

Precision Public Health: Future Directions A Structured Umbrella Review

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Received on: 14-09-2025

Published on: 30-12-2025

ABSTRACT

Background: Precision public health (PPH) is a developing public health model that takes help of high resolution data, advanced analytics and targeted interventions to benefit population health. Information gained by precision medicine, population is more focused on, emphasising prevention, surveillance and equity.

Aims: By systematic compilation of reviews and their analysis and evidence on precision, public health, looking into its basics application and challenges and how to apply it in future, keeping in mind present day public health system

Methods: by systematic evaluation of reviews and their analysis using systematic reviews, scoping reviews, narrative reviews and authoritative conceptual or policy syntheses the focus was on precision public health and related approaches priority was given to reviews published since 2015. Findings were combined using narrative thematic synthesis.

Results: Precision public health has been used for infectious disease surveillance, targeted vaccination, environmental health monitoring and risk stratified prevention. However, there is evidence showing limited impact on population challenges like data quality and interoperability, algorithmic bias, privacy and governance concerns, and the capability to aggravate present health unfairness if equity is not specifically

Conclusion: Precision public health is capable to improve the outcomes of interventions used for public health for future benefits. It has to be thoroughly evaluated. The infrastructure should be privacy preserving, transparent analysis, generating a skilled workforce and governance structure that prioritise equity and public trust.

KEYWORDS: Big data, Digital epidemiology, Health equity, Population health, Precision public health.

Era's Journal of Medical Research. 12(3);2025 [doi: 10.24041/ejmr.2025.41]

INTRODUCTION

Precision public health mostly relies on indicators formed across the population and mostly on applied interventions to reduce the impact of disease. But these methods can make it difficult to see the diversity and risk exposure and response within population precision public health. Looks forward to talk about these limitations by using granular data and analytical methods to guide more targeted and timely public health action.¹

Recent advancement in genomics, digital technologies, geospatial science and machine learning have helped population to take interest in PPH, not like precision medicine, which mostly focuses on individual clinical decision making, PPH focuses more on population, aiming to improve prevention, surveillance and health system planning.² Despite growing enthusiasm, concerns remain regarding its empirical evidence base, ethical implications and capacity to deliver equitable health gains.³

This umbrella review synthesises existing review level literature to provide a balanced assessment of precision public health, integrating supportive and critical

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How to cite: Khan MSA. Precision Public Health: Future Directions A Structured Umbrella Review. *Era J Med Res.* 2025;12(3):122-124.

perspectives and outlining priority directions for research, policy and practice.

METHODS

An umbrella review design was selected to summarise and critically appraise evidence from multiple reviews addressing overlapping aspects of precision public health. This approach is well suited to rapidly evolving and conceptually diverse fields.⁴

Literature Scope and Eligibility

Eligible publications included systematic reviews, scoping reviews, narrative reviews and major conceptual or policy-oriented syntheses focusing on precision public health,

genomic epidemiology, digital epidemiology or precision prevention at the population level. Reviews published in English from approximately 2015 onwards were prioritised to reflect contemporary methodological and policy contexts.

Synthesis Approach

Key findings were synthesised narratively. Themes were identified iteratively and organised into domains covering conceptual foundations, data sources and analytical methods, application areas, ethical and governance challenges, and future directions. Particular emphasis was placed on equity and evaluation, given their prominence across the literature.

Conceptual Foundations of Precision Public Health

Precision public health is underpinned by the principle that population health interventions can be improved by accounting for variation across individuals, places and time.⁵ Rather than applying uniform strategies, PPH aims to stratify populations according to risk or vulnerability, enabling more efficient allocation of public health resources.

Forms of precision have long existed in public health, including outbreak investigation and targeted screening. Contemporary PPH differs primarily in its reliance on largescale, heterogeneous data and computational techniques capable of near real-time analysis. Reviews consistently emphasise that PPH should be regarded as an extension of epidemiological practice rather than a disruptive departure from established public health principles.^{1,2}

Data Sources and Analytical Approaches

The literature identifies a wide range of data sources central to PPH. Genomic and molecular data support pathogen surveillance and outbreak characterisation.⁶ Digital data from mobile devices, wearables and online platforms provide rapid signals of behavioural and symptom trends.⁷ Environmental monitoring, including wastewater surveillance, offers community-level early warning of infectious disease transmission.⁸ Linkage of administrative and clinical datasets enables detailed risk stratification and service planning.

