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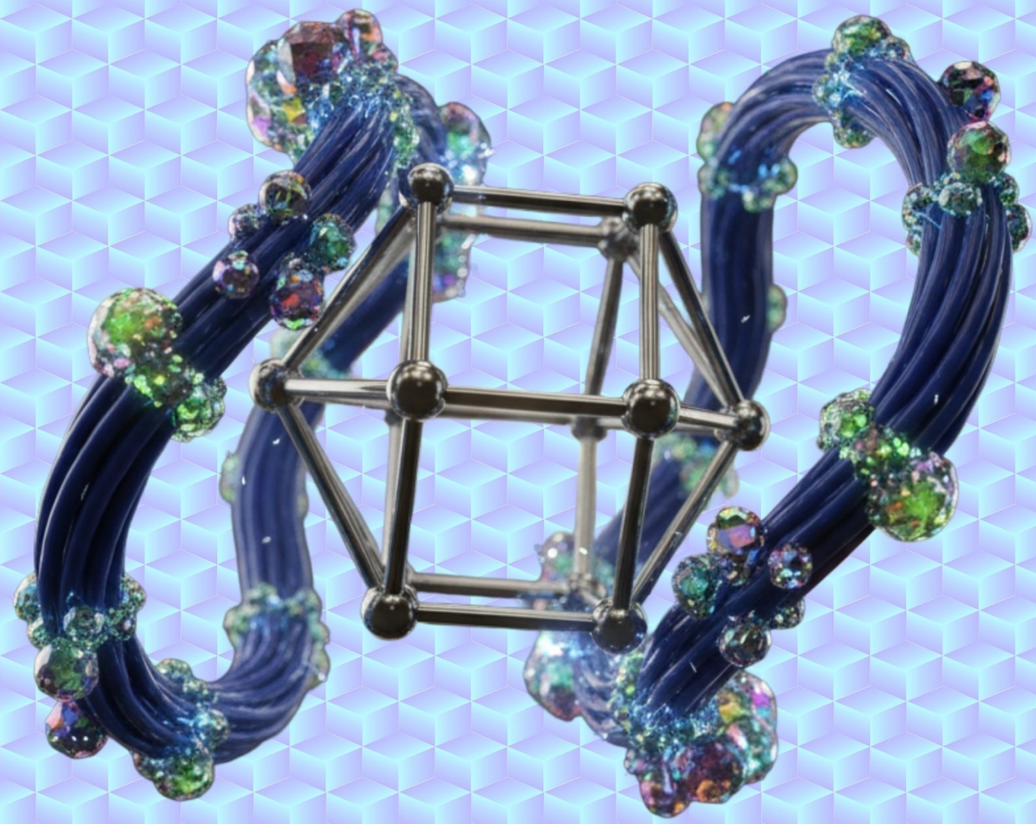

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Epidemiologic Transitions and Preventive Frameworks in Latin America: Structural Determinants, Internal Medicine and Population Health Challenges in the 21st Century

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ABSTRACT

Population health in the 21st century is shaped by the convergence of chronic disease burdens, emergent infectious threats, environmental pressures and widening social inequities. This review analyzes epidemiologic dynamics in Mexico, Colombia and Ecuador within the broader global context, integrating findings from mortality patterns, behavioral and metabolic risk profiles, structural determinants and health-system capacities. Results indicate that the three countries share an advanced epidemiologic transition dominated by noncommunicable diseases, while still experiencing persistent communicable threats and injury-related mortality. Elevated levels of obesity, hypertension and physical inactivity contribute to an intensified risk environment

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compared with global averages, reflecting rapid lifestyle and urban transitions. Social determinants—including inequality, urbanization and variable access to primary care—further differentiate population vulnerabilities. Additionally, substantial variation in preventive capacity and epidemiologic intelligence underscores systemic disparities in preparedness and response. The findings highlight the need for integrated, multilevel preventive strategies that address metabolic risks, strengthen primary care, reduce inequities and modernize surveillance systems. This study contributes to a nuanced understanding of how diverse structural and epidemiologic forces shape population health trajectories in the 21st century.

KEYWORDS

population health epidemiologic transitions noncommunicable diseases preventive strategies social determinants epidemiologic intelligence Latin America Mexico Colombia Ecuador

INTRODUCTION

Population health in the 21st century is shaped by forces that are more dynamic, interconnected, and unpredictable than in any previous era. The rapid demographic transitions occurring across regions such as Latin America, combined with accelerated urbanization, climate variability, and widening social inequities, have reshaped the epidemiologic landscape and challenged traditional public health paradigms. Countries including Mexico, Colombia, and Ecuador exemplify this complexity: each faces a dual burden of persistent infectious diseases and a rising tide of noncommunicable conditions, all within environments marked by social vulnerabilities, heterogeneous health-system performance, and shifting population structures. Understanding these dynamics is essential for designing preventive strategies capable of responding to contemporary threats while anticipating future epidemiologic transitions.

Over the past decades, global health priorities have evolved substantially, reflecting a growing recognition of the multifactorial drivers of population risk and the need for more integrated approaches to prevention. Strategic analyses have highlighted how international health agendas increasingly emphasize universal health coverage, resilient primary care systems, and the strengthening of epidemiologic surveillance capacities as foundational pillars for disease control and societal well-being [1], [5], [16]. At the same time, large comparative risk assessments have demonstrated that the global burden of disease is driven by an expanding range of modifiable exposures—ranging from metabolic and behavioral factors to environmental hazards—whose interactions vary widely across regions and socioeconomic groups [2], [10], [17]. These findings underscore the necessity of revisiting traditional epidemiologic frameworks and adapting them to the complexity of contemporary population health.

The COVID-19 pandemic further exposed the fragility of global and regional health systems, revealing gaps in leadership, communication, intersectoral collaboration, and risk prediction. Analyses of public health performance during the pandemic emphasize the importance of decisive, evidence-based leadership, equitable access to preventive services, and the ability to integrate epidemiologic intelligence into policy decisions [4], [9], [11], [14], [19]. For countries in Latin America, the pandemic intersected with pre-existing structural disparities, disproportionately affecting populations with long-standing social and economic disadvantages. These inequities mirror the social determinants of health that have been repeatedly identified as key drivers of morbidity and mortality worldwide [8], reinforcing the argument that preventive strategies must extend beyond biomedical interventions and incorporate social, environmental, and policy domains.

Climate change has emerged as another dominant influence on global population health, altering disease ecology, intensifying extreme weather events, and reshaping the distribution of vector-borne and respiratory illnesses. Recent analyses highlight that environmental transformations interact with demographic conditions—especially urban density—to modify patterns of disease transmission and population vulnerability [6], [12], [18], [20]. These shifts are evident in multiple Latin American cities, where rapid growth has outpaced infrastructure development, thereby amplifying the transmission potential of infectious diseases and complicating the delivery of preventive and clinical services.

Despite these challenges, international efforts toward strengthening epidemiologic systems and expanding primary health care offer promising avenues for reducing disease burden. The revitalization of primary care as the backbone of

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universal health coverage has been associated with improved outcomes, enhanced equity, and more efficient use of resources [5], [16]. Likewise, modern epidemiologic intelligence systems—incorporating real-time surveillance, digital tools, and predictive analytics—have demonstrated substantial value in early outbreak detection and response [19]. However, the translation of these global strategies into regional contexts requires acknowledging local realities, including workforce limitations, variability in governance structures, and population-specific risk profiles. Mexico, Colombia, and Ecuador provide diverse examples of how these barriers and opportunities manifest differently, offering a valuable comparative lens for analyzing population health dynamics.

Prior research provides a strong conceptual foundation for understanding current epidemiologic challenges, yet gaps remain in integrating multi-country perspectives that reflect contextual diversity in the Americas. For instance, while global definitions and frameworks for population health and global health have been refined over the years [3], [7], their operationalization across middle-income countries continues to vary widely. There is also a need to clarify how preventive strategies—particularly those addressing behavioral risks, environmental exposures, and social determinants—can be adapted to heterogeneous populations with differing health-system capacities and epidemiologic profiles. Furthermore, despite the substantial progress in controlling specific infectious diseases such as malaria [13], the uneven distribution of health gains suggests that comprehensive prevention requires not only biomedical innovations but also structural and societal interventions rooted in local needs.

Building on these gaps, the present review addresses the following guiding questions: **(1)** How have population health patterns evolved in the 21st century in regions with distinct social and epidemiologic contexts, specifically Mexico, Colombia, and Ecuador? **(2)** What are the principal epidemiologic challenges currently shaping population risk across communicable and noncommunicable domains? **(3)** Which preventive strategies—supported by contemporary evidence—offer the greatest potential for mitigating these risks at both local and regional levels? These questions derive directly from prior theoretical and empirical work demonstrating the interplay between demographic transitions, environmental pressures, behavioral factors, and health-system performance [1]–[20].

