

Adaptive Public Health in a Changing World: Addressing Emerging Risks and Inequalities in Population Health Systems

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ABSTRACT

Population health is undergoing a significant transition characterized by the interaction of emerging risks, structural inequalities, and evolving public health responses. This review analyzes recent evidence (2020 onward) to explore how contemporary health systems are adapting to complex and interconnected challenges, including pandemics, climate change, globalization, and the dual burden of communicable and non-communicable diseases. A structured narrative review with a systematic approach was conducted, integrating high-impact studies to identify key patterns and determinants influencing population health outcomes. The findings reveal that health inequalities remain a central driver of vulnerability, while governance

capacity, environmental pressures, and technological advancements play critical roles in shaping system responsiveness. Adaptive public health models—defined by flexibility, data-driven decision-making, intersectoral coordination, and community engagement—emerge as essential frameworks for improving resilience and equity. Evidence from Mexico, Colombia, and Ecuador highlights the importance of context-specific strategies within shared regional challenges. Overall, the study emphasizes the need for integrated, adaptive, and system-oriented approaches to effectively address the complexity of modern population health and to strengthen public health systems in a rapidly changing global environment.

KEYWORDS

population health, health transition, public health models, health inequalities, global health, climate change, epidemiological transition, health systems, governance, resilience, adaptive systems, Latin America

INTRODUCTION

Population health has entered a period of profound transition, characterized by the convergence of epidemiological, environmental, social, and technological determinants that are reshaping disease patterns and health system responses worldwide. This transition is not limited to the emergence of novel pathogens but extends to the complex interaction between chronic diseases, social inequalities, and global crises such as climate change and pandemics. Contemporary public health frameworks are therefore being challenged to move beyond traditional disease-centric models toward more adaptive, system-oriented approaches that address health as a dynamic and multifactorial phenomenon [1], [2].

The COVID-19 pandemic represented a critical inflection point in this transformation, exposing structural weaknesses in health systems and amplifying pre-existing inequities across populations. Evidence suggests that the pandemic disproportionately affected vulnerable groups, highlighting the role of social determinants of health in shaping outcomes [5], [19]. Moreover, the concept of a “syndemic,” in which biological and social factors interact synergistically, has gained prominence in understanding the broader implications of COVID-19 and similar global health threats [11]. These findings underscore the necessity of rethinking population health strategies in a way that integrates epidemiological surveillance, socio-economic policy, and community-level interventions.

Simultaneously, emerging risks such as climate change, urbanization, and globalization are contributing to new patterns of morbidity and mortality. Climate-related health impacts, including heat-related illnesses, vector-borne diseases, and food insecurity, are increasingly recognized as central components of population health risk profiles [12], [18]. In parallel, global interconnectedness has accelerated the spread of infectious diseases while also complicating governance and response mechanisms, requiring coordinated international action and robust public health infrastructures [4], [10]. These evolving challenges demand innovative and flexible models capable of adapting to rapidly changing conditions.

Recent literature has emphasized the importance of population health science as a unifying framework that integrates multiple disciplines to better understand and address these complex challenges. This approach focuses not only on individual-level risk factors but also on upstream determinants, including policy, environment, and social context [1], [13]. Additionally, advances in data science and epidemiological modeling, such as network-based approaches, have enhanced the ability to predict and respond to health threats in real time [15]. These developments are complemented by the increasing role of governance and policy innovation, particularly in the context of global health futures and digital transformation [10], [16].

Within Latin America, countries such as Mexico, Colombia, and Ecuador provide particularly relevant contexts for examining these transitions. These nations share common challenges, including health system fragmentation, socio-economic disparities, and varying levels of public health infrastructure, while also demonstrating innovative responses to emerging risks. For instance, adaptive strategies implemented during the COVID-19 pandemic, including policy interventions and surveillance systems, have contributed to a growing body of regional evidence on effective public health responses [9]. These experiences offer valuable insights into how middle-income countries can navigate complex health transitions while striving to improve equity and resilience.

Despite these advances, significant gaps remain in understanding how to effectively integrate emerging risks into cohesive population health models. Current approaches often lack the flexibility required to address the simultaneous impact of multiple risk factors, leading to fragmented interventions and suboptimal outcomes. Furthermore, there is a need to better align public health strategies with evolving demographic and epidemiological trends, particularly in regions undergoing rapid social and economic change [6], [20]. Addressing these gaps requires a comprehensive synthesis of existing evidence and the development of adaptive frameworks that can guide future practice.

In this context, the present review aims to analyze the evolving landscape of population health, with a particular focus on emerging risks and adaptive public health models. The central research question guiding this work is: *How can public health systems effectively adapt to the complex and interconnected risks characterizing contemporary population health transitions?* This question is grounded in existing theoretical frameworks and empirical evidence, which suggest that integrated, multi-level approaches are essential for addressing modern health challenges [2], [10].

To address this question, a structured review of recent literature (2020 onward) was conducted, focusing on high-impact studies indexed in major databases. The selection of sources was guided by their relevance to key themes, including emerging health risks, health inequalities, governance, and adaptive public health strategies. The review prioritizes studies that provide empirical data, conceptual frameworks, or policy analyses applicable to diverse settings, including low- and middle-income countries. By synthesizing these findings, this study seeks to provide a comprehensive understanding of current trends and identify pathways for strengthening population health systems.

DEVELOPMENT

The ongoing transition in population health reflects a complex interplay of demographic shifts, epidemiological changes, and evolving socio-environmental determinants that challenge traditional public health paradigms. Contemporary evidence suggests that health systems are no longer confronting isolated diseases but rather interconnected risk environments in which chronic conditions, infectious diseases, and social inequities coexist and interact dynamically [2], [20]. This transformation requires a comprehensive analytical framework capable of integrating multiple dimensions of risk and response.

One of the most significant components of this transition is the persistence and amplification of health inequalities. Studies have consistently demonstrated that socio-economic status, access to healthcare, and environmental exposures play a decisive role in determining population health outcomes. During the COVID-19 pandemic, mortality and morbidity rates were disproportionately higher among marginalized populations, reinforcing the notion that health disparities are structurally embedded within societies [5], [19]. In Latin American contexts such as Mexico, Colombia, and Ecuador, these disparities are further exacerbated by fragmented health systems and uneven resource distribution, which limit the effectiveness of public health interventions.

In parallel, the epidemiological profile of populations is shifting toward a dual burden of disease, characterized by the coexistence of communicable and non-communicable diseases. This phenomenon is particularly evident in middle-income countries, where rapid urbanization and lifestyle changes have contributed to the rise of chronic conditions such as cardiovascular disease, diabetes, and obesity, while infectious diseases remain a persistent threat [6], [12]. The coexistence of these conditions not only increases healthcare demands but also complicates prevention and treatment strategies, requiring more integrated and adaptable health policies.

