full-text review, 36 articles were included in the thematic analysis. The characterization of the 36 included articles is summarized in Appendix 2.

Most of the articles included are from Colombia, Peru, Argentina, Brazil, and Chile. The distribution of articles by country is presented in

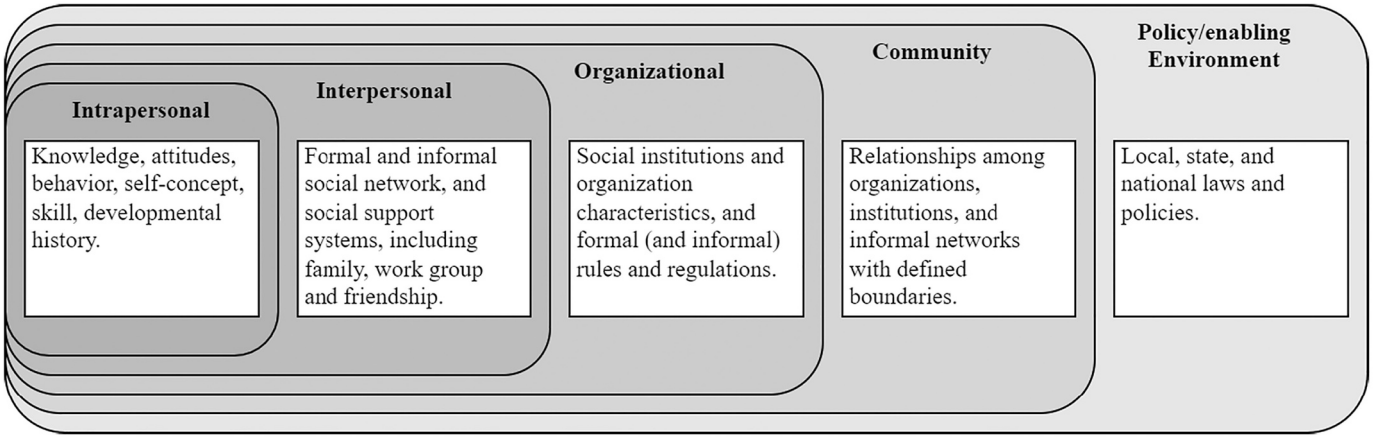

Fig. 1. Diagram and description of the different levels of the SEM. Adapted from McLeroy et al. [16].