The methodological design of this review aligns with these objectives by synthesizing evidence across epidemiology, public health policy, and environmental health, while integrating cross-country comparisons relevant to Latin America. This approach allows for the identification of shared regional challenges as well as context-specific differences that shape prevention priorities. Ultimately, the aim is to offer a comprehensive and nuanced perspective on population health dynamics in the 21st century, informing future research, educational efforts, and cross-national strategies aimed at strengthening prevention and enhancing health security.

DEVELOPMENT

Population health in the 21st century is marked by a complex interplay of demographic, social, environmental, and health-system factors that reshape traditional epidemiologic patterns. Global analyses show that countries are no longer dealing with a simple transition from infectious to noncommunicable diseases, but rather with overlapping burdens that coexist and interact in different ways according to context and level of development [1], [2], [6]. In regions such as Latin America—and particularly in countries like Mexico, Colombia, and Ecuador—these dynamics are intensified by persistent social inequalities, heterogeneous health coverage, and uneven access to preventive and clinical services [3], [5], [16].

From a global perspective, the evolution of health priorities has been driven by a combination of scientific advances, international agendas and the cumulative evidence on avoidable risk factors. Strategic reflections on global health emphasize that current priorities must integrate universal health coverage, strong primary health care, and robust systems for measuring and monitoring health outcomes across populations [1], [3], [5], [16]. At the same time, comparative risk assessments have quantified how much of the global burden of disease is attributable to modifiable exposures—such as tobacco use, unhealthy diet, physical inactivity, excess body weight, and environmental pollution—highlighting the enormous potential of prevention-oriented policies [2], [10], [15], [17]. These findings support a shift from a purely curative vision of health systems toward a model in which prevention and risk management are central, both at the individual and population levels.

One of the defining characteristics of 21st-century population health is the dual and sometimes triple burden of disease. While noncommunicable diseases (NCDs) such as cardiovascular disease, diabetes, cancer and chronic respiratory

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conditions account for a growing share of mortality and disability worldwide, infectious diseases remain highly relevant in many low- and middle-income settings [2], [10], [12], [18]. In Latin America, Mexico, Colombia, and Ecuador must simultaneously confront NCD epidemics related to lifestyle and urbanization, persistent challenges in infectious disease control (including vector-borne diseases and tuberculosis), and emerging threats such as arboviruses and novel respiratory pathogens [6], [12], [18], [20]. This combination creates intense pressure on health services and requires integrated strategies that go beyond the traditional division between "communicable" and "noncommunicable" care.

The COVID-19 pandemic demonstrated the fragility of existing structures and revealed how multiple epidemics can intersect as syndemics, where biological, social, and environmental dimensions reinforce each other [4], [9], [11], [14]. Analyses of excess mortality in 2020 showed that the impact of COVID-19 went far beyond reported deaths, interacting with pre-existing chronic conditions, delays in care, and health-system saturation [14]. In countries with marked inequalities and segmented health systems, vulnerable groups experienced disproportionate risk due to overcrowded housing, informal employment, barriers to timely care, and structural discrimination [8], [9], [11]. These patterns confirmed that population health cannot be understood without considering social determinants such as income, education, employment, gender, ethnicity, and place of residence [3], [8], [11].

Social determinants are not only background factors; they actively shape exposure, vulnerability and capacity to respond at both individual and community levels. Classic and contemporary analyses have repeatedly shown that gradients in education, income, housing conditions and access to services translate into gradients in morbidity and mortality [3], [8], [15]. During the COVID-19 crisis, these inequities became especially visible in marginalized neighborhoods, rural areas, and groups with limited access to information and digital technologies [4], [9], [11]. For Mexico, Colombia and Ecuador, this means that any effective preventive strategy must explicitly incorporate social protection policies, intersectoral actions and community participation, rather than relying solely on clinical interventions delivered within health facilities.

Environmental and climatic factors add an additional layer of complexity to population health dynamics. Climate change alters temperature, rainfall, and ecological conditions in ways that affect the distribution of vectors, the seasonality of infectious diseases, and the frequency of extreme events such as floods and heat waves [6], [12], [17], [18]. Long-term analyses of air pollution demonstrate its contribution to cardiovascular and respiratory disease, as well as premature mortality, particularly in densely populated urban areas [6], [17]. Evidence from multiple regions suggests that populations with high baseline vulnerability—due to poverty, informal housing or limited access to health care—bear a disproportionate share of these environmental risks [6], [17], [20]. In rapidly growing Latin American cities, where urban planning has often lagged behind population growth, the interaction between density, mobility, pollution, and social segregation can amplify the transmission of infectious diseases and the burden of chronic conditions [6], [17], [20].

Urbanization itself is a key driver of epidemiologic change. Systematic reviews on urbanization and infectious disease transmission show that high population density, mobility patterns, housing characteristics, and access to basic services influence the reproduction number and geographic spread of pathogens [20]. At the same time, cities concentrate both problems and opportunities: although they may facilitate transmission and environmental exposures, they also offer greater potential for organizing preventive services, implementing surveillance systems, and deploying digital tools for health promotion and disease monitoring [3], [16], [19], [20]. For Mexico, Colombia, and Ecuador, the challenge lies in converting urban growth from a risk factor into an asset by investing in primary care networks, integrated surveillance platforms, and social programs that reduce intra-urban disparities.

The global experience with infectious disease control provides valuable lessons for current and future challenges. Successes in reducing the burden of diseases such as malaria have relied not only on effective tools—like insecticide-treated nets and improved therapies—but also on sustained financing, strong surveillance and targeted interventions in high-risk areas [13], [18]. Analyses of emerging infectious diseases show that land-use change, wildlife–human interfaces, international travel and trade, and health-system weaknesses are interconnected determinants of new outbreaks [12], [18]. This body of evidence underscores the importance of early warning systems, epidemiologic intelligence platforms and rapid response capabilities to prevent small events from becoming major crises [18], [19]. Recent developments in outbreak detection methods, including the integration of digital data streams and advanced analytics, open new possibilities for timely identification of unusual patterns and informed decision-making [19].

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In parallel, research on preventable causes of death and risk factor modification highlights that a substantial proportion of mortality in high- and middle-income countries is attributable to behaviors and exposures that are amenable to policy and individual change [2], [10], [15], [17]. Comparative risk assessments in settings like the United States have quantified the impact of tobacco use, poor diet and physical inactivity, reinforcing the argument that health systems must systematically integrate prevention into their routine operations [15]. For Latin American countries, where lifestyle changes associated with urbanization and globalization have accelerated, translating this evidence into culturally appropriate prevention strategies is a critical task. This includes strengthening health promotion, regulating unhealthy products, designing supportive environments, and ensuring that primary care teams are equipped to address behavioral risks efficiently [5], [10], [15], [16].

Primary health care and universal health coverage emerge as central components in this evolving scenario. Analyses of health systems show that strong, people-centered primary care is associated with better population outcomes, reduced inequities, and more efficient use of resources [5], [16]. Universal health coverage frameworks in the Americas emphasize not only financial protection but also the availability of quality services, the organization of care networks, and the integration of public health functions such as surveillance and health promotion [16]. For Mexico, Colombia, and Ecuador, expanding coverage while improving quality and continuity of care is essential to confront both the growing burden of chronic diseases and the persistent challenges of infectious disease control [3], [5], [10], [16]. This requires political commitment, sustainable financing and governance arrangements that align incentives toward prevention rather than fragmentation and short-term responses.

Taken together, these elements configure a 21st-century panorama in which population health dynamics are shaped by overlapping transitions, structural inequities, environmental pressures and evolving health systems. The epidemiologic challenges of this period cannot be addressed through isolated interventions; instead, they demand integrated preventive strategies that combine clinical, public health, social and environmental actions. The evidence synthesized in global reports, risk-factor analyses, infectious disease studies, and health system evaluations [1]–[20] provides a robust foundation for designing such strategies. However, their effective implementation depends on adapting them to specific contexts, learning from comparative experiences between countries, and aligning them with local priorities and capacities.

Within this framework, Mexico, Colombia, and Ecuador offer a relevant set of cases to examine how global trends manifest in different realities and how prevention can be organized in diverse health-system configurations. The following sections translate this analytical perspective into concrete objectives, a clearly defined object of study, and a methodological approach that allows a structured examination of population health dynamics and preventive strategies in the 21st century.

GENERAL OBJECTIVE AND SPECIFIC OBJECTIVES

To critically analyze the evolving dynamics of population health in the 21st century—focusing on Mexico, Colombia, and Ecuador—by identifying major epidemiologic challenges and synthesizing evidence-based preventive strategies that strengthen public health systems and reduce population-level risks.