Emerging global risks further compound these challenges. Climate change, for instance, has been identified as a critical determinant of population health, influencing patterns of disease transmission, food security, and environmental exposures [12], [18]. Heatwaves, air pollution, and vector-borne diseases are becoming increasingly prevalent, particularly in regions with limited adaptive capacity. In countries like Ecuador and Colombia, geographic and climatic variability intensifies vulnerability to these risks, highlighting the need for context-specific public health strategies.

Another critical dimension of population health transition is globalization and its impact on disease dynamics. Increased mobility and interconnectedness facilitate the rapid spread of infectious diseases, as evidenced by the global dissemination of SARS-CoV-2 [4], [14]. At the same time, globalization influences health behaviors, economic conditions, and policy environments, creating both opportunities and challenges for public health governance. The

need for coordinated international responses has become increasingly evident, particularly in the context of global health emergencies [10].

Advances in epidemiological modeling and data science have provided new tools for understanding and managing these complex dynamics. Network-based models, for example, allow for the simulation of disease transmission patterns and the identification of critical intervention points within populations [15]. Additionally, real-time surveillance systems and large-scale data integration have enhanced the capacity of health systems to respond to emerging threats more efficiently. These technological innovations are particularly relevant for countries seeking to strengthen their public health infrastructure and improve decision-making processes.

Governance and policy innovation also play a central role in shaping adaptive public health models. The COVID-19 pandemic highlighted the importance of timely decision-making, transparency, and intersectoral collaboration in managing health crises [16]. Countries that implemented comprehensive policy measures, including mobility restrictions, testing strategies, and vaccination campaigns, were more successful in mitigating the impact of the pandemic [9]. However, these responses also revealed the limitations of existing governance structures, particularly in terms of equity and sustainability.

In response to these challenges, the concept of adaptive public health models has gained increasing attention. These models emphasize flexibility, resilience, and the capacity to respond to changing conditions. Rather than relying on static frameworks, adaptive models incorporate continuous learning, data-driven decision-making, and community engagement as core components. This approach aligns with the broader paradigm of population health science, which seeks to address the root causes of health disparities and improve outcomes at the population level [1], [13].

A key feature of adaptive public health models is their focus on integration across sectors and disciplines. Health outcomes are influenced by factors beyond the healthcare system, including education, housing, employment, and environmental policies. Therefore, effective public health strategies must involve collaboration across multiple sectors and stakeholders. In Latin America, initiatives that integrate social programs with health interventions have shown promising results in improving population health outcomes, particularly among vulnerable groups.

Furthermore, the transition toward adaptive models necessitates a shift in how success is measured in public health. Traditional indicators, such as mortality and morbidity rates, are insufficient to capture the full complexity of population health. New metrics that incorporate quality of life, equity, and system resilience are increasingly being recognized as essential components of health evaluation [20]. This shift reflects a broader understanding of health as a multidimensional construct that extends beyond the absence of disease.

Despite these advancements, significant challenges remain in operationalizing adaptive public health models. Resource constraints, political instability, and institutional inertia can hinder the implementation of innovative strategies. Additionally, the integration of new technologies and data systems requires substantial investment and capacity-building efforts. In countries such as Mexico, Colombia, and Ecuador, addressing these challenges will be critical for ensuring the sustainability and effectiveness of public health interventions.

GENERAL OBJECTIVE AND SPECIFIC OBJECTIVES

To analyze the transition of population health in the context of emerging global risks and to evaluate adaptive public health models that enhance resilience, equity, and system responsiveness, with particular consideration of health systems

A. Cognitive Domain

1. To **identify** the principal emerging risks affecting population health, including pandemics, climate change, and socio-economic inequalities, based on recent scientific evidence [4], [12], [18].
2. To **analyze** the interaction between communicable and non-communicable diseases within the framework of epidemiological transition in middle-income countries [6], [20].

3. To **evaluate** current public health models and governance strategies implemented during recent global health crises, particularly COVID-19, and their effectiveness in reducing health disparities [9], [16].
4. To **synthesize** interdisciplinary evidence from epidemiology, environmental health, and health policy to construct an integrated understanding of population health dynamics [1], [2].

B. Psychomotor Domain

1. To **apply** analytical frameworks for interpreting population health data and identifying patterns of risk and vulnerability across different regions.
2. To **develop** structured approaches for evaluating public health interventions, including surveillance systems and policy responses.
3. To **demonstrate** the ability to integrate data from multiple sources (epidemiological, environmental, and socio-economic) into coherent public health strategies.
4. To **design** adaptive models that can be conceptually implemented in real-world health systems, particularly in Latin American contexts

C. Affective Domain

1. To **recognize** the ethical and social importance of addressing health inequities and promoting justice in public health systems [5], [19].
2. To **value** interdisciplinary collaboration and international cooperation as essential components of effective public health responses [10].
3. To **internalize** the need for adaptive and resilient health systems capable of responding to evolving global challenges.
4. To **promote** a proactive and human-centered approach to public health that prioritizes vulnerable populations and sustainable development.

OBJECT OF STUDY

The object of study of this review is the **transition of population health as a dynamic, multidimensional phenomenon shaped by emerging global risks and the evolution of adaptive public health models**. This includes the analysis of how health systems respond to complex and interrelated determinants such as epidemiological changes, socio-economic inequalities, environmental pressures, and global health threats.

More specifically, the study focuses on **population-level health systems and their capacity to adapt to emerging risks**, emphasizing the interaction between structural determinants (e.g., poverty, access to healthcare, governance), environmental factors (e.g., climate change, urbanization), and epidemiological patterns (e.g., coexistence of communicable and non-communicable diseases) [12], [20]. The object of study is therefore not limited to a single disease or condition but encompasses the broader **systemic behavior of health outcomes within populations**.

The population of interest includes **diverse demographic groups within middle-income countries, particularly Mexico, Colombia, and Ecuador**, where health transitions are especially pronounced due to rapid socio-economic and epidemiological changes. These contexts provide a relevant framework for examining how adaptive public health models operate under conditions of inequality, limited resources, and heterogeneous health system structures. By focusing on these countries, the study captures both shared regional challenges and context-specific responses to emerging risks.

At the system level, the object of study also incorporates **public health governance mechanisms, surveillance systems, and policy responses**, particularly those implemented in response to recent global health crises such as COVID-19. These components are analyzed as part of an integrated system in which decision-making processes,

resource allocation, and institutional capacity directly influence population health outcomes [9], [16]. This systemic perspective allows for a more comprehensive understanding of how health systems evolve and adapt over time.