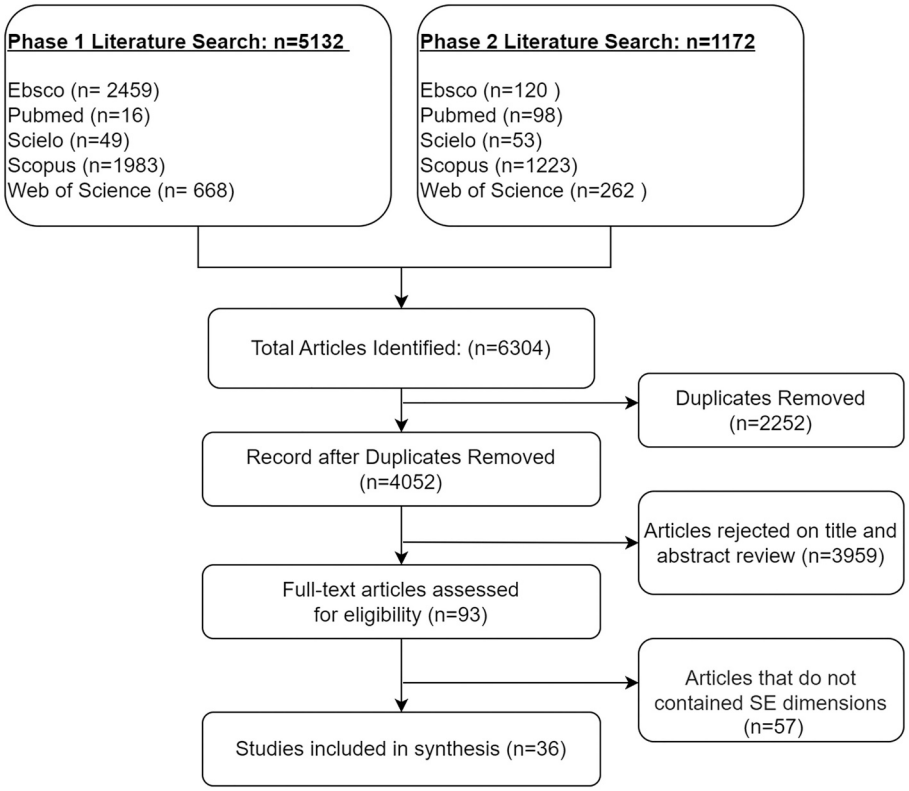

Fig. 2. Flow chart showing the selection process of articles (and yield) on social ecological factors affecting the exposure of zoonotic diseases in rural Latin America.

Fig. 3.

The most frequent rural population studied were rural families raising domestic animals (26) followed by occupationally exposed workers (6). The studies included were diverse in their objectives and methodological approaches. Most articles used a quantitative approach with a cross-sectional design (25 studies). Other studies used case-control, cohort designs, and other descriptive approaches. Five studies used pure qualitative methods including ethnography and grounded theory approaches. Also, three studies used mixed-methods designs with qualitative and quantitative data analysis approaches. Most of the studies were based on one single etiology (27). The reported agents of interest were leptospirosis (8), rabies (6), hydatidosis (4), neuro-cysticercosis/cysticercosis (3), brucellosis (3), flu (2), and other (10).

3.1. Thematic analysis results

Extracted themes were interpreted as factors aligning with different levels of the SEM as follows.

The themes extracted from the thematic analysis are mainly of two kinds, the first group corresponds to intrapersonal and interpersonal level factors, and the second group corresponds to the outer structural and social determinants of health (See Table 1).

3.2. Individual and interpersonal level factors

The intrapersonal factors were Knowledge and misconceptions, risk perceptions, educational level, and psychological affectation.

Knowledge and misconceptions about zoonotic diseases, pertaining to the intrapersonal level, was the most frequent SEM factor (19/37).

Fig. 3. Geographic distribution of studies found in the present review.

This theme concerns the lack of knowledge and misconceptions about disease causation and mechanisms, disease transmission routes, early recognition of signs and symptoms, and awareness of serious consequences and impacts of the disease as a barrier to prevention.

Several articles reported that a lack of knowledge and misconceptions are associated with a higher risk of disease transmission or emergence. For instance, Pavez-Muñoz E. [17] found that the lack of knowledge can lead to the misuse of antimicrobials in backyard poultry. Also, Ramírez D. et al. [18] found the importance of knowledge in favoring the transmission of echinococcosis:

> *"Many of these [factors that favor the persistence of E. granulosis] persist due to the ignorance of the biological cycle misguided beliefs and practices…"* [Spanish]

Others recognized the link of lack of knowledge to high-risk practices. Carnero et al. [19] and Ron-Roman et al. [20] mentioned the lack of knowledge as a limiting factor for the implementation of prevention of brucellosis for agricultural and animal trading markets workers.

> *"[There is a] great lack of information from these occupational groups on the importance of applying preventive measures to minimize the risk of transmission of brucellosis during work."* [19]

In the same way, Cerón et al. [21] state that *"The gulf in (the) understanding of […] disease concepts and the language used […] Impedes implementing community-based surveillance"*, enforcing the importance of lack of knowledge as a limiting factor for proper implementation of prevention programs.

Similarly, other studies, reported that knowledge could be a driver of preventive practices and lower disease risks in different scenarios [22–25]. For instance, for the prevention of leptospirosis in a riverside population in Argentina, Ricardo et al. [25] stated that knowledge was associated with practicing prevention. Coincidentally, also for the prevention of leptospirosis in rural parishes in Jamaica, McGwin [23] found that people with better knowledge of the disease have less probability of seropositivity.

In contrast, some studies reported that knowledge does not translate into preventive behaviors, or it is not associated with high-risk perception. For example, as an indicator that knowledge does not always

Table 1
Summary of the extracted SEM themes and descriptions.