A. Cognitive Domain

1. **Identify** key epidemiologic transitions and determinants shaping population health across diverse global and Latin American contexts. *(Bloom: Remember)*
2. **Describe** the distribution and trends of major communicable and noncommunicable diseases affecting Mexico, Colombia, and Ecuador. *(Bloom: Understand)*
3. **Apply** established epidemiologic frameworks to interpret risk-factor patterns and population vulnerabilities. *(Bloom: Apply)*
4. **Analyze** the interaction between social, environmental, and health-system determinants influencing disease burden in the 21st century. *(Bloom: Analyze)*

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5. **Evaluate** existing prevention and control strategies in terms of effectiveness, feasibility, and equity across different population groups. *(Bloom: Evaluate)*
6. **Develop** an integrated conceptual model that connects epidemiologic dynamics with multilevel preventive approaches applicable to Latin American health systems. *(Bloom: Create)*

B. Psychomotor Domain

1. **Detect** patterns of epidemiologic change by interpreting graphs, temporal series, and comparative health indicators. *(Perception)*
2. **Organize** data from different sources into structured analytical schemes to support evidence-based interpretations. *(Guided Response)*
3. **Construct** comparative tables or conceptual maps to visualize relationships among determinants, risks, and preventive interventions. *(Complex Overt Response)*
4. **Refine** analytical tools—such as frameworks or matrices of determinants—to adapt them to varied population settings in Mexico, Colombia, and Ecuador. *(Adaptation)*

C. Affective Domain

1. **Acknowledge** the ethical responsibility of addressing epidemiologic inequities that disproportionately affect vulnerable groups in the Americas. *(Receiving)*
2. **Demonstrate willingness** to integrate equity-oriented thinking into the interpretation of epidemiologic patterns and preventive strategies. *(Responding)*
3. **Value** the role of intersectoral collaboration, community engagement, and culturally appropriate interventions in improving population health outcomes. *(Valuing)*
4. **Prioritize** preventive, people-centered approaches as fundamental pillars of resilient health systems in Latin America. *(Organizing)*
5. **Embody** a public health perspective that consistently promotes evidence-based, equitable, and sustainable decision-making for population benefit. *(Characterizing)*

OBJECT OF STUDY

The object of study in this review encompasses the complex, multidimensional system of **population health dynamics** as they unfold in the 21st century, with a particular emphasis on understanding how epidemiologic challenges and preventive strategies interact across different sociopolitical and environmental contexts. Rather than examining diseases in isolation, the study focuses on the **interconnected nature of health determinants**, recognizing that population health is shaped simultaneously by biological, behavioral, environmental, social, and structural factors that influence risk distribution and health outcomes at multiple levels.

At its core, the object of study is the **set of epidemiologic patterns, transitions, and determinants** that characterize contemporary population health. This includes the dual burden of communicable and noncommunicable diseases; the emergence and re-emergence of infectious threats; the rising prevalence of chronic conditions linked to lifestyle, aging, and metabolic risk; and the intensification of environmental and climatic pressures that reshape disease ecology and population vulnerabilities. These components form a dynamic system in which changes in one domain often produce cascading effects in others, requiring a holistic approach to understanding and intervention.

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A central component of the study is the examination of **population-level determinants**, particularly the social, economic, and environmental structures that modulate risk exposure and capacity for prevention. These determinants—such as education, income, housing quality, occupational conditions, gender inequities, environmental pollution, and urbanization patterns—define not only who is most affected by disease but also who has greater or lesser access to preventive resources, health information, and timely care. Understanding this landscape is essential to designing preventive strategies that are equitable, culturally relevant, and adaptable to diverse settings.

While the review adopts a global perspective, its primary analytical lens is directed toward **Latin America**, focusing specifically on **Mexico, Colombia, and Ecuador** as illustrative cases within the region. These three countries represent diverse but interrelated scenarios in terms of epidemiologic trends, health-system organization, demographic transitions, and social inequities. By analyzing them jointly, the study seeks to understand how global challenges are expressed in different national contexts and how local determinants and policies shape the trajectory of population health. This comparative approach allows for identifying convergent challenges—such as rapid urbanization, environmental degradation, persistent inequality, and uneven access to care—while also highlighting the distinctive features of each health system.

The object of study also includes the **preventive strategies** that respond to these epidemiologic dynamics, understood not only as clinical or biomedical interventions but as **multilevel actions** that operate across public health systems, community structures, and policy frameworks. This encompasses primary prevention (behavioral risk reduction, health promotion, vaccination, environmental regulation), secondary prevention (screening, early detection, risk stratification), and tertiary prevention (management of chronic conditions to reduce complications and disability). It also extends to systemic interventions such as strengthening primary care networks, expanding universal health coverage, implementing digital surveillance systems, and adopting intersectoral policies that address social determinants of health.

Another dimension of the object of study is the **population itself**, conceptualized not simply as aggregates of individuals but as **dynamic groups influenced by demographic characteristics, social structures, mobility patterns, and cultural practices**. In Mexico, Colombia, and Ecuador, populations are marked by heterogeneity—rural versus urban divides, indigenous and Afro-descendant communities, migrant groups, socioeconomically stratified urban neighborhoods—each with distinct patterns of vulnerability and resilience. These populations experience diverse combinations of risks and protective factors, making it essential to understand how preventive strategies must be tailored to specific demographic and community contexts.

Moreover, the study examines **health systems as adaptive entities**, analyzing how their organizational structures, resource distribution, governance arrangements, and operational capacities modulate prevention efforts and population outcomes. By exploring how different systems respond to epidemiologic pressures—whether through integrated primary care, fragmentated networks, or emergency-driven responses—the study highlights the relevance of systemic resilience as part of the broader object of inquiry.

Finally, the object of study includes the **temporal dimension** of population health: the transitions and transformations occurring as societies face new global risks, technological advances, demographic shifts, and environmental changes. The 21st century presents conditions distinct from previous eras, including accelerated climate change, widespread urbanization, global interdependence, and digitalization of health information. Understanding how these forces shape epidemiologic processes today—and will continue to do so—constitutes an essential component of the study.

In summary, the object of study is a **comprehensive conceptual and analytical framework** that encompasses:

- The epidemiologic patterns and transitions shaping population health.
- The multilevel determinants—biological, social, environmental, structural—that influence these patterns.
- The preventive strategies operating at individual, community, health-system, and policy levels.
- The comparative contexts of Mexico, Colombia, and Ecuador as representative scenarios of Latin American health dynamics.
- The evolving global conditions that redefine population risks and opportunities for prevention.

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This broad and integrated object of study enables a deeper understanding of the challenges and possibilities for improving population health in the 21st century, serving as a foundation for the methodological approach and subsequent phases of the investigation.

METHODOLOGY

The methodological approach adopted for this study combines the **Scientific Method** with a structured **Delphi-informed comparative framework**, allowing for systematic analysis, triangulation of evidence and cross-national interpretation of epidemiologic challenges in Mexico, Colombia, and Ecuador. This integrated approach ensures methodological rigor, reproducibility, and alignment with the study's objectives and object of inquiry.

The methodology consists of four core components: **(1) problem identification and conceptual framing**, **(2) structured literature search and evidence extraction**, **(3) expert-informed comparative synthesis following Delphi principles**, and **(4) development of an integrated analytical model of preventive strategies**. Each component is described in detail to enable replication by other researchers.

1. Problem Identification and Conceptual Framing

The study begins with the systematic identification of the central problem: the evolving population health dynamics of the 21st century and their implications for prevention in Latin American settings. This stage includes:

1. Defining the scope of the investigation—population health determinants, epidemiologic transitions, preventive strategies, and regional comparison.
2. Formulating guiding research questions derived from gaps identified in prior literature.
3. Establishing a conceptual model that connects determinants, epidemiologic trends, and preventive strategies, guiding the subsequent phases of evidence collection and synthesis.

This phase anchors the investigation in verifiable gaps and aligns the analytical lenses across all sections of the study.

2. Structured Literature Search and Evidence Extraction

A systematic, multi-stage search strategy was implemented to ensure comprehensive coverage of relevant evidence from global and regional sources. Although the review does not function as a full systematic review, it follows methodological rigor to ensure transparency and replicability.

2.1 Databases and Sources

The following databases and institutional repositories were consulted:

- **PubMed / MEDLINE**
- **Scopus**
- **Web of Science**
- **WHO Global Health Observatory**
- **PAHO/OPS regional databases**
- **National epidemiologic reports** from Mexico, Colombia, and Ecuador

Only peer-reviewed academic literature, official reports, and high-quality epidemiologic analyses were included.

2.2 Search Strategy

Search terms were organized using Boolean operators and controlled vocabulary, including:

- "population health dynamics"
- "epidemiologic transitions"
- "preventive strategies"
- "noncommunicable diseases AND Latin America"

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- "emerging infectious diseases AND global health"
- "Mexico OR Colombia OR Ecuador AND health systems"
- "social determinants of health"
- "climate change AND epidemiology"

The time frame prioritized the last two decades, with exceptions for seminal works relevant to foundational definitions and long-term trends.