Analytical approaches include geospatial modelling, machine learning, predictive risk algorithms and causal inference methods. While these tools offer substantial promise, reviews caution that insufficient transparency, validation and interpretability may undermine their utility and credibility in policy decision-making.^{3,9}

Applications of Precision Public Health

Infectious Disease Surveillance and Control

Infectious disease control represents the most mature application of PPH. Genomic epidemiology combined with

spatial and mobility data has enhanced outbreak detection, variant tracking and targeted response strategies, particularly during the COVID-19 pandemic.^{6,8}

Targeted Prevention and Screening

Risk-stratified approaches to screening and prevention, including for no communicable diseases, have been proposed to improve efficiency and cost-effectiveness. Reviews suggest potential benefits, provided that predictive models are accurate, transparent and equitable.²

Environmental and Occupational Health

High resolution environmental data have supported targeted interventions for air pollution exposure, vector control and occupational risk mitigation. Precision approaches may be particularly valuable in settings with limited public health resources.

Monitoring Health Inequities

Several reviews highlight the capacity of PPH to reveal disparities concealed by aggregate indicators. However, this potential is dependent on inclusive data collection and explicit equity focused analysis; otherwise, biased datasets may reinforce existing inequities.¹⁰

Ethical, Equity and Governance Challenges

Ethical considerations are central to the future of precision public health. Maintaining privacy of data taking consent and gaining trust of public are major concerns, mostly where non-traditional methods to obtain data are used.⁹ Governance structure recurrently lacks behind technological developments, creating uncertainty about who owns the data and who has access to it and who is accountable for it.

Equity is considered as a major opportunity and also as a risk. While PPH can identify inadequately provided populations, unfair data representation and algorithmic bias may aggravate inequality if not actively talked about. Reviews advocate for equity by design approaches, community engagement and transparent accountability mechanisms.^{10,11}

Evaluation and Evidence Gaps

Across all the reviews, there is a constant result that there is limited availability of thorough evaluations, demonstrating population level, health impact linked to PPH interventions. Most of the initiatives are either descriptive or predictive. There is a weak link to the outcomes that are measurable. It is highly recommended that there should be a standard evaluating structure that incorporates effectiveness, cost, effectiveness, effectiveness, and equity

Future Directions

Precision, public health in future should give priority to the development of privacy, preserving data structure, and more use of transparent explainable analytic methods

and development of a workforce, use of data science and incorporate ethics and community engagement is essential. Governance framework must protect public interest as well as maintain balance with innovation. Most importantly, PPH initiative should majorly link to operable interventions and should be evaluated against clear population, health, and equity outcomes.

DISCUSSION

It is clearly indicated that after this review that PPH offers tools that are valuable to enhance the responsiveness and improve the efficiency of public health practice however, these benefits are not auto generated without the use of robust evaluation, strong governance frameworks and without giving major attention to equity there is a risk that PPH can become technologically driven venture with only limited amount of real world impact.

For public health system, the major hurdles are the precision approach. This precision approach. Precision approach should focus more to give strength to our proven public health strategies rather than displacing them with investment decisions, guided by demonstrable population benefit, and equity considerations and the long term benefit of PPH interventions depend on long-term ability of health systems. To maintain this amount of high-quality data pipelines and interdisciplinary support and workforce training also ensure continuous algorithm validation. Focus must also be given to build public trust with transparent communication and community engagement. Combining PPH into current health, frustrate chair will require careful planning to avoid double effort and ensure that the benefits should reach to the population inadequately provided. They should be a close collaboration between researchers, policymaker and practitioners to make actionable public health policies and to maintain a balance between innovation and practicality and also between data driven precision and ethical responsibility.

CONCLUSION

Precision public health can be of great use to current traditional public health approach and to support more targeted and effective interventions. Ongoing critical evaluation will be essential to realise its potential. PPH is an important evaluation in public health practice by using advancement in availability of data, analytical capacity and when it will be implemented with transparency, governance and commitment to equity, it will be of great help.

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