SEM factors (levels)	Summary	References
Knowledge and misconceptions in zoonosis prevention (intrapersonal)	Lack of knowledge and misconceptions about disease causation and mechanisms concepts, disease transmission routes, early recognition of signs and symptoms, and awareness of serious consequences and impacts of the disease as a barrier to prevention	19 articles: [17–25,27,28,30,37,45–48]
Inequality (Community, organizational, political)	Low education level, belonging to a minority or neglected community, lack of or deficient public services, etc., are barriers to the prevention of zoonotic diseases.	12 articles: [21,26,29,35–42,49]
Risk perception (Intrapersonal)	Low risk perception decreases the implementation of preventive practices. The overconfidence of experienced professionals increases their risks.	9 articles: [20,25,26,29–34]
The knowledge gap between actors (Interpersonal, Organizational, community)	Differences in knowledge between decision-makers, preventive intervention agents, and people at risk. Language and communication barriers between different actors decrease the effectiveness of prevention interventions.	3 articles: [21,30,43]
Policy level factors (Policy - enabling)	Allocation of resources. Lack of widespread prevention programs. Lack of knowledge about zoonotic diseases impacts institutions' officials and policy agents.	2 articles [37,44]
Culture and traditions (intrapersonal, interpersonal, community)	Culture and traditions associated with high-risk practices	1 article: [20]
The psychological impact of diseases (Intrapersonal, interpersonal)	To suffer a zoonotic disease within the family unit psychologically affects the members of the family and their relationships and dynamics.	1 article: [18]

translate to protective risk perception, Allwood [26] said *"… while the majority of respondents had some knowledge of leptospirosis, a large proportion did not think that they or their families were at risk for the disease"* Others studies were not able to find associations of relevant variables with knowledge [27–29].

Risk perception was another recurrent intrapersonal level (9/36). This theme concerns the perceptions of risks related to zoonotic diseases in rural communities. Many articles reported that low risk perception could lead to potentially high-risk behaviors or high exposure to zoonotic diseases. In the study of Rivière-Cinnamond et al. [30], they found that *"… The low level of risk perception […] represents an important barrier in the implementation of preventive measures against plague."* indicating the barrier that low risk perception represents for the prevention of plague. Similarly, other studies reviewed [20,25,31–33] mentioned that risk perception is relevant in various aspects of prevention, and either relates to a lack of knowledge or is a direct barrier to prevention. In contrast, some studies reported that they could not find an association between knowledge and risk perception [26,29,31].

The importance of risk perception related to animal health and production was reported by 3 reviewed articles, they found that, among veterinarians, the higher experience was related to low risk perception and their level of exposure to zoonotic diseases [32–34]. Also, differences in risk perception between men and women were reported [34]. Finally, an article mentioned culture and traditions associated with the manipulation and consumption of potentially contaminated products [20].

Educational level, an intrapersonal factor but also a frequently reported socioeconomic indicator of inequality, was mentioned. Some of the studies pointed at this factor as a relevant one for prevention efforts. Specifically, Villacé et al. [29], reported that *"An association was detected between EL (educational level) and knowledge about the concept of zoonosis…"* [Spanish].

Similarly, other articles also found that low educational level was a factor related to the higher prevalence of zoonotic parasitic infections in depressed rural populations in Brazil and Peru respectively [35,36]. In contrasting results, one study reported that higher education was a risk factor for intentions to vaccinate their animals against rabies [37]. Additionally, one article failed to find an association between educational level and treatment decisions [21].

Psychological and social affectation is a theme at the interpersonal level that concerns the impacts of diseases in terms of mental health issues. Ramírez D. et al. [18] described an impact in their relationships and interactions that results in psychological affectation caused by having a family member affected by cystic echinococcosis.