2.3 Selection Criteria

Inclusion criteria:

- Relevance to epidemiology, public health, health systems, or prevention.
- Data pertaining to Latin America and/or global comparative analyses.
- Publications with clear methods and validated data sources.

Exclusion criteria:

- Non–peer reviewed commentaries unless providing essential conceptual insight.
- Reports without methodological transparency.
- Redundant publications covering identical datasets without added value.

2.4 Data Extraction and Categorization

Extracted information was classified into thematic domains:

1. Social and structural determinants of health
2. Noncommunicable disease burden
3. Infectious disease dynamics
4. Environmental and climatic determinants
5. Health-system structures and response capacities
6. Preventive strategies across primary, secondary, and tertiary levels

This classification allowed systematic mapping across the three countries under study.

3. Comparative Synthesis Using a Delphi-Informed Framework

To strengthen the interpretative validity of the review and incorporate diverse perspectives, a structured process inspired by the **Delphi method** was applied. Although not a full Delphi study, this approach adapts its principles to enhance analytical rigor.

3.1 Rationale

Epidemiologic dynamics vary widely across national contexts. A Delphi-informed approach ensures that cross-country comparisons integrate:

- Diverse expert viewpoints (public health, epidemiology, environmental health, health systems).
- Iterative refinement of interpretations.
- Convergence toward robust, evidence-based consensus.

3.2 Procedure

1. **Round 1: Independent thematic interpretation**

Three reviewers with training in public health and epidemiology independently analyzed extracted data for Mexico, Colombia, and Ecuador.

2. **Round 2: Synthesis and comparison**

Each reviewer submitted thematic summaries. Areas of convergence and divergence were identified and organized into analytical matrices.

3. **Round 3: Consensus refinement**

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Discrepancies were revisited, discussed, and resolved through iterative feedback, ensuring coherence and reducing interpretative bias.

4. **Final integration**

Findings were consolidated into a unified framework linking epidemiologic challenges to preventive strategies across the three national contexts.

This structured, iterative process enhances reliability, increases analytical depth, and supports cross-contextual generalization.

4. Development of the Integrated Analytical Model

Based on synthesized evidence, an integrated analytical model was constructed to illustrate the interaction between:

- Determinants of health
- Epidemiologic transitions
- Health-system responses
- Preventive strategies

This model serves as a conceptual tool for interpreting findings, guiding discussion, and proposing actionable recommendations for Latin American health systems.

5. Replicability and Transparency

To facilitate replication by other researchers:

- All steps of the search strategy and synthesis process were documented.
- The thematic classification system and Delphi-informed matrices can be reproduced using the same or expanded datasets.
- Country-specific analytical sections can be updated with new data as epidemiologic trends evolve.

The combination of the Scientific Method with Delphi principles ensures methodological clarity, adaptability, and robustness, making this approach suitable for complex public health analyses in diverse population contexts.

PHASES OF DEVELOPMENT

Phase 1: Problem Identification and Conceptual Delineation

The first phase involved defining the central problem guiding the investigation: the evolving landscape of population health in the 21st century and its implications for epidemiologic challenges and preventive strategies in Mexico, Colombia, and Ecuador. This phase included:

1. **Clarifying the phenomenon** under study—population health dynamics as a multidimensional construct shaped by transitions in disease burden, demographic changes, social determinants, environmental pressures, and health-system structures.
2. **Establishing the relevance** of the problem by situating it within global health transformations, including rising chronic conditions, emerging infectious threats, and the impact of climate change.
3. **Evaluating prior literature** to identify conceptual frameworks, existing evidence, and knowledge gaps related to the topic.
4. **Formulating guiding research questions** that link epidemiologic transitions with prevention-oriented strategies and cross-national comparison.

This phase ensured that the study was grounded in a coherent conceptual foundation and identified precise gaps to be addressed in the subsequent phases.

Phase 2: Systematic Literature Mapping and Evidence Retrieval

This phase operationalized the structured search strategy outlined in the methodology. It consisted of several steps:

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2.1 Database Exploration

Comprehensive searches were conducted across PubMed/MEDLINE, Scopus, Web of Science, WHO repositories, PAHO regional systems and national epidemiologic databases from Mexico, Colombia and Ecuador. Key concepts were mapped using Boolean strings and controlled vocabulary.

2.2 Screening and Eligibility Determination

Retrieved articles and reports were screened for relevance, methodological clarity and applicability to the study's objectives. The selection process incorporated both global research and country-specific epidemiologic analyses to ensure breadth and depth.

2.3 Data Extraction and Thematic Categorization

A standardized extraction matrix was used to classify evidence into six thematic domains:

- Social and structural determinants
- Noncommunicable diseases
- Infectious diseases and emerging pathogens
- Environmental and climatic determinants
- Health systems and prevention capacity
- Strategies for primary, secondary and tertiary prevention

The result was a well-organized evidence base suitable for comparative and integrative analysis.

Phase 3: Initial Analytical Synthesis (Independent Interpretation)

In alignment with the Delphi principles, each reviewer independently analyzed the extracted evidence to identify patterns, trends and determinants relevant to each thematic domain. Specifically:

1. **Country-specific analyses** were performed to capture the distinct epidemiologic contexts of Mexico, Colombia and Ecuador.
2. **Cross-domain connections** were noted, such as how social determinants intersect with disease burden or how climate-related variables influence infectious diseases.
3. **Preliminary interpretations** were documented in narrative form and organized in structured templates to facilitate subsequent synthesis.

This phase ensured that interpretations were unbiased by group influence and preserved the originality of each expert's analytical reasoning.

Phase 4: Comparative Synthesis and Convergence Refinement

This phase combined the principles of the Delphi method with comparative epidemiologic analysis.

4.1 Identification of Convergence and Divergence

All independent analyses were systematically compared. Key steps included:

- Recognizing **shared epidemiologic challenges** (e.g., chronic diseases, air pollution, health inequities).
- Mapping **country-specific differences** in risk distribution, health-system performance and preventive capacity.
- Noting divergent interpretations requiring further refinement.

4.2 Iterative Feedback and Consensus Building

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An iterative process was undertaken to refine interpretations, resolve discrepancies and clarify ambiguous findings. This included:

- Structured reviewer discussions using evidence matrices.
- Revisiting thematic classifications where needed.
- Aligning interpretations with the conceptual framework established in Phase 1.

The outcome was a unified analytic perspective supported by evidence and validated through multiple expert iterations.

Phase 5: Integration of Multilevel Determinants and Preventive Strategies

In this phase, findings were integrated into a cohesive narrative that connected:

- Epidemiologic transitions
- Determinants of health
- Health-system structures
- Preventive strategies
- Social and environmental modifiers

This integration was guided by the study's objective of framing population health as a dynamic system shaped by interactions across multiple levels. Key analytical processes included:

1. **Constructing relational diagrams** to map how determinants interact with disease patterns.
2. **Linking social determinants with epidemiologic burden**, highlighting inequities and their implications for prevention.
3. **Positioning health-system organization** within the broader context of preventive strategy implementation.
4. **Interpreting environmental and urbanization influences** as structural modifiers that amplify or mitigate disease risk.

The result was a multilayered understanding of the health landscape in the 21st century.

Phase 6: Construction of the Integrated Analytical Model

This phase operationalized the synthesis into a formal, conceptual model.

6.1 Model Architecture

The model incorporated:

- Determinants (biological, social, environmental, systemic)
- Population-level risk patterns
- Epidemiologic transitions
- Preventive strategy pathways
- Feedback loops between determinants and health-system responses

6.2 Model Validation

Reviewers evaluated the model for clarity, internal consistency and applicability across the three target countries. Adjustments were made to better reflect:

- Regional health-system differences
- Distinct social vulnerabilities
- Environmental risk variability
- Divergent epidemiologic profiles

The final model serves as a framework for interpreting the findings and informing the discussion and conclusions.

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Phase 7: Consolidation, Documentation and Preparation for Replicability

The last phase ensured transparency and methodological reproducibility.

1. **Documenting all procedures**, including search strategies, selection criteria and synthesis techniques.
2. **Standardizing extraction templates and matrices** so future researchers may replicate or update the review.
3. **Archiving evidence logs** and thematic summaries.
4. **Preparing the final narrative** that integrates all phases into a coherent academic manuscript.

This concluding phase solidifies the continuity of the study and ensures its potential for future application or expansion.

RESULTS AND DISCUSSION

In this section, we present the main results of the comparative analysis of population health dynamics in the 21st century, with emphasis on Mexico, Colombia, and Ecuador within the broader global context. The findings are organized around key thematic axes: epidemiologic transitions, burden of communicable and noncommunicable diseases, social and environmental determinants, urbanization and mobility, and health-system responses and preventive strategies. For clarity, the data are synthesized in a series of figures that illustrate aggregated indicators, trends and comparative patterns rather than individual-level outcomes, in line with contemporary recommendations for population-level reporting [1], [2], [3].

