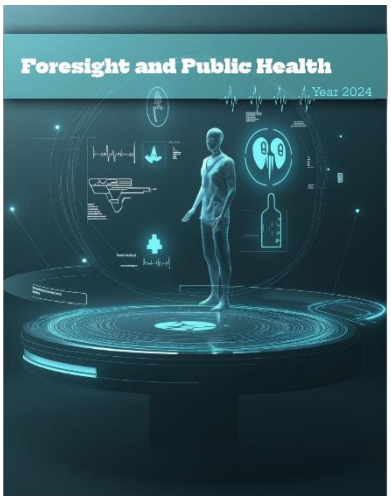
Volume 1, Issue 3, pp 42-50
Article history:
Received 17 April 2024
Revised 08 June 2024
Accepted 18 June 2024
Published online 01 July 2024

Article type:
Original Research



Artificial Intelligence and the Future of Public Health: A Qualitative Inquiry into Ethical, Social, and Policy Scenarios

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How to cite this article:
Olsen, G., & Bastholm, M. (2024). Artificial Intelligence and the Future of Public Health: A Qualitative Inquiry into Ethical, Social, and Policy Scenarios. Foresight and Public Health, 1(3), 42-50. https://doi.org/10.61838/jfph.1.3.5

ABSTRACT

This study explores the ethical, social, and policy implications of artificial intelligence (AI) in public health. This qualitative study employed semi-structured interviews with 32 experts in AI research, public health policy, bioethics, and healthcare administration. Participants were recruited through online announcements and professional platforms, ensuring a diverse representation of viewpoints. Data collection continued until theoretical saturation was achieved. Interviews were transcribed verbatim and analyzed using NVivo software through thematic analysis, following an inductive coding approach to identify key ethical, social, and policy concerns. The analysis revealed three main themes: ethical scenarios, social scenarios, and policy scenarios. Ethical concerns included bias in AI models, privacy and data security risks, and trust in AI-driven healthcare, with participants emphasizing the need for bias mitigation strategies and transparent AI governance. Socially, the findings highlighted AI's impact on the healthcare workforce, disparities in AI accessibility, and the evolving patient-doctor relationship, raising concerns about public trust and the digital divide. Policy challenges centered on the lack of standardized AI regulations, unclear accountability mechanisms, and the need for global collaboration in AI governance, with participants advocating for clearer compliance frameworks and cross-border AI policy alignment. While AI holds transformative potential in public health, its successful integration requires ethical safeguards, inclusive social adaptation, and comprehensive policy frameworks. Addressing algorithmic bias, strengthening data security, fostering public trust, and establishing robust governance structures are essential for ensuring that AI-driven public health interventions align with ethical principles, social equity, and regulatory standards.

Keywords: Artificial Intelligence, Public Health, Ethics, Social Implications, AI Governance, Healthcare Policy, Bias in AI, AI Regulation

Introduction

The integration of artificial intelligence (AI) into public health systems is rapidly reshaping the way healthcare services are delivered, analyzed, and managed. AI-driven technologies have demonstrated their potential in predictive analytics, real-time disease surveillance, personalized treatment recommendations, and large-scale data management, offering unprecedented opportunities for improving public health outcomes (Bazzano et al., 2025; Wang & Li, 2024). However, alongside these advancements, significant ethical, social, and policy challenges arise, necessitating critical discussions on governance, bias mitigation, societal trust, and regulatory frameworks (Edelstein, 2024; Hassan et al.,

2024). While AI promises to enhance efficiency and decision-making in public health, its widespread adoption also raises concerns regarding privacy, equity, and the unintended consequences of algorithmic decision-making (Chen & Ryoo, 2025; Franken & Vepřek, 2025). Addressing these concerns is crucial for ensuring that AI-driven public health interventions align with ethical standards, social equity, and policy frameworks that promote responsible innovation.

One of the most pressing ethical issues associated with AI in public health is the presence of bias in AI algorithms, which can lead to significant disparities in healthcare outcomes (Han et al., 2024; Wright et al., 2024). AI models trained on historical healthcare data often inherit the biases present in those datasets, leading to discriminatory practices that disproportionately affect marginalized communities. For instance, predictive models used in clinical decision-making may reinforce existing disparities in treatment recommendations, exacerbating inequities in healthcare access and outcomes (Hisham et al., 2024). Furthermore, concerns regarding privacy and data security have become more pronounced as AI-driven public health initiatives increasingly rely on large-scale data collection and analysis. The aggregation of sensitive health data raises questions about informed consent, data ownership, and the potential misuse of personal health information, underscoring the need for robust ethical frameworks and governance structures (Gul et al., 2024; Tamrat et al., 2024).