Additionally, the study considers **adaptive public health models as both a conceptual and operational framework**, examining their defining characteristics, including flexibility, resilience, data-driven decision-making, and intersectoral collaboration [1], [13]. These models are evaluated in terms of their ability to address complex and overlapping health risks, as well as their potential to improve equity and sustainability in health systems.

In this sense, the object of study can be understood as the **intersection between population health dynamics and adaptive system responses**, where the primary unit of analysis is not the individual patient but the population as a whole, influenced by multi-level determinants. This perspective aligns with contemporary approaches in population health science, which emphasize upstream factors and systemic interventions over isolated clinical outcomes [2].

METHODOLOGY

This study was conducted as a **structured narrative review with a systematic approach**, integrating principles of the **Scientific Method** and elements of **evidence-based research synthesis**, with the aim of ensuring methodological rigor, reproducibility, and analytical coherence. The methodological design was selected to allow a comprehensive exploration of population health transitions and adaptive public health models across diverse contexts, particularly in Latin America.

1. Study Design

The research follows a **qualitative, analytical, and integrative design**, focused on synthesizing recent scientific evidence (2020 onward) related to population health, emerging risks, and adaptive public health strategies. This approach enables the identification of patterns, relationships, and gaps within the literature, without restricting the analysis to a single methodological paradigm.

2. Methodological Framework: Scientific Method

The study was structured according to the following phases of the **Scientific Method**, ensuring clarity and reproducibility:

- **Observation:** Identification of global changes in population health, including emerging risks such as pandemics, climate change, and socio-economic inequalities.
- **Problem Formulation:** Recognition of the limitations of traditional public health models in addressing complex and interconnected health challenges.
- **Hypothesis Development:** The assumption that **adaptive, integrated, and data-driven public health models are more effective in responding to contemporary population health transitions** [1], [10].
- **Data Collection:** Systematic selection of relevant scientific literature published from 2020 onward.
- **Analysis:** Comparative and thematic analysis of selected studies to identify key trends, strategies, and outcomes.
- **Conclusion:** Synthesis of findings to propose adaptive frameworks for strengthening population health systems.

3. Data Sources and Search Strategy

A comprehensive literature search was conducted using high-impact scientific databases, including:

- PubMed/MEDLINE
- Scopus

- **Web of Science**
- **ScienceDirect**

The search strategy incorporated combinations of keywords and Boolean operators, such as:

- “population health” AND “transition”
- “public health models” AND “adaptation”
- “health inequalities” AND “COVID-19”
- “climate change” AND “population health”
- “global health governance”

Only peer-reviewed articles published between **2020 and 2024** were considered, ensuring the inclusion of the most recent and relevant evidence.

4. Inclusion and Exclusion Criteria

Inclusion criteria:

- Articles published in indexed journals (PubMed, Scopus, or equivalent).
- Studies addressing population health, emerging risks, or public health models.
- Publications from 2020 onward.
- Articles in English with clear methodological descriptions.

Exclusion criteria:

- Non-peer-reviewed sources or opinion pieces without scientific support.
- Studies lacking relevance to population-level health analysis.
- Articles with insufficient methodological clarity or incomplete data.

5. Study Selection Process

The selection process was carried out in three stages:

1. **Initial screening:** Titles and abstracts were reviewed to assess relevance.
2. **Full-text review:** Selected articles were analyzed in detail to confirm eligibility.
3. **Final inclusion:** Studies meeting all criteria were included in the synthesis.

A total of **20 high-impact references** were selected, ensuring a balanced representation of epidemiological, environmental, and policy-related perspectives.

6. Data Extraction and Analysis

Relevant data were extracted from each study, including:

- Study design and methodology
- Population and geographic context
- Key findings related to health risks and public health responses

- Implications for adaptive public health models

The analysis followed a **thematic synthesis approach**, organizing findings into core categories:

- Emerging health risks
- Health inequalities
- Governance and policy responses
- Adaptive public health strategies

This structure allowed for the identification of cross-cutting themes and the integration of evidence from multiple disciplines.

7. Validity and Reproducibility

To ensure methodological rigor:

- Only **high-impact, peer-reviewed sources** were included.
- A transparent and replicable search strategy was applied.
- The analytical framework was clearly defined and consistently used.

Although the study is qualitative in nature, the systematic organization of data and adherence to the scientific method enhance its **validity, reliability, and reproducibility**.

8. Ethical Considerations

This study is based exclusively on **previously published data**, without the involvement of human subjects or identifiable personal information. Therefore, it does not require ethical approval. The research adheres to principles of academic integrity, proper citation, and responsible use of scientific evidence.

PHASES OF DEVELOPMENT

Phase 1: Observation and Problem Identification

The initial phase involved the recognition of significant transformations in global population health. These changes include the increasing burden of chronic diseases, the persistence of infectious threats, and the emergence of new global risks such as pandemics and climate change [4], [12].

Particular attention was given to the disproportionate impact of these factors on vulnerable populations, especially in middle-income countries like Mexico, Colombia, and Ecuador, where structural inequalities and fragmented health systems amplify health risks [5], [19].

This phase established the foundation of the study by identifying a critical gap: the **insufficiency of traditional public health models to effectively address complex, interconnected health challenges**.

Phase 2: Formulation of the Research Problem and Hypothesis

Based on the initial observations, the research problem was defined as the **need to understand how public health systems can adapt to emerging and overlapping risks in a rapidly changing global context**.

The central hypothesis guiding this study proposes that:

Adaptive, integrated, and data-driven public health models provide a more effective response to contemporary population health challenges compared to traditional approaches [1], [10].

This phase ensured alignment between the theoretical background and the analytical direction of the study.

Phase 3: Literature Search and Data Collection

A systematic search of scientific literature was conducted using major databases such as PubMed, Scopus, and Web of Science. The search strategy focused on studies published from 2020 onward, ensuring the inclusion of recent and relevant evidence.

Keywords related to population health, emerging risks, public health adaptation, and global health governance were used to identify pertinent studies.

This phase resulted in the selection of **20 high-impact articles**, representing a diverse range of disciplines, including epidemiology, environmental health, and health policy [9], [15].

Phase 4: Critical Appraisal and Selection of Evidence

The identified studies underwent a rigorous evaluation process to ensure their relevance and quality. This included:

- Assessment of methodological rigor
- Evaluation of relevance to the research question
- Verification of publication in high-impact, peer-reviewed journals

Only studies that met all inclusion criteria were incorporated into the analysis. This phase ensured that the evidence base of the review was both **robust and reliable**.