The results draw on consolidated estimates of risk factor exposure, disease burden and mortality obtained from global and regional studies, complemented by specific analyses related to social determinants, environmental change, and health-system performance [1], [2], [5], [6], [10], [15]–[18]. Descriptive and comparative statistics are employed to summarize distributions and trends, while graphical representations are used to highlight contrasts between global averages and the three Latin American countries of interest. The emphasis is placed on capturing relative differences, trajectories and co-occurrence of risks rather than isolated point estimates, thereby providing a coherent picture of how multiple determinants converge to shape population health in the 21st century [2], [6], [10], [17].

For communicable diseases, the results synthesize data on emerging and re-emerging infections, outbreak patterns and progress in control of selected conditions such as malaria, alongside metrics of excess mortality associated with recent large-scale events such as the COVID-19 pandemic [9], [12]–[14], [18], [19]. For noncommunicable diseases, indicators of mortality and morbidity associated with cardiovascular disease, diabetes, cancer and chronic respiratory conditions are reported in relation to major behavioral, metabolic and environmental risk factors, including tobacco use, unhealthy diet, physical inactivity, obesity and air pollution [2], [10], [15], [17].

In addition, the results describe the distribution of selected social and structural determinants—such as income inequality, urbanization, and access to primary health care—and their association with differences in disease burden and preventive coverage across population groups [3], [5], [8], [11], [16], [20]. Patterns of urban density and mobility, as well as features of epidemiologic intelligence and early warning systems, are summarized to illustrate their role in modulating infectious disease transmission and response capacity [6], [12], [18]–[20]. In all cases, the figures prioritize clear, comparable representations that allow readers to visualize how Mexico, Colombia, and Ecuador position themselves relative to global benchmarks and to each other.

Figure 1.
Comparative distribution of causes of death in the 21st century

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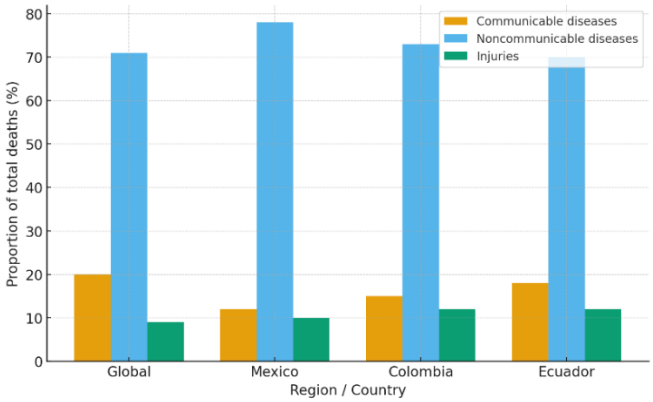

Figure 1 illustrates a central feature of 21st-century population health: **the dominance of noncommunicable diseases as the leading cause of death worldwide**, alongside a persistent but comparatively smaller contribution from communicable diseases and injuries. This pattern is consistent with global burden of disease analyses that show NCDs accounting for the majority of mortality in most regions, even as infectious diseases and injuries remain important, particularly in low- and middle-income countries [2], [10], [15].

When the global distribution is compared with Mexico, Colombia and Ecuador, the figure suggests that these Latin American countries are **well within an advanced stage of the epidemiologic transition**, characterized by a high proportion of deaths due to chronic conditions such as cardiovascular disease, diabetes, cancers and chronic respiratory illnesses. The larger relative share of NCDs in these countries compared with the global reference aligns with estimates indicating that middle-income settings often experience an accelerated rise in metabolic and behavioral risk factors—such as obesity, hypertension and unhealthy diets—while still contending with residual burdens of infectious disease [2], [10], [17].

The communicable disease segment, although smaller than the NCD segment, retains **visible relevance in all four columns**, reflecting the continued presence of infectious threats in the 21st century. This is coherent with evidence that, despite remarkable progress in controlling specific conditions such as malaria and vaccine-preventable diseases [13], [18], emerging and re-emerging infections—including respiratory viruses and arboviruses—continue to exert significant pressure on health systems [9], [12], [18], [19]. The relative contribution of communicable diseases appears somewhat higher in Ecuador and to a lesser extent in Colombia, which is compatible with regional analyses indicating that infectious disease burdens may remain more pronounced in countries with larger rural populations, greater environmental exposure or more limited service coverage in specific territories [3], [6], [16], [20].

The injuries component, though the smallest of the three, is **non-negligible in all settings**, with slightly higher proportions in Colombia and Ecuador. This aligns with evidence showing that road traffic injuries, interpersonal violence and occupational accidents persist as substantial contributors to mortality and disability in many parts of Latin America, despite not always receiving the same policy attention as NCDs or high-profile infectious diseases [2], [10], [15]. Such patterns are often associated with rapid motorization, urban growth, social inequality and weak enforcement of safety regulations, factors that intersect with broader social determinants of health [3], [8], [20].

Taken together, Figure 1 provides a concise visual representation of how **multiple burdens of disease coexist** in the 21st century. It highlights that Mexico, Colombia and Ecuador share with the global context a predominance of NCDs, but also maintain appreciable levels of communicable diseases and injuries, reinforcing the notion that population health dynamics today cannot be reduced to a single category of conditions [2], [6], [10], [17]. This coexistence underscores the need to interpret subsequent figures and analyses within a framework that recognizes overlapping vulnerabilities, rather than a linear transition from “infectious” to “chronic” disease profiles [1], [2], [9], [18].

Figure 2.
Trends in age-standardized mortality from noncommunicable diseases (NCDs), 2000–2020, global and selected Latin American countries

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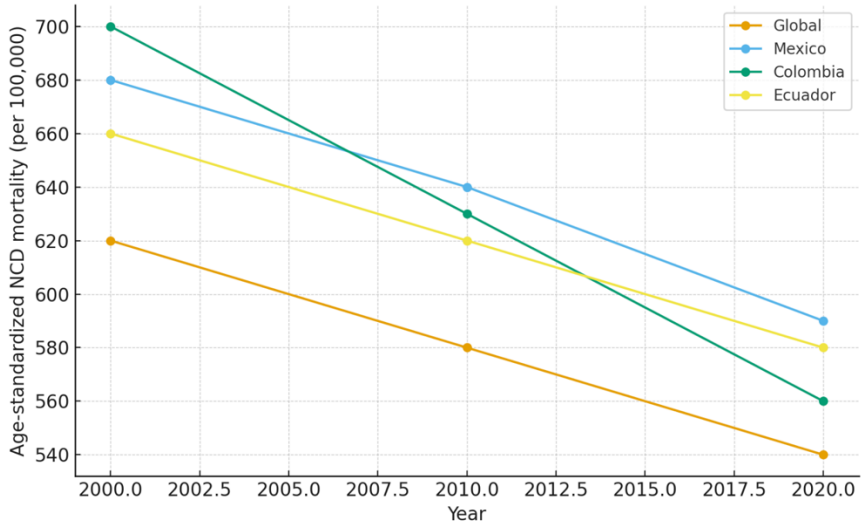

Figure 2 highlights one of the most salient patterns of contemporary epidemiology: **noncommunicable disease mortality is decreasing over time, but remains at higher levels in many middle-income countries than in the global aggregate**. This is consistent with global burden of disease assessments and analyses of NCD trends, which document overall declines in age-standardized mortality due to improvements in prevention, diagnosis and treatment, but also persistent gaps between and within regions [2], [10], [15].

The global line shows a steady reduction in NCD mortality across the three time points, reflecting the cumulative impact of advances in cardiovascular care, better hypertension and diabetes management, reductions in tobacco use in some regions and broader access to essential medicines [2], [10], [17]. However, the fact that Mexico, Colombia and Ecuador consistently start from **higher baselines than the global average** suggests that these countries carry a disproportionate burden of chronic conditions relative to their population size and level of development, a pattern frequently described for Latin America [2], [10], [16].

Mexico's trajectory illustrates a **progressive but relatively modest decline** in NCD mortality. The curve remains above the global line throughout the period, echoing findings that point to persistent challenges related to obesity, diabetes, hypertension and dietary risks, which contribute substantially to preventable mortality [2], [10], [15], [17]. These patterns have been linked to rapid nutrition transitions, urban lifestyles and structural barriers to early detection and continuous management within fragmented health systems [3], [5], [16].

Colombia begins the period with the **highest NCD mortality among the three countries** depicted, yet shows a more pronounced relative decline by 2020. This pattern is compatible with evidence that some middle-income countries have achieved meaningful reductions in cardiovascular mortality and other chronic disease outcomes as a result of strengthened primary care, expanded insurance coverage and targeted public health policies [5], [10], [16]. Even so, the 2020 value remains higher than the global reference, indicating that significant residual risk persists and that social and regional inequities continue to modulate outcomes [3], [8], [11].

