



Decoding Multi-Scale Complexities in Population Health Through Evolution, Epidemiology and Equity

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Abstract

Modern global health is shaped by intersecting challenges, including the growing burden of non-communicable diseases and antimicrobial resistance, zoonotic spillover, and persistent structural and social inequities. As human health emerges from complex interactions across genetic, ecological, environmental, and socio-political systems, disciplinary fragmentation can constrain scientific understanding and effective public-health action. The *Journal of Population Health Dynamics* (JPHD) brings together Evolution, Epidemiology, and Equity to foster interdisciplinary research that bridges biomedical science, planetary health, social health, population health, and the healthcare needs of marginalized communities.

Key Points

- Population health is a multi-scale, interconnected system, shaped by evolutionary, genetic, ecological, environmental, social, and technological forces that transcend conventional disciplinary boundaries.
- The *Journal of Population Health Dynamics* (JPHD) integrates Evolution, Epidemiology, and Equity, addressing contemporary challenges including antimicrobial resistance, zoonotic spillover, metabolic diseases, structural inequities, and the health needs of marginalized populations.
- Seven scientific pillars create a transdisciplinary framework linking genomics, epidemiology, health systems, equity, One Health, traditional medicine, and data innovation to advance evidence-based and equitable population-health interventions.

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1 Introduction

Global health in the 21st century is defined by non-linear biological, ecological, and societal transitions. The classic epidemiological transition models, which once posited a predictable, unidirectional shift from infectious diseases to degenerative non-communicable disorders, fail to capture the complexities of modern disease dynamics [1]. Instead, modern populations face overlapping crises: the rapid emergence of antimicrobial- and insecticide-resistant pathogens, climate-accelerated zoonotic spillovers, expanding metabolic disease burdens, and widening structural inequities between ur-

ban centres and isolated indigenous communities [2, 3]. Fundamentally, human health is an emergent property arising from interconnected networks operating across multiple scales: from the molecular architectures of host and pathogen genomes, through vector bionomics and ecological interfaces, to socio-political determinants and digital data ecosystems [4].

Yet, contemporary biomedical and public health research remains fragmented, with evolutionary biologists, clinical epidemiologists, health economists, veterinarians, anthropologists, and computational data scientists frequently researching and publishing in siloed domains. This conceptual divide limits translational progress. Addressing modern population-level challenges requires a unified scientific paradigm.

The *Journal of Population Health Dynamics* (JPHD) promises, at least by looking at its composition, to fulfil this missing transdisciplinary synthesis, grounded in the foundational triad of Evolution, Epidemiology and Equity. This is because, the dynamics of human disease cannot be understood by examining clinical symptoms in isolation from evolutionary history and ecological contexts [2, 4]. The justification for a specialized, integrative journal rests on four scientific developments that necessitate a convergence platform.

2 Evolutionary Mismatch and Host–Pathogen Dynamics

Darwinian medicine demonstrates that human physiological vulnerabilities often stem from evolutionary mismatches between ancestral adaptations and modern environments [2]. Concurrently, infectious disease agents and vectors undergo rapid micro-evolution under the selective pressures of therapeutics, vaccines, and insecticides [5]. Treating disease control as an engineering problem without accounting for evolutionary principles consistently leads to operational failures. For example,

in an infectious disease model like malaria, multi-drug resistance, diagnostic escape mutations (such as *pfrp2/3* gene deletions in parasites), and behavioural resistance in vectors [5, 6], integrating evolutionary biology and population genomics into public health surveillance is essential for anticipating pathogen trajectories before control gains are reversed.

3 Planetary Health and Zoonotic Spillover Interfaces

More than 60% of emerging infectious diseases in humans are zoonotic, driven by deforestation, agricultural expansion, biodiversity loss, and habitat fragmentation [7]. The transmission cycles of pathogens such as those that cause simian malarias (*Plasmodium knowlesi*, *Plasmodium cynomolgi*), arboviruses, and coronaviruses demonstrate that human populations cannot be protected by clinical interventions alone [7, 8]. A One Health framework that analyzes the shared biology of humans, animals, and changing landscapes is a scientific prerequisite for early threat detection and sustainable disease prevention [7].

4 Structural Inequities and the “Edges” of Health Systems

Health disparities are not merely biological variations; they are structured by social, economic, and geographical inequities [3]. Standardized, top-down health policies frequently fail in hard-to-reach populations, such as isolated island ecosystems, forest-dwelling communities, and marginalized tribal belts [9]. Understanding population health requires combining quantitative spatial epidemiology with social medicine, bioethics, and implementation science, while recognizing the value of ethnobotanical and traditional knowledge systems through rigorous, evidence-based validation [10].