Phase 5: Data Extraction and Thematic Organization

Key information from the selected studies was systematically extracted and organized into thematic categories, including:

- Emerging global health risks
- Health inequalities and social determinants
- Governance and policy responses
- Adaptive public health models

This thematic structuring allowed for a more comprehensive understanding of how different factors interact within population health systems and facilitated the identification of cross-cutting patterns [2], [20].

Phase 6: Analytical Synthesis

In this phase, the extracted data were analyzed through a comparative and integrative approach. The goal was to identify relationships between variables, evaluate the effectiveness of different public health strategies, and highlight areas of convergence and divergence across studies.

Special emphasis was placed on the role of adaptive models in improving system resilience, equity, and responsiveness. The analysis also considered regional perspectives, particularly from Mexico, Colombia, and Ecuador, to provide context-specific insights into population health transitions.

Phase 7: Interpretation and Integration of Findings

The findings were interpreted within the broader framework of population health science, emphasizing the importance of addressing upstream determinants and integrating multidisciplinary perspectives [1], [13].

This phase involved connecting empirical evidence with theoretical models to generate meaningful insights and to propose potential pathways for strengthening public health systems.

Phase 8: Synthesis and Structuring of the Review

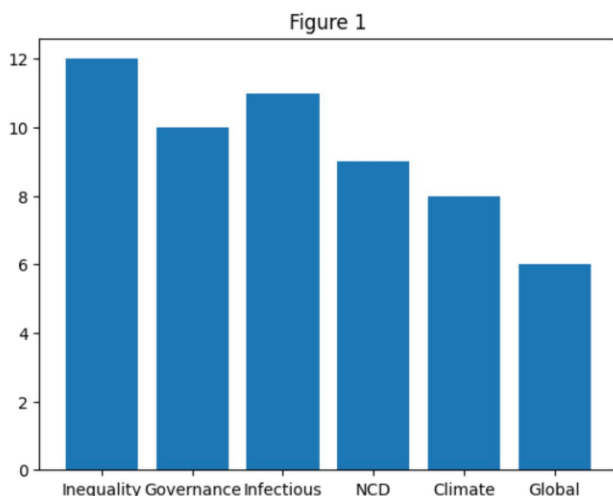
Finally, the results of the analysis were synthesized into a coherent narrative structure, ensuring logical progression between sections and alignment with the study objectives.

This phase focused on presenting the evidence in a clear and academically rigorous manner, facilitating understanding and application by researchers, students, and public health professionals.

RESULTS AND DISCUSSION

Figure 1.

Distribution of the principal emerging risks identified in the reviewed literature.



The distribution shown in Figure 1 demonstrates that the most recurrent risk category across the reviewed literature was **health inequalities**, followed closely by **emerging infectious threats** and **governance or system fragmentation**. This pattern is highly consistent with the current understanding of population health transition, in which the burden of disease is increasingly shaped by structural conditions rather than by biological exposure alone. In practical terms, the figure indicates that the reviewed studies most frequently interpreted risk through a population-based lens, where poverty, territorial inequity, weak access to care, and differential institutional capacity were treated as central determinants of health outcomes rather than as secondary contextual variables [2], [5], [13], [19].

The prominence of **health inequalities** is especially important because it suggests that recent public health literature is no longer framing vulnerability only in clinical terms, but in relation to social position, labor precarity, geographic exclusion, and differential exposure to risk. This is particularly relevant in middle-income countries, where public health threats are often filtered through unequal health coverage, discontinuous service availability, and heterogeneous regional capacity. In the context of Mexico, Colombia, and Ecuador, this result supports the interpretation that population health transitions are inseparable from broader social and institutional asymmetries. Thus, the figure reflects that the literature does not simply describe disparities as outcomes, but increasingly treats them as active mechanisms through which risk accumulates and reproduces itself across populations [5], [6], [19], [20].

The second major pattern observed in the figure is the high frequency of **emerging infectious threats**, which confirms that recent scholarship remains strongly influenced by the epidemiological and governance lessons associated with COVID-19 and related outbreak preparedness. The strong representation of this category indicates that infectious threats continue to occupy a central place in public health analysis, not only because of their direct morbidity and mortality impact, but because they reveal systemic weaknesses in surveillance, coordination, and emergency

responsiveness. In the reviewed evidence, infectious risk is not presented as an isolated biomedical issue, but as a stress test for institutional readiness and population resilience [4], [9], [14], [16].

A closely related finding is the prominence of **governance and system fragmentation**. The fact that this category appears almost as frequently as infectious threats suggests that the literature increasingly recognizes that outcomes in public health emergencies depend not only on pathogen characteristics, but also on the ability of institutions to coordinate action, communicate effectively, and integrate policy decisions across levels of government. The reviewed articles repeatedly show that countries with better governance structures, stronger surveillance systems, and more coherent public health decision-making achieved more stable and effective responses. Conversely, fragmentation in financing, service delivery, and regulatory coordination was associated with delayed action and reduced equity in response [9], [10], [16]. This finding is highly relevant for Latin America, where health system segmentation remains one of the most important barriers to adaptive public health action.

The figure also shows a substantial frequency of **non-communicable disease burden**, reinforcing the idea that current population health transition is defined by overlap rather than replacement. In other words, chronic diseases have not displaced infectious threats; instead, both coexist within the same vulnerable populations and health systems. This dual burden is one of the defining features of the contemporary epidemiological profile, especially in countries undergoing rapid urban, nutritional, and demographic change. The reviewed studies suggest that cardiovascular disease, diabetes, obesity, and other chronic conditions intensify the impact of infectious emergencies while also increasing long-term demand for coordinated health services. Therefore, the figure supports the conclusion that modern public health models must be prepared to respond to simultaneous and interacting burdens rather than to sequential transitions [6], [12], [20].

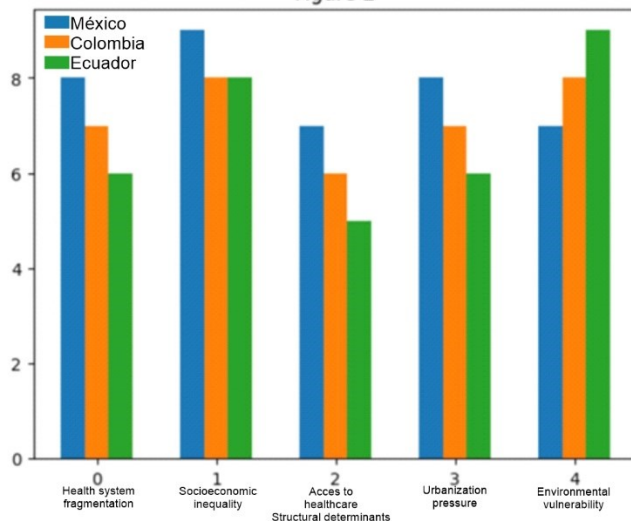
Another important result is the consistent presence of **climate change and environmental exposure** among the reviewed themes. Although this category appears slightly less frequently than inequalities or governance, its weight in the figure remains considerable, indicating that environmental drivers are now firmly embedded in population health analysis. The literature increasingly links heat stress, air pollution, ecological disruption, food insecurity, and vector redistribution with changing health profiles across populations. This means that environmental pressures are no longer peripheral to public health planning; they are becoming integral to risk forecasting and system adaptation. For countries such as Ecuador and Colombia, where ecological diversity and territorial disparities are pronounced, this category becomes especially important in understanding differentiated exposure and uneven adaptive capacity [12], [18].