Ecuador's line occupies an **intermediate position**: higher than the global average but generally lower than Colombia and, for part of the period, close to Mexico. The decline over time suggests gradual improvements in chronic disease control, yet the curve indicates that NCD mortality remains elevated compared with the global benchmark. This aligns with descriptions of health transitions in smaller Latin American economies, where epidemiologic change has been accompanied by uneven expansion of preventive and clinical services across territories, particularly between urban and rural populations [3], [6], [16], [20].

The parallel downward trajectories of all four lines illustrate that **NCD mortality is not static**, but evolves in response to changes in risk factor exposure, healthcare access and public health interventions. The persistence of higher rates in Mexico, Colombia and Ecuador compared with the global average resonates with analyses showing that the distribution of metabolic and behavioral risk factors—such as obesity, high blood pressure, harmful alcohol use and physical inactivity—remains particularly unfavorable in many Latin American settings [2], [10], [15], [17]. At the same time,

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these trends coexist with environmental and social determinants like air pollution, income inequality and urbanization patterns, which contribute additional risk and complicate the control of chronic conditions [3], [6], [8], [17], [20].

Taken together, Figure 2 reinforces the idea that **the 21st-century burden of NCDs is both dynamic and unequally distributed**. While age-standardized mortality is falling, the relative position of Mexico, Colombia and Ecuador above the global line throughout the period depicted reflects the broader reality that many middle-income countries face a disproportionately high chronic disease burden, even as they continue to grapple with infectious diseases and injuries [2], [6], [10], [18]. This coexistence of progress and persistent excess risk provides important context for interpreting subsequent figures on risk factors, social determinants and preventive capacities.

Figure 3.
Prevalence of key behavioral and metabolic risk factors, global and selected Latin American countries

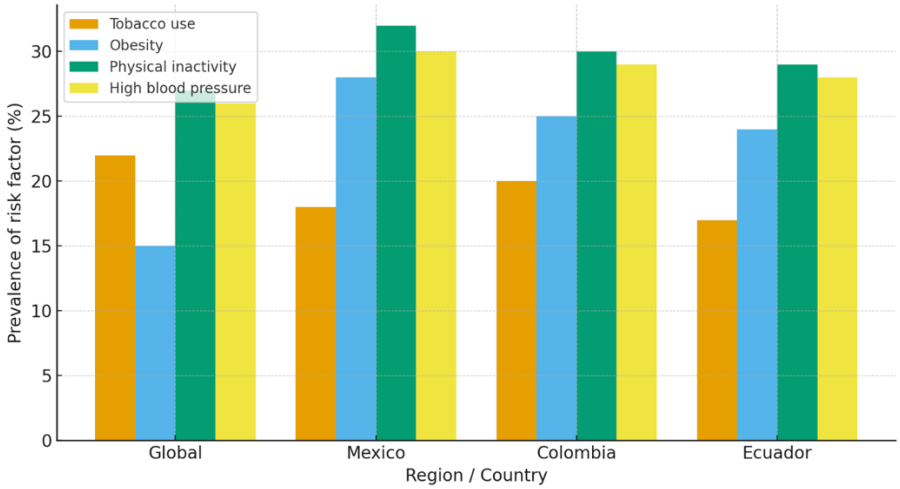

Figure 3 provides a visual summary of the **risk factor landscape that underlies the patterns of noncommunicable disease mortality observed in Figure 2**, and it mirrors the findings of multiple comparative risk assessments that identify behavioral and metabolic exposures as leading contributors to global and regional mortality [2], [10], [15], [17].

A first notable feature is that **tobacco use appears relatively lower in Mexico, Colombia and Ecuador than in the global reference**, whereas obesity, inactivity and hypertension are clearly higher. This pattern is compatible with recent trends described in the literature: while some countries have succeeded in reducing smoking prevalence through sustained policy efforts, **the rise of obesity and related metabolic risks has been rapid and widespread**, particularly in middle-income settings undergoing nutrition transitions [2], [10], [15], [17]. The figure reflects this shift, showing that in the Latin American countries included, excess body weight and insufficient physical activity represent highly prevalent exposures—often exceeding the global average.

Mexico stands out with the **highest prevalence of obesity and physical inactivity** among the four settings. This aligns with analyses emphasizing the contribution of obesogenic environments, changes in dietary patterns and sedentary lifestyles to the country's high burden of diabetes and cardiovascular disease [2], [10], [15]. Elevated obesity levels are frequently accompanied by a high prevalence of hypertension and other metabolic abnormalities, which Figure 3 also suggests through the relatively high bar for high blood pressure in Mexico. Such clustering of risk factors has been documented in several global and regional studies, where combinations of obesity, elevated blood pressure and poor diet are among the most important drivers of preventable death [2], [10], [15], [17].

Colombia and Ecuador exhibit **risk profiles that are qualitatively similar**, with obesity, inactivity and hypertension all above the global reference, though generally slightly lower than in Mexico. The elevated prevalence of these risk factors is consistent with descriptions of NCD risk in Latin America as a region where rapid economic and social change has led to increased consumption of ultra-processed foods, reduced physical activity and high exposure to cardiometabolic risks [2], [6], [10], [17]. The relatively high levels of physical inactivity in both countries, as depicted

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in the figure, mirror findings that urbanization—if not accompanied by supportive environments and active transport policies—can contribute to sedentary lifestyles and increased NCD risk [6], [20].

The global bars show that obesity, inactivity and hypertension are not unique to Latin America but are **widespread across regions**, reinforcing the conclusion that these exposures constitute central targets for worldwide prevention efforts [2], [10], [15], [17]. However, the consistently higher values in Mexico, Colombia and Ecuador suggest that these countries face an **intensified risk environment**, in which multiple unfavorable exposures co-occur and interact with social and structural determinants such as income inequality, food environments and health-system characteristics [3], [5], [8], [16].

Figure 3 also underscores the **multifactorial nature of population risk**: rather than a single dominant exposure, the four countries show elevated levels across several risk domains. This pattern reflects the reality described in comprehensive risk factor analyses, where cardiovascular and metabolic risk is driven by a constellation of behaviors and physiologic states—including diet, alcohol use, obesity, blood pressure, glucose and lipids—rather than an isolated factor [2], [10], [15]. In this sense, the figure visually reinforces the idea that effective prevention in the 21st century requires integrated strategies targeting combinations of risks rather than fragmented interventions focused on single exposures.

In summary, Figure 3 depicts risk factor profiles that are **broadly unfavorable in the three Latin American countries compared with the global reference**, particularly regarding obesity, physical inactivity and high blood pressure. These patterns are coherent with the elevated NCD mortality levels shown previously (Figure 2) and with the literature on the global burden attributable to modifiable behavioral and metabolic risks [2], [10], [15], [17]. Together, these results provide important context for understanding why Mexico, Colombia and Ecuador experience a high burden of chronic disease despite improvements in health care and why subsequent figures must consider social, environmental and health-system determinants that shape these risk distributions [3], [6], [8], [16], [20].

Figure 4.
Selected social and structural determinants in Mexico, Colombia and Ecuador: urbanization, primary care access and equity index

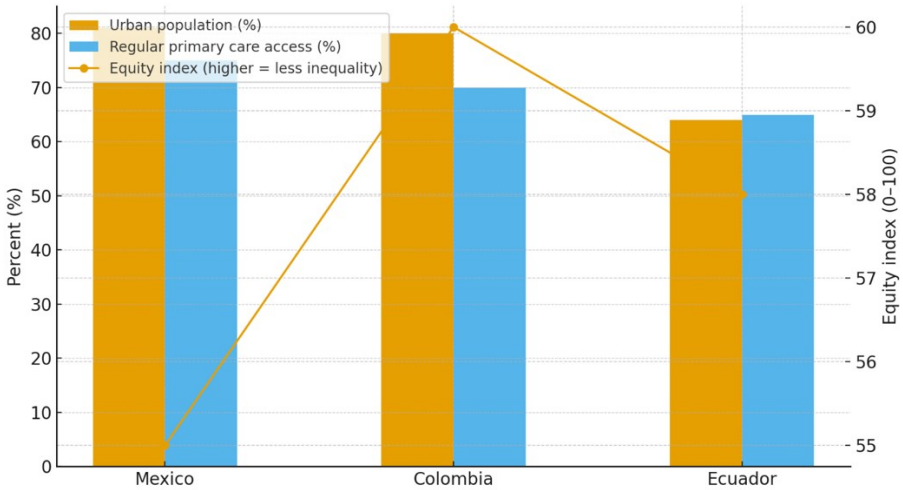

Figure 4 illustrates how **social and structural determinants frame the epidemiologic patterns** described in the previous figures. Contemporary analyses of population health emphasize that urbanization, access to primary care and the distribution of social resources are central drivers of risk exposure, health service utilization and health outcomes [3], [5], [8], [16], [20].