3.3. Structural social determinants of health

Inequality was found as a recurrent theme in the reviewed documents (12/36). This identified issue is part of the political level. The most common socio-economic barrier was the absence of basic utilities related to high-risk environments for exposure to zoonotic agents [26,38–40]. Specifically, Allwood et al. [26] reported that:

> *"The presence of poor refuse disposal practices was a widespread finding that seemed to be linked to the limited availability of municipal collection services…"*

This increases the presence of rodents and thus the risk for exposure to *Leptospira* in rural farming families in a parish of Jamaica. Supporting that this factor is common in other settings, Carhuallanqui et al. [39], explain how the lack of sewage can be related to the risk of Cysticercosis in depressed dwellings in the Amazon region of Peru.

Low socioeconomic status was reported by two articles as an important factor. For McCune et al. [41] a high-risk practice such as feeding pigs with poultry carcasses was related to the economic benefit that overcame the potential risks.

In another study, the failure of treatment adherence for a case of cutaneous cellulitis of poultry workers in Argentina was attributed to social factors of poverty and inequality [42].

Gaps between different actors of different levels. Not only the knowledge about zoonotic diseases was found relevant, but also, the existence of knowledge and communications gaps between different actors and institutions was recognized in the documents reviewed. Due to the multiple actors involved, this theme transects the interpersonal, organizational, and community levels of the SEM. Different authors coincide in that differences in perceptions and knowledge, and in prevention priorities between decision-makers, preventive intervention agents, and people at risk were barriers to adequate implementation of preventive interventions. This is supported by the following statements by Rivière-Cinnamond et al. [30]:

> *"The differing views between the two groups show the gap existing between the community and the decision-makers. […] inconsistencies*

between perceived causes and suggested solutions, might be associated to lack of communication and collaboration across stakeholders' categories and sectors of action"

and by Cerón et al. [21], saying *"The gulf in (the) understanding of … disease concepts and the language used […] is an impediment to implementing community-based surveillance"*. Also, Costa and Fernandes [43] mentioned that the knowledge gap could significantly affect the prevention of zoonosis.

Policy level factors were addressed in 2 articles. Fragmented preventive efforts and lack of awareness by the community were reported related to the risk of Rabies. As reported by Dantas-Torres & Oliveira-Filho [44], *"[lack of] community awareness constitutes one of the biggest deficiencies in most rabies control programs"*.

Organizational responsibility, as a preventive factor, was mentioned by Góngora et al. [33], advocating for the responsibility of slaughterhouses beyond providing mandatory personal protective equipment, but also training their workers to protect themselves.

3.4. Context compelling recommendations from authors

Many of the analyzed articles provided recommendations for future interventions that contain or were related to SEM factors, components, or levels. We analyzed these recommendations, as there are relevant directives from people involved in local research with the potential to be feasible, acceptable, and appropriate interventions for the prevention of zoonotic diseases in these populations (See Table 2).

Some authors recommended interventions with specific methods or components such as: being persistent in time and including multidisciplinary and multilevel approaches [18,30].

Also, there is a great deal of consensus on the importance of delivering accurate and precise knowledge related to mechanisms of diseases, epidemiological links, and the importance of the severe consequences of diseases [19,21,25,30,48,50].

Specifically, at the intrapersonal level, using culturally targeted prevention messages in a lay or ordinary language directed to the populations at higher risk was a recurrent recommendation [21,37,38,43,51].

At the interpersonal level, some recommendations targeting different levels of community engagement included the value of interpersonal dissemination of knowledge, and the freedom to choose responsibilities and compromises in prevention programs [21,45].

At the organizational level, we found recommendations about accompanying diagnosis with immediate preventive actions, keeping continuous prevention programs running, proper training of medical professionals, and providing social and psychological support to the affected populations [18,21,43,52].

The community-level recommendations were the most recurrent in the analyzed articles. Community-based dissemination strategies and community-based surveillance systems were among the recommendations. Some authors also praised the value of community-based interventions' effectiveness and efficacy in low resources in rural settings. Also, promoting awareness in the community and the broader group of stakeholders could increase the demand for preventive actions at the community level [21,48,51].