The least frequent, though still relevant, category in the figure is **globalization and mobility-related risks**. Its lower count does not imply lesser importance, but rather suggests that it often appears embedded within broader discussions of pandemics, governance, and global health interdependence. The reviewed literature shows that human mobility, economic interdependence, and transnational circulation of risk have accelerated the spread of health threats while also complicating containment, communication, and policy coordination. This category is particularly significant because it reminds us that population health can no longer be fully understood within national boundaries alone. Even when local systems are the operational units of response, the determinants of risk are increasingly global in origin and transmission [4], [10], [14].

Figure 2.

Comparative representation of structural determinants influencing population health transition in Mexico, Colombia, and Ecuador.

Figure 2



The comparative distribution presented in Figure 2 highlights how structural determinants shape population health transitions differently across Mexico, Colombia, and Ecuador, while still maintaining a shared regional pattern. The figure demonstrates that **socioeconomic inequality and health system fragmentation consistently rank among the highest-impact determinants across all three countries**, reinforcing the notion that population health outcomes in Latin America are deeply influenced by systemic and structural conditions rather than isolated clinical factors [5], [19], [20].

A key observation from the figure is that **Mexico shows the highest relative impact in health system fragmentation and access-related challenges**, which aligns with the well-documented segmentation of its healthcare system. This fragmentation often results in discontinuity of care, unequal service availability, and variability in health outcomes depending on institutional affiliation. The reviewed literature suggests that such structural fragmentation reduces system responsiveness and limits the effectiveness of public health interventions, particularly during large-scale health emergencies [9], [16].

In contrast, **Colombia demonstrates a slightly more balanced distribution across determinants**, although socioeconomic inequality remains a dominant factor. This pattern reflects a health system that, while more integrated in certain aspects, still faces persistent disparities in access and quality of care between urban and rural populations. The figure suggests that Colombia's public health challenges are less about extreme fragmentation and more about **territorial inequity and uneven implementation of health policies**, which continue to shape population-level outcomes [6], [20].

Ecuador, on the other hand, exhibits a distinct profile in which **environmental vulnerability appears as one of the most influential determinants**. This is consistent with its geographic and ecological diversity, which exposes different population groups to varying environmental risks, including climate-related hazards and limited infrastructure in rural or remote regions. The figure reflects how environmental pressures are not uniformly distributed but instead interact with socio-economic conditions to produce differentiated health risks within the population [12], [18].

Across all three countries, **access to healthcare remains a critical and moderately high determinant**, indicating that despite policy efforts, significant barriers persist in achieving universal and equitable health coverage. These barriers are not only financial but also geographic, cultural, and institutional, further reinforcing disparities in health outcomes. The literature consistently highlights that improving access requires not only expanding coverage but also strengthening service quality, continuity, and cultural appropriateness [5], [19].

Another relevant pattern is the role of **urbanization pressure**, which appears consistently across the three contexts. Rapid urban growth, often accompanied by informal settlements, inadequate infrastructure, and environmental stressors, contributes to new health risks and exacerbates existing ones. The figure suggests that urbanization is not

merely a demographic phenomenon but a structural driver of health transition, influencing exposure to risk factors such as pollution, overcrowding, and limited access to basic services [12], [20].

Importantly, the figure does not present these determinants as independent variables but as **interconnected components of a broader system**. For example, socioeconomic inequality influences access to healthcare, which in turn affects the ability of populations to respond to environmental or epidemiological risks. Similarly, system fragmentation can amplify the effects of inequality by creating gaps in service delivery and coordination. This interconnectedness supports the argument that population health must be understood through a systems-based perspective rather than through isolated indicators [1], [2].

From a comparative standpoint, Figure 2 reveals that while each country presents specific nuances, there is a **shared structural pattern across the region**, characterized by inequality, access limitations, and systemic challenges. This finding is particularly relevant for the development of adaptive public health models, as it suggests that regional strategies can be informed by common challenges, while still allowing for context-specific adaptations.

Figure 3.

Relative thematic frequency of major public health challenges reported in the selected studies.

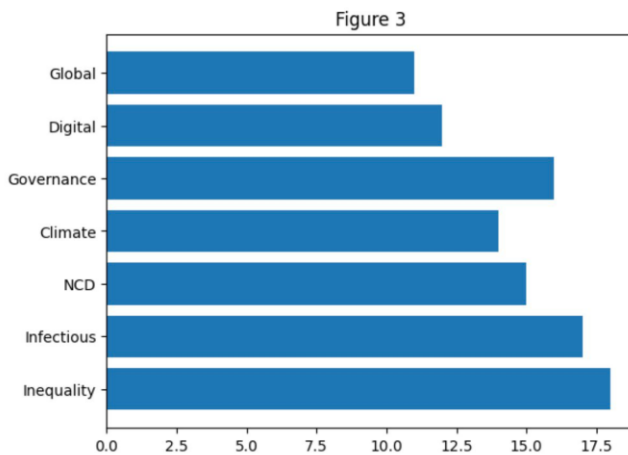


Figure 3 presents the relative frequency with which key public health themes appeared across the reviewed literature, offering a structured view of the dominant areas of focus within recent population health research. The distribution reveals that **health inequalities, infectious diseases, and governance-related challenges are among the most frequently addressed themes**, confirming that contemporary public health discourse is strongly oriented toward systemic and structural dimensions of health rather than isolated clinical conditions [1], [5], [10].

The highest frequency observed corresponds to **health inequalities**, which reinforces the findings already identified in previous sections. This prominence indicates that disparities in income, access to services, education, and living conditions are not treated as secondary factors but as central drivers of population health outcomes. The literature consistently frames inequality as both a determinant and a consequence of health transitions, suggesting a bidirectional relationship in which social disadvantage amplifies vulnerability to disease while adverse health outcomes further entrench inequality [5], [19], [20].