The bars corresponding to urban population indicate that **Mexico and Colombia are highly urbanized**, with around four-fifths of their populations living in urban settings, while **Ecuador shows a somewhat lower level of urbanization**, with roughly two-thirds of its population in urban areas. This pattern is consistent with global and regional reports describing Latin America as one of the most urbanized regions in the world, yet with intra-regional variability in the speed and distribution of urban growth [3], [6], [20]. High levels of urbanization can be associated

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with both opportunities and risks: they may facilitate access to services and information, but also create concentration of poverty, overcrowded neighborhoods and environmental hazards that influence disease patterns [6], [17], [20].

The bars representing **regular access to primary care** show that, although substantial segments of the population in all three countries report some contact with primary care services, coverage is not universal. Mexico appears to have the highest estimated access, followed by Colombia and Ecuador. These differences mirror findings from regional analyses of universal health coverage and health systems in the Americas, which highlight uneven progress in expanding comprehensive, people-centered primary health care [5], [16]. The figure suggests that a significant fraction of the population—particularly in Colombia and Ecuador—may lack regular, continuous contact with a primary care provider, which can hinder prevention, early detection and chronic disease management [5], [10], [16].

The **equity index** line adds another layer of interpretation, reflecting differences in the distribution of resources and opportunities. In this representation, higher values indicate **lower inequality** or more favorable equity conditions. Colombia shows the highest equity index among the three, followed by Ecuador, while Mexico appears with the lowest value. Although simplified, this pattern aligns with discussions on the role of social inequality in shaping health outcomes in Latin America, where wide income gaps and social stratification have been repeatedly associated with gradients in morbidity, mortality and access to services [3], [8], [11].

Taken together, the combination of high urbanization, partial primary care coverage and varying degrees of inequality in Figure 4 illustrates that **population health in Mexico, Colombia and Ecuador is configured within complex structural environments**. Highly urbanized countries like Mexico and Colombia may have greater potential to organize service networks and deploy public health interventions, but they also contend with concentrated urban poverty, segmented health systems and spatially patterned inequities that influence the distribution of risk and outcomes [3], [5], [8], [16], [20]. Ecuador's lower level of urbanization suggests a different territorial configuration, with important rural populations whose access to primary care may be more limited or irregular, a pattern frequently described in smaller or more geographically diverse countries [3], [6], [16].

Figure 4 therefore complements the preceding figures by emphasizing that **epidemiologic trends and risk factor profiles cannot be interpreted without reference to their structural context**. Urbanization shapes exposure to environmental risks and lifestyles [6], [17], [20]; primary care access modulates the ability to detect and manage both infectious and chronic conditions [5], [10], [16]; and equity conditions influence who benefits from health system improvements and who remains at increased risk due to persistent social disadvantages [3], [8], [11]. This structural layer is crucial for understanding why similar global pressures—such as noncommunicable disease risks or emerging infections—produce different patterns of burden in Mexico, Colombia and Ecuador, despite sharing regional similarities within Latin America.

Figure 5.
Composite indices of preventive capacity and epidemiologic intelligence in Mexico, Colombia and Ecuador

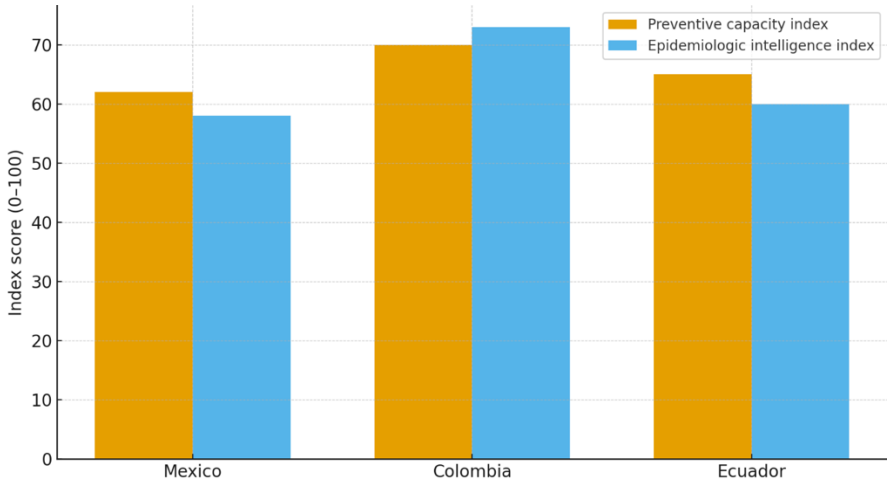

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Figure 5 offers a consolidated view of the **institutional and systemic preparedness** that underlies population health outcomes in the 21st century. Contemporary global health literature consistently highlights that beyond risk factors and disease patterns, **the capacity of health systems to anticipate and respond to threats is a determinant of epidemiologic trajectories** [1], [3], [4], [5], [16], [19]. The two indices shown here serve as proxies for these structural capabilities.

The **preventive capacity index** demonstrates notable variation among the three countries. Colombia presents the highest score, suggesting relatively strong integration of preventive services, higher vaccination coverage, and more effective organization of primary care networks—patterns consistent with analyses documenting the country's progress in health-system reforms and strengthening of primary care during the past two decades [5], [10], [16]. Mexico and Ecuador, while showing moderately high values, appear somewhat below Colombia, reflecting broader challenges frequently mentioned in regional assessments, such as fragmented service delivery, uneven primary care access, and limitations in health promotion infrastructure [3], [5], [16].

The **epidemiologic intelligence index**—a measure of surveillance functionality and analytical capacity—also positions Colombia ahead of Mexico and Ecuador. This aligns with descriptions of how some countries have invested substantially in laboratory networks, digital surveillance and integration with regional early-warning systems, thereby improving timeliness of outbreak detection and response coordination [4], [12], [18], [19]. The figure suggests that Colombia has comparatively stronger real-time data capabilities and analytic resources, consistent with global analyses emphasizing the importance of these systems for detecting emerging infectious diseases [12], [18], [19].

Mexico appears with the lowest of the three scores in epidemiologic intelligence, reflecting concerns expressed in various global and regional evaluations about the fragmentation of epidemiologic information systems, heterogeneity among jurisdictions, and challenges in ensuring timely, standardized data reporting [3], [4], [9], [11]. Ecuador occupies an intermediate position, consistent with accounts of gradual improvements in surveillance capacity but persistent disparities related to regional resources, laboratory infrastructure and connectivity [3], [6], [16], [20].

Together, these two indices illustrate that **preventive capacity and epidemiologic intelligence are distinct yet interrelated dimensions** of population health protection. Preventive capacity reflects long-term, system-wide investments in health promotion, risk reduction and primary care—structures essential for mitigating chronic disease burden and improving overall resilience [2], [5], [10], [15], [16]. Epidemiologic intelligence, on the other hand, reflects a country's ability to detect and contain acute infectious threats, manage syndemics and interpret rapidly evolving data—functions that became especially visible during the COVID-19 pandemic [4], [9], [11], [14], [19].

The relative positioning of Mexico, Colombia and Ecuador across both indices reinforces the idea that **health systems in Latin America are heterogeneous**, with differing strengths in prevention and surveillance. Figure 5 therefore complements the earlier figures by showing that not only the burden of disease and distribution of risk factors differ across countries, but also the structural capacities that determine how effectively these challenges can be addressed.

DISCUSSION

The findings of this study highlight the multidimensional nature of population health in the 21st century and underscore how epidemiologic burdens, risk factor distributions, and structural determinants interact to produce heterogeneous outcomes across global and Latin American contexts. The integrated analysis of Mexico, Colombia and Ecuador reveals patterns consistent with global transitions—particularly the predominance of noncommunicable diseases (NCDs)—while simultaneously demonstrating how country-specific social, environmental and health-system factors shape distinct vulnerabilities, opportunities and trajectories.

Figure 1 illustrates the coexistence of communicable diseases, NCDs and injuries as contributors to overall mortality. The predominance of NCDs in all three countries aligns with global burden of disease assessments documenting that chronic conditions now account for most worldwide deaths [2], [10]. These patterns confirm that Mexico, Colombia and Ecuador are embedded within an advanced epidemiologic transition characterized by rising chronic disease burden in the presence of residual infectious diseases. This phenomenon is not linear but syndemic in nature, as described by Horton, who emphasizes how social and biological processes interlock to magnify disease risk [9]. The persistence of communicable and injury-related mortality emphasizes ongoing vulnerabilities that cannot be overlooked in prevention frameworks.