Finally, at the policy level, some authors' general recommendation is that this level's actors should be more informed and involved in the planning and carrying out of the preventive programs with the allocation of enough resources for the broad and continuous applications of such. Some other authors stated recommendations related to the need to adapt the legal framework, promote multi-sectoral policies, and strengthen cooperation between institutions to improve prevention [30,37].

Table 2
Context recommendations and sample supporting excerpts extracted from the reviewed articles.

Recommendations	Sample excerpts
Specific methods and components	*"Promoting multi-sectoral policies and plan of actions lead by local mayors integrating public, private and civil society sectors from a participatory process perspective to enable early engagement of all stakeholders"* [30]
Delivering accurate zoonotic diseases knowledge	*"…targeting health education messages to facilitate understanding of the disease and thus prevention and early reaction…" [30]*
Culturally compelling interventions	*"Ethno-cultural education campaigns and improving training in animal management practices could increase the notification of human rabies exposure in all Colombia[n] regions."* [38]
Community-based knowledge transfer	*"[the dissemination of prevention knowledge] take advantage of the existing community structure for dissemination."* [21]
Supporting prevention programs following diagnosis	*"…there is a clear need for specific educational initiatives involving the local population and the public health entities." [43]*
Community engagement	*"…the community engagement initiated during this study offers the opportunity to provide this (prevention) information, especially to leaders within the community, and therefore take advantage of the existing community structure for dissemination." [21]*
Policy level recommendations	*"[policies should focus on] promoting multi-sectoral policies and plan of actions, […] adapting the legal and regulatory framework, […] and promoting healthy housing and healthy community" [30]*

4. Discussion

Zoonotic diseases are a significant burden on animal and human health, particularly in developing countries where assessment and surveillance are often challenging [53]. Poor reporting is a major constraint to the surveillance of both emerging and endemic zoonoses, and several important barriers to reporting can be identified: (i) a lack of tangible benefits when reports are made; (ii) a lack of capacity to enforce regulations; (iii) poor communication among communities, institutions and sectors; and (iv) complexities of the international regulatory environment [54]. In Latin America the so-called neglected zoonoses mainly affect poor people, who live in close association with livestock or wildlife and who have little access to health services, coping with an underestimation of their public health and economic significance and the lack of coordinated research and control effort.

Using the Social Ecological Model as a guiding framework we were able to elucidate, from published works, several relevant factors that affect the transmission and prevention of zoonotic diseases for rural inhabitants of Latin-American. Relevant structural social determinants were found as relevant. First, these dimensions of inequality, poverty, and lack of basic utilities, were relevant for exposure. Second, the gaps in knowledge and miscommunication were reported in several articles, describing the issues of lack of consistency of language, different levels of understanding of different actors, and institutional disconnection. And third, political factors such as issues for allocation of resources, dissemination, and fragmentation of existing preventive programs, were found to be important for prevention. Regarding Intrapersonal, and interpersonal factors, knowledge was found to be a relevant SEM factor affecting risk of exposure, preventive practices, and being associated with risk perception. Also, risk perception, educational level, and culture and traditions were found to be related to overconfidence, risky behaviors, and higher exposure.

4.1. Structural social levels

As there are often complex social and political issues around the prevention and control of zoonoses, a comprehensive understanding that takes into account the broader causes and impacts of zoonotic

diseases would be useful for developing countries. Eco health and One Health are such holistic frameworks for understanding human, animal, and environmental health [53,55], shifting the focus of research from assessment and diagnosis to management and communication of diseases and using as a key principle the engagement and participation of decision-makers, local communities, and researchers as partners in developing health solutions. Participatory approaches are a family of methods with the core assumption that people must participate fully in the processes of learning about their needs and opportunities and in the action required to address them. Regarding the relevance of equity and health, in 2021 the Quadripartite Alliance (WHO-OIE-FAO-UNEP), supported the new definition of One Health stating that this is an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals, and ecosystems. It recognizes the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent. With the One Health approach in place, it will be easier for people to better understand the co-benefits, risks, trade-offs, and opportunities to advance equitable and holistic solutions for health challenges [56].