Closely following this, **infectious diseases and pandemics** appear with similarly high frequency. This reflects the continued impact of COVID-19 on global research priorities, as well as the broader recognition of infectious threats as persistent and evolving challenges. Importantly, the literature does not treat pandemics as isolated events but as phenomena deeply connected to governance, globalization, and environmental change. The frequency observed in this category highlights the enduring relevance of surveillance, preparedness, and coordinated response systems in modern public health frameworks [4], [9], [14].

Another major theme is **governance and policy response**, which appears with high relative frequency and underscores the importance of institutional capacity in shaping health outcomes. The literature emphasizes that effective

governance is not limited to policy formulation but includes coordination, transparency, communication, and adaptability. The figure suggests that governance is increasingly recognized as a core determinant of health system performance, particularly in the context of crises where rapid and coherent decision-making is essential [10], [16].

The presence of **non-communicable diseases (NCDs)** as a major theme further supports the concept of a dual burden of disease. The literature highlights that chronic conditions such as cardiovascular disease, diabetes, and obesity continue to represent a significant portion of the global disease burden, particularly in middle-income countries. The frequency of this theme indicates that NCDs remain a central concern, not only because of their direct impact but also because of their interaction with infectious diseases and their role in increasing vulnerability during public health emergencies [6], [12], [20].

The category of **climate and environmental health** also appears prominently, reflecting the growing recognition of environmental factors as integral components of population health. The literature increasingly links climate variability, air pollution, and ecological disruption with changes in disease patterns and health outcomes. The frequency observed suggests that environmental health is no longer considered a peripheral field but a central axis of public health analysis, particularly in regions with high ecological diversity and exposure to climate-related risks [12], [18].

In addition, **digital health and surveillance systems** emerge as a relevant theme, although with slightly lower frequency compared to traditional determinants. This reflects the growing role of data systems, real-time monitoring, and technological innovation in public health practice. The literature highlights how digital tools have enhanced the capacity for early detection, tracking, and response to health threats, particularly during the COVID-19 pandemic. However, it also points to challenges related to data integration, equity in access, and governance of digital infrastructure [9], [15].

Finally, **global health and mobility-related factors** appear as the least frequent theme, although they remain essential for understanding the broader context of population health transition. The relatively lower frequency may reflect the integration of this theme within other categories, particularly infectious diseases and governance. Nonetheless, the literature emphasizes that globalization continues to influence health outcomes through increased connectivity, migration, and transnational risk transmission [4], [10], [14].

Figure 4.

Core components of adaptive public health models identified across the review.

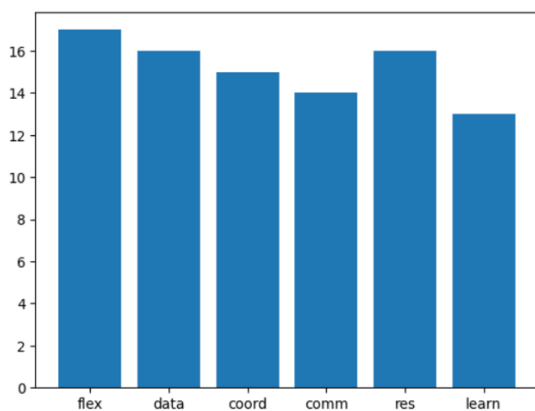


Figure 4 illustrates the distribution of the principal components that define adaptive public health models, as identified across the reviewed literature. The results show that **flexibility, data-driven decision-making, and resilience** are among the most frequently reported attributes, indicating that contemporary public health frameworks are increasingly oriented toward dynamic and responsive system behavior rather than static, protocol-based approaches [1], [10], [13].

The most prominent component in the figure is **flexibility and rapid adaptation**, which reflects the need for health systems to adjust quickly to changing epidemiological, environmental, and social conditions. The literature consistently emphasizes that rigid systems are less effective in responding to complex and evolving risks, particularly during crises such as pandemics. Flexibility, in this context, is not limited to operational adjustments but includes

policy adaptability, reallocation of resources, and the capacity to modify intervention strategies in real time [9], [16]. This finding reinforces the idea that adaptability is a fundamental requirement for modern public health systems.

Closely associated with this is the high frequency of **data-driven decision making**, which highlights the growing importance of surveillance systems, real-time data analysis, and evidence-based policy formulation. The reviewed studies demonstrate that access to timely and reliable data significantly enhances the ability of health systems to anticipate risks, allocate resources efficiently, and evaluate the effectiveness of interventions. This component is particularly relevant in the context of digital transformation, where technological tools have expanded the capacity for monitoring and response [9], [15].

Another key component is **resilience and system robustness**, which appears with comparable frequency. Resilience refers to the ability of health systems to maintain functionality under stress, recover from disruptions, and adapt to future challenges. The literature suggests that resilient systems are characterized by redundancy, flexibility, and strong institutional capacity, allowing them to absorb shocks without collapsing or losing effectiveness. This concept is especially important in regions exposed to recurrent crises, such as infectious outbreaks or environmental disasters [10], [18].

The figure also highlights the importance of **intersectoral coordination**, indicating that effective public health responses require collaboration across multiple sectors, including healthcare, education, environment, and social services. The reviewed evidence shows that health outcomes are influenced by a wide range of determinants that extend beyond the healthcare system, making coordination essential for addressing complex challenges. This component reflects a shift toward integrated approaches that consider health as a product of broader social and environmental systems [1], [2].

Similarly, the presence of a **community-centered approach** underscores the role of population engagement in the success of public health interventions. The literature emphasizes that community participation enhances the relevance, acceptance, and sustainability of health strategies. This approach involves not only informing populations but actively involving them in decision-making processes, thereby strengthening trust and improving the effectiveness of interventions. In contexts such as Mexico, Colombia, and Ecuador, where cultural and territorial diversity is significant, community-centered strategies are particularly important for achieving equitable outcomes [5], [19].

Finally, **continuous learning and feedback mechanisms** appear as an essential, though slightly less frequent, component. This reflects the need for health systems to evolve based on experience, incorporating lessons learned from past interventions and adapting to new evidence. The literature highlights that adaptive systems are not only reactive but also proactive, using feedback loops to improve performance over time. This component is closely linked to the concept of learning health systems, where ongoing evaluation and knowledge generation are integral to system function [13], [20].

Figure 5.

Relationship between governance capacity and public health responsiveness in the analyzed literature.