Beyond ethical concerns, the social dimensions of AI in public health also warrant careful examination. The implementation of AI has significant implications for the healthcare workforce, particularly in terms of job displacement and role redefinition (Hemphill et al., 2023). AI-driven automation is expected to transform traditional healthcare roles, raising concerns about the extent to which AI can or should replace human expertise in clinical decision-making. While some argue that AI can enhance healthcare professionals' efficiency by reducing administrative burdens and enabling data-driven insights, others caution against over-reliance on AI, emphasizing the irreplaceable role of human judgment and empathy in patient care (Hitch, 2023). Furthermore, public trust in AI-driven healthcare interventions remains a critical factor in determining the success or failure of AI implementation in public health systems (Liamputtong & Rice, 2023). Misinformation, lack of transparency, and fears of AI-driven decision-making have contributed to public skepticism, highlighting the need for stakeholder engagement and public education initiatives to foster trust and acceptance (Bergman et al., 2024).

At the policy level, AI governance and regulation remain key challenges in the integration of AI into public health frameworks. Currently, the regulatory landscape for AI in healthcare is fragmented, with inconsistencies in ethical guidelines, compliance mechanisms, and international standards (Edelstein, 2024; Nene & Hewitt, 2023). Governments and regulatory bodies face the challenge of balancing innovation with ethical and legal considerations, ensuring that AI applications in public health align with human rights principles and public welfare objectives (Luzingu et al., 2025). The lack of standardized AI governance mechanisms has led to calls for comprehensive policy frameworks that establish clear guidelines on AI accountability, transparency, and ethical use (Surendran, 2024). Additionally, the integration of AI into public health systems requires significant infrastructure investment, particularly in low-resource settings where access to digital health technologies remains limited (Tucker et al., 2023). Addressing these disparities is essential for ensuring equitable AI adoption and preventing further exacerbation of global health inequities (Tamrat et al., 2023).

Despite these challenges, AI holds immense potential to address some of the most pressing public health issues of the 21st century. AI-powered disease surveillance systems have demonstrated their ability to track and predict disease outbreaks with remarkable accuracy, enabling proactive public health responses and resource allocation (Wang et al., 2023). During the COVID-19 pandemic, AI-driven models were instrumental in monitoring disease spread, optimizing vaccine distribution, and analyzing the effectiveness of public health interventions (Delli, 2024). Moreover, AI applications in personalized medicine have shown promise in tailoring treatment plans to individual patients based on genetic, environmental, and behavioral factors, paving the way for more precise and effective public health interventions (Dr Ummi Farhani binti et al., 2024). The ability of AI to process vast amounts of health data in real time also offers new possibilities for predictive analytics, enabling early detection and prevention of chronic diseases such as diabetes and cardiovascular disorders (Hassan et al., 2024).

However, realizing the full potential of AI in public health requires a multidisciplinary approach that incorporates ethical, social, and policy considerations. Ethical AI development must prioritize fairness, accountability, and

transparency, ensuring that AI models are free from discriminatory biases and that their decision-making processes are explainable (Bazzano et al., 2025). Socially, efforts must be made to bridge the digital divide and ensure that AI-driven healthcare innovations are accessible to all populations, particularly those in underserved communities (Tamrat et al., 2024). On the policy front, governments must collaborate with academic institutions, technology developers, and public health organizations to create comprehensive regulatory frameworks that promote responsible AI use while fostering innovation (Franken & Vepřek, 2025). Global cooperation is also essential in establishing ethical guidelines and governance structures that address the transnational nature of AI applications in public health (Luzingu et al., 2025; Nene & Hewitt, 2023).

This study aims to explore the ethical, social, and policy implications of AI in public health through a qualitative inquiry into expert perspectives.