Poverty, economic isolation, inequity, and difficult access to educational levels are recognized social determinants of health and have been broadly acknowledged as important barriers to implementation and access to preventive programs [57–59]. Poverty is linked to infectious diseases in every society, even more in the rural areas of developing countries where zoonoses are prevalent. Marginalization of the human and animal health systems and prevention programs makes this issue more challenging [60,61]. We believe that this is one of the SE factors that is most influenced by the enabling (policy) level since a great deal of the factors affecting access to basic resources and allocation of resources depend on the decision-making processes and motivations at this level [62]. In low-income countries, zoonoses and diseases which recently emerged from animals make up 26% of the DALYs lost to infectious diseases and 10% of the total DALYs lost. In contrast, in high-income countries, zoonoses and diseases recently which emerged from animals represent less than 1% of DALYs lost to infectious disease and only 0.02% of the total disease burden, showing the importance of the social context in zoonosis prevention and control [53]. In terms of potential for interventions, the policy level is the most difficult level to intervene in since the decision-making process at this level mostly obeys political agendas, and unfortunately, these agendas are not always aligned with the actual needs of the public [63].

Another important identified factor that crosses different levels of the SE is the gap in knowledge, language barriers, and differences in perceived priorities between either organizational or policy level actors and the community. The disconnection between stakeholders, science, and decision-makers has been addressed. Decision-making always obeys the motivations and knowledge of the decision-makers, and this should be driven by science. Unfortunately, due to the lack of communication skills and spaces, science does not always reach decision-makers. The use of communication science has been brought up in discussions of impactful science results dissemination and what might be the best strategies to overcome these gaps [63,64].

Effective communication amid cultural and linguistic differences between actors add another layer of complexity to the prevention programs. Culture and language barriers are contained within levels of other characteristics of the populations such as ethnicity, race, religion, regionalism, or membership among others [65]. The public needs to receive the culturally appropriate information, this only can be achieved if the prevention agents are knowledgeable of the customs of the community where they work. Thus, continuous training in cultural and linguistic competency should occur to assure the effectiveness of the message delivered.

Besides inequity, a political factor related to the allocation of resources for continuity and dissemination of preventive programs was also reported in two of the articles. Effective translation of research findings into policy is slow in many under-resourced countries [66]. The deficiencies in dissemination are usually linked to lacking resources such as personnel and facilities, so strategies of community engagement and mobilization came into place to increase the reach and maintenance of health programs [5,67]. Implementation of science approaches are necessary to increase the effectiveness of prevention programs in under-resourced settings.

Factors such as workplace culture and climate have been associated with occupational health-related events [68,69]. In our study, an article reviewed concluded that the low prevalence of antibodies in slaughterhouse workers was due to the adequate use of PPE, but also to the supporting culture and climate beyond the mandatory safety rules [33].

4.2. Intrapersonal and interpersonal

Knowledge has been broadly identified as a driver of zoonosis prevention in many rural settings [11,70–72]. The behavior and practices of people at risk change when they understand the epidemiology and biology of the agents producing diseases [73,74]. However, the change of knowledge by itself is not enough, it must be accompanied by a supportive environment and adequate channels of knowledge dissemination [75]. In our study, the frequency of papers mentioning knowledge (or lack of it) is an indicator of the relevance of this factor. Lack of knowledge was frequently associated with a lack of preventive actions and with a high risk of exposure and transmission of zoonotic diseases. We also found that some articles reported not finding an association of knowledge with risk perception or other variables. This could be explained by the lack of a favorable environment for translating knowledge into actions due to a different level of knowledge being measured or by the lack of statistical power.

Similar to knowledge, low risk perception is a recurrent SE factor that affects intentions to practice prevention and implementation of prevention practices. The relation of risk perception with prevention practices has been broadly studied; it is clear that a high-risk perception motivates the implementation of preventive actions [76,77]. Another important finding is that in many articles the risk perception is not directly related to the knowledge variables. This may be an indicator that the knowledge of diseases may be adequate to affect risk perception in this population. Further exploration of the triggers and channels of dissemination of risk perception in these populations is required. In the case of the finding of low risk perceptions among rural professionals (veterinary services), it has been described that overconfidence and experience are related to low risk perceptions [78]. Other authors conclude that perception of risk is likely to vary between different countries, depending on what the news media chose to report, what people chose to discuss, what cultural norms were perceived as important, and what technical and legal opportunities existed for the control and regulation of [79]. It would be beneficial to include content directed to raising awareness about these barriers in preventive interventions.