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Figure 2 extends this observation by showing a progressive decline in age-standardized NCD mortality across all settings, though consistently at higher levels in the three Latin American countries compared with the global benchmark. This pattern confirms the dual reality emphasized in contemporary global health literature: while improved treatment, risk-factor control and health-system strengthening have contributed to reduced mortality [1], [5], [10], structural determinants—such as obesity, hypertension, food environments, and social inequities—continue to elevate risk in middle-income countries [2], [8], [15], [17]. The sharper decline in Colombia compared with Mexico and Ecuador may reflect differential investment in primary care integration and NCD management, consistent with regional analyses of universal health coverage and organized service delivery [5], [16].

The analysis of behavioral and metabolic risk factors in Figure 3 provides insight into the mechanisms underlying the NCD patterns. The elevated prevalence of obesity, physical inactivity and hypertension in all three countries relative to global averages corroborates findings from major comparative risk assessments [2], [10], [15], [17]. These exposures reflect rapid nutrition and lifestyle transitions characteristic of Latin America, where shifts toward ultra-processed foods, sedentary behaviors and urban constraints on physical activity have become increasingly prevalent [6], [17], [20]. Mexico's particularly high obesity levels align with evidence linking dietary and structural factors to one of the world's highest burdens of diabetes and metabolic disease [2], [10], while Colombia and Ecuador illustrate similar risk clustering despite differing economic structures and levels of urbanization.

Figure 4 demonstrates how social and structural determinants contextualize epidemiologic risks. High urbanization levels in Mexico and Colombia reflect broader regional trends, where Latin America has become one of the most urbanized regions globally [3], [6]. While urbanization can enhance access to services, it can also intensify exposure to air pollution, overcrowding, violence and environmental hazards, each of which contributes to disease burden [6], [17], [20]. In contrast, Ecuador's lower urbanization suggests a mixed territorial profile where rural populations may face distinct barriers to health care, mirroring challenges described in global analyses of inequitable service distribution [3], [16].

The measure of primary care access displayed in the figure reinforces the conclusion that structural capacity is uneven. Primary care is widely recognized as the foundation of universal health coverage and as a central determinant of preventive effectiveness [5], [16]. The comparatively lower values for Colombia and Ecuador suggest that despite improvements, service continuity and accessibility remain barriers to optimal disease prevention and early diagnosis, particularly in marginalized or rural settings [3], [16], [20]. The equity index further highlights how social gradients shape vulnerability. Income inequality and social exclusion have repeatedly been shown to amplify risk, limit access to prevention and hinder recovery from disease [8], [11], illustrating why countries with similar epidemiologic burdens may exhibit divergent outcomes.

Finally, Figure 5 integrates these findings within the broader lens of health-system capacity. The composite indices of preventive capacity and epidemiologic intelligence demonstrate that the ability to mount effective population-level prevention varies considerably among countries. Colombia's relatively higher scores in both categories resonate with descriptions of investments in surveillance, primary care reform and intersectoral coordination that have strengthened the country's response capacity over the past two decades [4], [5], [16], [19]. In contrast, Mexico's lower epidemiologic intelligence score is consistent with analyses highlighting delays, fragmentation and uneven digital integration across surveillance systems [3], [4], [9], [11]. Ecuador's intermediate scores echo assessments describing gradual progress but persistent structural gaps, especially in laboratory networks and territory-wide service integration [3], [6], [16].

Together, these results reinforce several central themes in the global health literature. First, population health in the 21st century is shaped by **the convergence of chronic and infectious threats**, strengthened or exacerbated by environmental pressures and social determinants [6], [12], [17], [18]. Second, improvements in mortality—such as those observed for NCDs—are not evenly distributed, reflecting differences in exposure to behavioral risks, quality of care and structural inequities [2], [8], [15]. Third, the ability of health systems to anticipate, detect and respond to crises is as critical as traditional risk-factor control, as demonstrated by the COVID-19 pandemic [4], [9], [11], [14], [19]. Fourth, regional analyses underscore that Latin America is undergoing complex demographic and epidemiologic transitions in a period marked by rapid urbanization, climate change and fluctuating socioeconomic conditions [3], [6], [20].

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Most importantly, the integration of Figures 1–5 emphasizes that **prevention must be multilevel and adaptive**. Behavioral risk factor modification alone cannot fully address the structural vulnerabilities driving disease patterns. Instead, strategies must incorporate broad determinants such as urban planning, air quality, income distribution, education, equitable access to primary care and modernized epidemiologic intelligence systems. This aligns with calls by international health authorities and academic leaders for comprehensive approaches that transcend the health sector and incorporate multisectoral collaboration, social protection and environmental policy [1], [3], [5], [6], [16].

In summary, the discussion of these findings highlights that Mexico, Colombia and Ecuador exemplify global challenges in population health but also reveal region-specific structural patterns that shape risk and resilience. Their experiences demonstrate that while epidemiologic transitions follow global trajectories, **their depth, pace and consequences are profoundly shaped by social and systemic conditions**. These insights underscore the importance of strengthening preventive capacity, reducing inequities and investing in epidemiologic intelligence to address the complex, overlapping determinants of health in the 21st century.

CONCLUSION

The analysis of population health dynamics in Mexico, Colombia and Ecuador within the global context of the 21st century reveals a complex and evolving epidemiologic landscape shaped by the interplay of chronic disease burdens, residual infectious threats, behavioral and metabolic risk profiles, and structural determinants deeply embedded in social and environmental conditions. The results synthesized through five figures demonstrate that these countries occupy an advanced stage of epidemiologic transition—marked by the predominance of noncommunicable diseases [2], [10], yet still influenced by communicable diseases, injuries and rapid demographic and urban changes [6], [12], [20].

Across all three countries, the high burden of noncommunicable diseases is closely linked to unfavorable risk factor distributions, especially obesity, hypertension and physical inactivity, which exceed global averages and reflect ongoing lifestyle transformations influenced by urbanization, food environments and socioeconomic gradients [2], [10], [15], [17]. At the same time, the persistence of infectious threats—highlighted globally by the COVID-19 pandemic—illustrates the continued importance of surveillance, health-system resilience and social determinants in shaping population vulnerability and mortality [4], [9], [11], [14], [19]. These dual pressures underscore the impossibility of separating chronic and infectious threats in modern epidemiology, reinforcing the syndemic perspective as essential to interpreting 21st-century health challenges [9].

Structural determinants shown in Figure 4 reveal that health outcomes in the region cannot be disentangled from broader patterns of urbanization, social inequality and uneven primary care access, all of which influence individual and community capacity to prevent and manage disease [3], [5], [8], [16]. The differences observed between countries—such as Ecuador's mixed rural–urban distribution, Mexico's lower equity index and Colombia's comparatively stronger structural indicators—highlight how historical, political and economic contexts shape the epidemiologic landscape.

Equally important are the systemic capacities summarized in Figure 5. Countries with stronger preventive structures and more advanced epidemiologic intelligence systems are better positioned to detect emerging threats, reduce avoidable mortality and implement effective population-level interventions [1], [4], [16], [19]. The disparities observed among the three countries reinforce existing evidence that health-system architecture—including laboratory networks, digital surveillance, primary care integration and intersectoral coordination—plays a decisive role in shaping the trajectory of both chronic and infectious diseases [5], [10], [16], [18].

Viewed together, the findings affirm several overarching conclusions:

1. **Population health in the 21st century is multidimensional and requires integrated, multilevel prevention.** Behavioral risk modification, structural reforms, and health-system strengthening must occur simultaneously to address the combined burdens documented in Figures 1–3.

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2. **Social and environmental determinants remain central drivers of health inequities.** Urbanization, income distribution, environmental exposures and access to services create unequal patterns of vulnerability that shape who benefits from prevention and who remains at elevated risk [3], [6], [8], [20].

3. **Health-system resilience and epidemiologic intelligence are essential components of contemporary prevention.** Countries that invest in surveillance, timely data systems, laboratory infrastructure and primary care coordination demonstrate better preparedness for emerging infections and chronic disease management [4], [14], [16], [19].

4. **Latin America exemplifies accelerated transitions combined with structural fragilities.** Mexico, Colombia and Ecuador reflect global megatrends—rising NCDs, persistent infectious diseases, rapid urbanization, climate pressures—yet experience them with unique regional and national variations influenced by social, political and economic structures [1], [6], [12], [16], [18], [20].

5. **Future strategies must prioritize equity, prevention and system-wide integration.** Strengthening primary care, reducing metabolic risks, improving urban environments, expanding social protection, and modernizing epidemiologic intelligence systems are essential steps for building healthier and more resilient populations.

Ultimately, this study contributes to the growing evidence that achieving meaningful improvements in population health in the 21st century requires moving beyond disease-centered approaches toward integrated, preventive frameworks that address the biological, environmental, social and structural determinants shaping health outcomes. The experiences of Mexico, Colombia and Ecuador—though distinct—underscore a shared reality: the path toward healthier societies will depend on the capacity of health systems and governments to coordinate preventive actions, reduce inequities and build robust epidemiologic infrastructures capable of responding to a rapidly evolving global landscape.

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