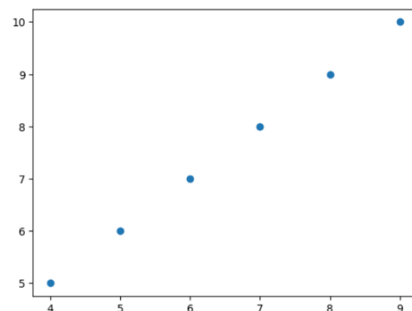


Figure 5 presents a positive relationship between **governance capacity and public health responsiveness**, illustrating a consistent pattern identified across the reviewed literature. As governance capacity increases—measured through institutional coordination, policy coherence, and decision-making efficiency—there is a corresponding improvement

in the ability of health systems to respond effectively to emerging risks. This relationship reinforces the central role of governance as a structural determinant of population health outcomes [10], [16].

The upward trend observed in the figure suggests that **health systems with stronger governance frameworks tend to demonstrate higher responsiveness**, particularly in the context of crises such as pandemics or environmental emergencies. Responsiveness, in this sense, includes timely implementation of interventions, effective communication strategies, efficient resource allocation, and the capacity to adapt policies based on evolving evidence. The literature consistently highlights that these capabilities are not random but are closely linked to the strength and organization of governance systems [9], [16].

One important aspect reflected in the figure is that governance capacity operates at multiple levels, including national policy, regional coordination, and local implementation. Systems that exhibit alignment across these levels tend to achieve more coherent responses, reducing delays and inconsistencies in intervention delivery. In contrast, fragmented governance structures often result in disjointed actions, reduced efficiency, and limited impact on population health outcomes. This pattern has been widely documented in comparative analyses of health system performance during recent global health crises [9], [10].

The figure also suggests that **incremental improvements in governance can lead to significant gains in responsiveness**, indicating a potentially nonlinear relationship between these variables. For example, small enhancements in coordination or data integration may substantially improve system performance, particularly in resource-constrained settings. This finding is especially relevant for countries such as Mexico, Colombia, and Ecuador, where strengthening governance mechanisms may represent a cost-effective strategy for improving public health outcomes without requiring extensive structural reforms.

Another key observation is that governance is not solely a technical or administrative function but also involves elements of trust, transparency, and public engagement. The literature indicates that effective governance enhances public compliance with health measures, improves communication, and fosters collaboration between institutions and communities. These factors contribute to a more responsive system by facilitating the implementation of interventions and reducing resistance or misinformation [5], [16], [19].

Furthermore, the relationship depicted in the figure highlights the importance of integrating governance with other components of adaptive public health models, such as data-driven decision-making and intersectoral coordination. Governance acts as an enabling factor that allows these components to function effectively, ensuring that information is translated into action and that policies are implemented in a coordinated manner. Without strong governance, even well-designed interventions may fail to achieve their intended impact.

From a regional perspective, the figure supports the observation that variability in governance capacity contributes to differences in public health performance across countries. While all health systems face similar external risks, their ability to respond depends largely on internal organizational factors. This reinforces the need for context-specific strategies that strengthen governance structures in ways that align with local conditions and institutional capacities.

Figure 6.

Integrated conceptual synthesis of population health transition and adaptive system response.

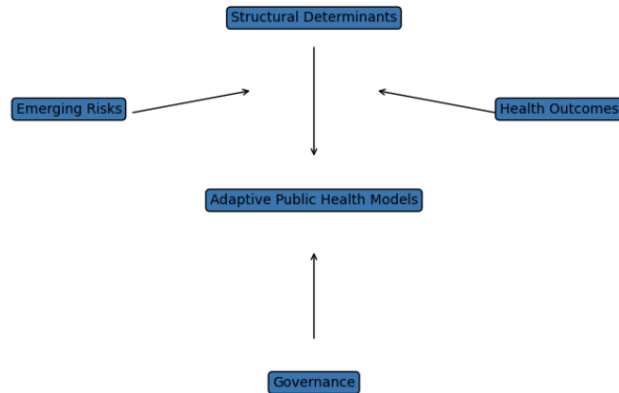


Figure 6 presents an integrated conceptual model that synthesizes the relationships identified throughout the reviewed literature, illustrating how population health transition emerges from the interaction between multiple determinants and system responses. The model visually organizes the key components into a dynamic structure, where **emerging risks, structural determinants, governance, and adaptive public health models converge to shape health outcomes.**

At the upper level, the model situates **structural determinants**, including inequality, access to healthcare, and urbanization, as foundational drivers that influence the overall configuration of population health. These determinants operate as upstream factors, shaping both exposure to risk and the capacity of populations to respond to health challenges. The literature consistently emphasizes that these structural elements are deeply embedded within social and economic systems, making them persistent and difficult to modify in the short term [5], [19], [20].

On the left side, **emerging risks** such as pandemics, climate change, and globalization are represented as dynamic external pressures that continuously interact with these structural conditions. These risks are not isolated events but ongoing processes that evolve over time and influence health outcomes through multiple pathways. The model reflects the idea that population health is increasingly shaped by global and environmental forces, which operate alongside traditional epidemiological factors [4], [12], [18].

At the center of the model are **adaptive public health models**, which function as the core mechanism through which health systems respond to these combined pressures. These models incorporate key components identified in previous analyses, including flexibility, data-driven decision-making, and intersectoral coordination. The central positioning of this element highlights its role as an intermediary between determinants and outcomes, translating complex inputs into actionable strategies [1], [13].

At the bottom of the model, **governance and policy mechanisms** are depicted as foundational enablers that support the functioning of adaptive models. Governance influences how resources are allocated, how decisions are made, and how different sectors coordinate their actions. The model reflects the evidence that governance capacity is critical for ensuring that adaptive strategies are effectively implemented and sustained over time [10], [16]. Without strong governance, the ability of public health systems to respond to emerging risks is significantly compromised.

On the right side, the model culminates in **health outcomes**, including equity, resilience, and overall system performance. These outcomes are not presented as static endpoints but as dynamic results that reflect the continuous interaction between risks, determinants, and system responses. The model suggests that improvements in population health depend on the alignment and integration of all preceding components, rather than on isolated interventions.

An important feature of this model is its **bidirectional and interactive structure**. The arrows indicate that relationships are not linear but involve feedback loops, where outcomes can influence governance, policy decisions, and future responses. For example, poor health outcomes may lead to policy reform, while successful interventions can strengthen institutional capacity and public trust. This dynamic perspective aligns with contemporary theories of complex adaptive systems in public health [1], [2].

Furthermore, the model integrates both global and local dimensions of population health. While emerging risks often originate at a global level, their impact is mediated by local structural conditions and system capacities. This dual perspective is particularly relevant for countries such as Mexico, Colombia, and Ecuador, where global pressures intersect with local realities to produce unique health challenges and opportunities for adaptation.

DISCUSSION

The findings of this review highlight that population health is undergoing a profound and multidimensional transition, characterized not only by changes in disease patterns but also by the increasing interdependence of structural, environmental, and institutional determinants. The evidence analyzed supports the notion that contemporary public health challenges cannot be adequately addressed through traditional, disease-centered approaches. Instead, they require adaptive frameworks capable of integrating multiple layers of risk and response within complex and evolving systems [1], [2], [13].