One article mentioned the potential personal, and interpersonal impact of Cysticercosis in rural families. The psychological impact of infectious diseases has been described [80]. Health events are stressful events with psychological affectation, and this is most evident in rural or remote areas where the health event economic burden is also significant [81,82]. The accompaniment of psychological and social workers counseling for families affected with infectious diseases is necessary.

Considering the added value of being drawn by a researcher that understands their local context. We analyzed the recommendations for the implementation of interventions targeting the identified problems in the different levels of the SEM. Intrapersonal level: increase specific knowledge of the people at risk and improve risk perception. Interpersonal level: use targeted messages with adequate terminology and language and train peers as adequate channels of communication. Community-level: generate community engagement and participatory responsibility, community-based dissemination of knowledge, and community-based surveillance. Organizational level: implement immediate preventive and supportive actions following diagnosis, and proper

training of health and prevention agents. Political: continuity and wider dissemination of programs, and promoting articulation and interoperability among organizations and the community.

Considering the added value of being drawn by a researcher that understands their local context. We analyzed the recommendations for the implementation of interventions targeting the identified problems in the different levels of the SEM (Fig. 4).

Below, we discuss some of the major limitations of our study. We found a large number of articles from different databases, however, despite our efforts, only 36 articles were included in the analysis which might difficult the generalization of the results. In the title and abstract screening, most papers were excluded based on being wrong subject articles (47.6%), not related to zoonotic diseases (12.1%), not in Latin America (8.7%), and other exclusion criteria (29.2%). During the full text, the exclusion decision was due to articles not mentioning any social and behavioral factors related to the epidemiology of zoonotic diseases, or that the study was a review. This finding is also an indicator that an important dimension of the epidemiology of zoonotic diseases in rural Latin America, such as the social determinants of health, is neither being addressed nor published often enough. Being a review there is the intrinsic limited scope of coming up with novel findings, however the systems approach help us understand better how these SE factors affect the prevention in different contexts. In this literature review, we did not assess the quality of the articles included. We based this decision on the fact that the overall quality of research is related to the availability of resources. The major factors contributing to these barriers are limited access to funding opportunities, insufficient budgets, outdated infrastructure and equipment, and inadequate salaries or job stability for researchers [83]. In this case, excluding studies based on the quality of research would have biased our findings to higher resources settings.

5. Conclusions

The thematic analysis identified and structured links between different information sources around a common goal. We were able to extract and analyze several diverse sources of information within the mass of knowledge and despite the diversity of topics, diseases, locations, and methods of the articles, we found convergence on themes that are valid across multiple settings.

Distinct dimensions of the social ecology around zoonosis were extracted. However, the methodology used in most of the articles did not aim to understand the social-ecological systems. This indicates that even though the authors recognize the importance of social factors in the epidemiology of zoonotic diseases, there is still a need to integrate these concepts through theoretical or empirical frameworks.

The systems approach to the problem allowed us to identify themes that are culturally congruent to inform or improve prevention interventions against zoonotic diseases in the rural populations of Latin America with an EcoHealth/One Health perspective. This perspective, which recognizes the interdependence of human, animal, and ecosystem health and the important influence of social, political, and economic subsystems on health outcomes, could make the costs of zoonoses more visible. Additionally, the prevention programs should be based on a multilevel understanding of the health problems that allowed to close the knowledge and priorities gap between the actors in the social ecosystem.

Funding

This was supported in part by the institutions Universidad de La Salle, Cyted Network on Climate Change and One Health, and CIDEIM with the salary support of the researchers and time allowance. Also with the personal resources and time of students and coauthors.

Fig. 4. Summary of the recommendations extracted from the selected articles aligned with the SEM.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.onehlt.2022.100444.

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