5 The Computational Revolution and Precision Public Health

The expansion of high-throughput multi-omics, Earth Observation satellite imagery, digital health records, and artificial intelligence/machine learning (AI/ML) architectures offers unprecedented tools for epidemiological modelling [11]. However, analysing/extrapolating big data without biological grounding and socio-contextual nuances risks generating spurious associations [11]. A dedicated platform is required to synthesize complex computational methodologies with empirical field epidemiology and health policy design.

6 Seven Scientific Pillars of Population Health Dynamics

To address these interconnected challenges, the JPHD organizes its scholarship around seven integrated and transdisciplinary scientific domains (Fig. 1):

1. **Evolution and Genomics:** Investigating how natural selection, population structure, genetic drift, and host–parasite–vector co-adaptation dictate disease transmission dynamics, therapeutic failure, and phenotypic

vulnerability [2, 5].

2. **Epidemiology and Population Sciences:** Advancing causal inference, longitudinal disease tracking, micro-stratification, and surveillance methodologies across communicable and non-communicable diseases [4, 11].
3. **Public Health and Health Systems:** Evaluating implementation science, health-economic optimization, primary healthcare resilience, and health policy frameworks to achieve universal health coverage [3].
4. **Equity, Society and Vulnerable Populations:** Unravelling the socio-structural determinants of health, bioethics, and community-centred adaptations tailored to historically marginalized, tribal, and island communities [9].
5. **One Health and Planetary Health:** Analyzing cross-species spillover, vector ecological bionomics, antimicrobial resistance ecologies, and the population-level impacts of climate change [7, 8].
6. **Traditional Medicine:** Establishing an evidence-based bridge between indigenous medical knowledge and modern pharmacology through reverse pharmacology, bioactive characterization, and rigorous clinical trials [10].
7. **Methods, Data and Innovation:** Developing computational platforms, AI/ML predictive analytics, geospatial modelling, and decentralized point-of-care technologies to translate complex data into real-time health interventions [11].

7 Advancing the Population Health Paradigm

The JPHD is poised to move beyond descriptive epidemiology. It provides an international medium for rigorous empirical research, mechanistic investigations, methodological innovations, and policy analyses that view population health as an integrated, evolving system. By linking evolutionary biology with health policy, and pairing computational data science with social equity, the journal aims to advance scientific knowledge and inform evidence-based public health action globally.

Declarations

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used ChatGPT to refine the English language. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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Conflict of interest

The authors have no conflict of interest to declare.

Ethics approval

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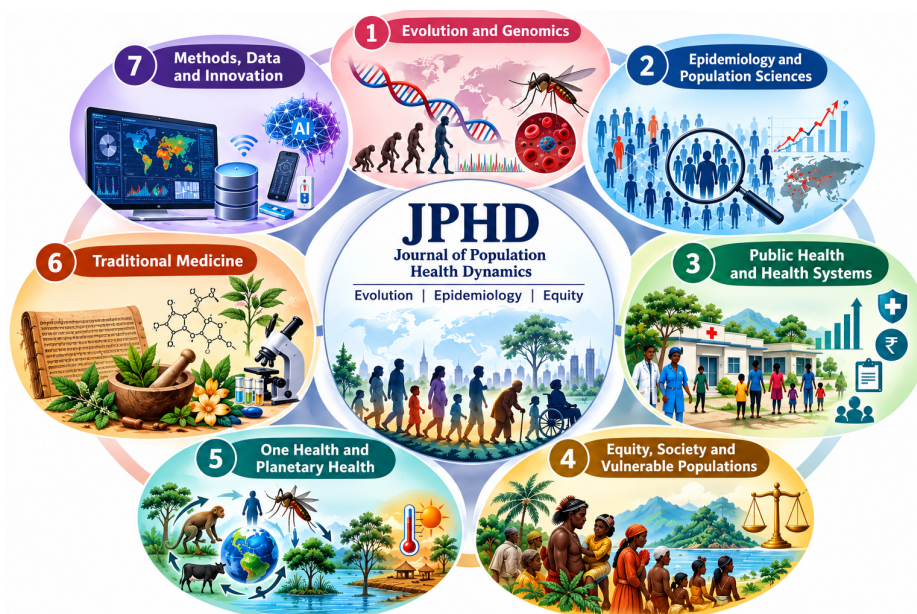


Figure 1. Schematic representation of the seven scientific pillars of population health dynamics. The framework integrates biological, ecological, social, health-system, and technological perspectives to understand changing population-health patterns and inform evidence-based, equitable interventions.

Consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and material

Not applicable.

Code availability

Not applicable.

Authors' contributions

Aparup Das conceptualized the study, conducted literature survey, prepared the figure, and written the initial version of the manuscript. Manoranjan Ranjit jointly conceptualized the study and conducted additional literature survey. Both authors jointly wrote the final version of the manuscript.

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