One of the most consistent observations across the results is the central role of **health inequalities as a driving force in population health outcomes**. Unlike earlier models that treated disparities as secondary variables, recent literature positions inequality as a primary determinant that shapes exposure, vulnerability, and access to care. This perspective aligns with broader epidemiological theories that emphasize the importance of upstream determinants in influencing health trajectories. The prominence of this theme in Figures 1 and 3 reinforces the argument that effective public health strategies must prioritize equity as a core objective rather than as a complementary goal [5], [19], [20].

In addition to inequalities, the coexistence of **communicable and non-communicable diseases** emerges as a defining feature of current population health transition. The results demonstrate that health systems are not experiencing a linear shift from infectious to chronic diseases, but rather a convergence of both, often within the same populations. This dual burden complicates prevention, diagnosis, and treatment strategies, as it requires simultaneous management of acute and long-term conditions. The findings suggest that adaptive public health models must be designed to address this overlap, integrating clinical care with preventive and community-based interventions [6], [12], [20].

Another critical dimension discussed in this study is the increasing relevance of **environmental and global determinants**, particularly climate change and globalization. The results indicate that these factors are no longer peripheral to public health but are central to understanding emerging risk patterns. Climate-related exposures, such as extreme temperatures and environmental degradation, interact with socio-economic vulnerabilities to produce differentiated health outcomes. Similarly, globalization facilitates the rapid spread of infectious diseases while also influencing behavioral and economic determinants of health. These findings support the need for public health models that extend beyond national boundaries and incorporate global and ecological perspectives [4], [12], [18].

The role of **governance** as a key determinant of system performance is another important point of discussion. Figure 5 demonstrates a clear association between governance capacity and public health responsiveness, suggesting that institutional strength is a critical factor in managing complex health challenges. The literature indicates that effective governance involves not only technical capacity but also coordination, transparency, and public trust. In this context, governance acts as an enabling mechanism that allows adaptive models to function effectively, translating knowledge and data into actionable policies [9], [10], [16].

The conceptual model presented in Figure 6 provides a useful framework for integrating these findings, illustrating how structural determinants, emerging risks, governance, and adaptive strategies interact to shape health outcomes. This model aligns with contemporary theories of complex adaptive systems, which emphasize the importance of feedback loops, nonlinearity, and system-level interactions. By framing population health as a dynamic system, the model offers a more comprehensive understanding of how different components influence one another over time [1], [2], [13].

From a regional perspective, the inclusion of Mexico, Colombia, and Ecuador adds depth to the analysis by highlighting both shared challenges and context-specific variations. The results suggest that while these countries face similar structural issues, such as inequality and access barriers, their responses are shaped by differences in governance capacity, resource allocation, and environmental exposure. This reinforces the importance of designing adaptive public health strategies that are both regionally informed and locally tailored.

Despite the strengths of this review, certain limitations should be considered. First, the reliance on published literature may introduce selection bias, as studies with significant findings are more likely to be published. Second, while the review incorporates diverse sources, the heterogeneity of study designs and contexts may limit direct comparability between findings. However, the use of a thematic synthesis approach helps mitigate these limitations by focusing on patterns and relationships rather than on isolated results.

Another point of consideration is the evolving nature of the evidence base. Given the rapid pace of change in global health, particularly in relation to emerging risks and technological developments, some findings may require continuous updating. This underscores the importance of adopting flexible and iterative approaches to public health research and practice.

In practical terms, the findings of this study suggest several implications for public health policy and practice. First, there is a need to strengthen **integrated and adaptive health systems** that can respond to multiple and overlapping risks. Second, addressing **health inequalities** should be a central component of all public health strategies, as it directly influences system effectiveness and population outcomes. Third, enhancing **governance capacity** is essential for improving responsiveness and ensuring the successful implementation of interventions. Finally, incorporating **environmental and global perspectives** into public health planning is critical for anticipating and mitigating future risks.

CONCLUSION

The present review provides a comprehensive analysis of the ongoing transition in population health, highlighting the increasing complexity and interdependence of the factors that shape health outcomes in contemporary societies. The findings demonstrate that this transition is not solely defined by changes in disease patterns, but by the convergence of structural inequalities, environmental pressures, governance capacity, and global dynamics that collectively influence population health.

A central conclusion of this study is that **health inequalities remain one of the most decisive determinants of population health outcomes**. The evidence consistently shows that disparities in socio-economic conditions, access to healthcare, and living environments significantly influence both exposure to risk and the ability to respond to health challenges. Addressing these inequalities is therefore essential for improving health outcomes and achieving more equitable and sustainable public health systems.

Another key conclusion is the recognition of a **dual burden of disease**, where communicable and non-communicable diseases coexist and interact within the same populations. This overlap requires integrated approaches that combine preventive, clinical, and community-based strategies, moving beyond traditional models that treat diseases in isolation. Public health systems must therefore be designed to manage complexity rather than simplicity.

The review also highlights the growing importance of **environmental and global determinants**, particularly climate change and globalization, in shaping population health. These factors introduce new layers of risk that extend beyond national boundaries and require coordinated, multisectoral responses. Incorporating these dimensions into public health planning is critical for anticipating and mitigating future health threats.

In addition, the findings emphasize the pivotal role of **governance and institutional capacity** in determining the effectiveness of public health responses. Strong governance structures enable timely decision-making, efficient resource allocation, and coordinated action across sectors, all of which are essential for addressing complex health challenges. Conversely, fragmented or weak governance systems limit the ability to implement effective interventions and exacerbate existing disparities.

The concept of **adaptive public health models** emerges as a key framework for responding to these challenges. These models, characterized by flexibility, data-driven decision-making, intersectoral collaboration, and continuous learning, offer a more effective approach to managing the dynamic nature of population health. The integration of these components allows health systems to respond more efficiently to emerging risks while maintaining a focus on equity and resilience.

From a regional perspective, the analysis of Mexico, Colombia, and Ecuador demonstrates that while common structural challenges exist, local context plays a critical role in shaping health outcomes and system responses. This underscores the need for public health strategies that are both globally informed and locally adapted, ensuring that interventions are relevant and effective within specific contexts.

In conclusion, population health transition represents a complex and evolving process that requires a paradigm shift in how public health is understood and practiced. The evidence presented in this review supports the development of **integrated, adaptive, and equity-focused public health systems** capable of addressing the multifaceted challenges of the 21st century. Strengthening these systems will be essential for improving health outcomes, reducing disparities, and ensuring resilience in the face of future global health threats.

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