Methods and Materials

This study employs a qualitative research design to explore the ethical, social, and policy implications of artificial intelligence (AI) in public health. The research follows an exploratory approach to gain an in-depth understanding of expert perspectives on the challenges and opportunities AI presents for the future of public health. The study is rooted in an interpretivist paradigm, emphasizing subjective experiences and social constructs related to AI-driven transformations in public health governance, ethics, and policymaking. The participant selection was based on a purposive sampling strategy, ensuring that individuals with relevant expertise and experience in AI, healthcare, bioethics, and public health policy contributed to the discussion. Theoretical saturation was achieved with 32 participants, all of whom were recruited through online announcements and digital platforms, ensuring a diverse range of viewpoints from professionals working in various sectors, including academia, healthcare administration, AI development, and public health governance.

Data collection was conducted using semi-structured interviews, allowing for flexibility in exploring participants' insights while maintaining a structured focus on key research themes. The interview protocol covered topics such as AI's ethical implications in public health decision-making, its impact on health equity, and policy frameworks needed to balance innovation with societal concerns. Each interview lasted between 45 and 90 minutes and was conducted via video conferencing platforms to facilitate engagement across different geographical locations. The interviews were recorded with participant consent and transcribed verbatim for accuracy. Reflexivity was maintained throughout the data collection process, with the researcher actively engaging in memo-writing to document emerging themes and potential biases.

The data analysis followed an inductive thematic analysis approach, utilizing Nvivo software to facilitate coding, theme identification, and data organization. The transcribed interviews were initially subjected to open coding, where key concepts and patterns were identified. This was followed by axial coding, which established connections between categories and broader analytical themes. Finally, a process of selective coding was conducted to refine and consolidate the key findings related to AI's ethical, social, and policy dimensions in public health. Theoretical saturation was reached when no new themes emerged from the data, ensuring comprehensive coverage of the research questions. Data trustworthiness was ensured through member checking, where participants reviewed and validated the findings, and triangulation, which involved cross-verification with existing literature on AI ethics and public health policy.

Findings and Results

The study included 32 participants, representing a diverse range of expertise in artificial intelligence, public health, bioethics, and healthcare policy. Among the participants, 14 were AI researchers and developers (43.8%), 10 were public health professionals and policymakers (31.3%), 5 were bioethics scholars (15.6%), and 3 were healthcare administrators (9.4%). The participants were recruited through online announcements and professional networking platforms, ensuring a broad geographical representation. In terms of gender distribution, 19 participants were male (59.4%), and 13 were female (40.6%). The majority of participants had over 10 years of experience (53.1%), while 25%

had between 5 and 10 years of experience, and 21.9% had less than 5 years of experience in their respective fields. Participants were based in various regions, including North America (37.5%), Europe (28.1%), Asia (21.9%), and other locations (12.5%), reflecting a global perspective on the ethical, social, and policy dimensions of AI in public health. The diversity in professional backgrounds and regional representation contributed to a well-rounded exploration of the challenges and opportunities AI presents in the public health domain.

Table 1. Categorization of Qualitative Data

Category	Subcategory	Concepts (Open Codes)
Ethical Scenarios	Bias and Fairness in AI	Algorithmic discrimination, Data bias, Ethical AI training, Socioeconomic bias, Transparency in AI models
	Privacy and Data Security	Informed consent, Data ownership, Patient confidentiality, Cybersecurity risks, AI-driven surveillance
	Informed Consent in AI-based Decisions	Autonomous decision-making, Patient autonomy, Ethical guidelines, Algorithmic accountability, Legal implications
	AI and Medical Responsibility	Liability issues, Human oversight, AI errors in diagnosis, Ethical frameworks, Professional accountability
	Trust in AI-driven Public Health	Public perception, Institutional trust, Misuse of AI, AI-driven misinformation, Trust-building strategies
Social Scenarios	AI and Health Inequality	Access disparities, Digital divide, Resource allocation, Socioeconomic factors, Rural vs urban healthcare
	Impact on Healthcare Workforce	Job displacement, AI-human collaboration, Skill shift, Resistance to AI, Training healthcare professionals
	Public Perception of AI in Health	Misinformation, Media influence, Fear of automation, Public awareness campaigns, Cultural acceptance, Ethical concerns
	Patient-Doctor Relationship	AI as decision support, Human empathy vs AI, Trust in AI recommendations, AI in personalized healthcare
	Societal Readiness for AI Adoption	Digital literacy, Policy adaptation, Economic factors, Ethical awareness, Legal readiness, Public engagement
Policy Scenarios	AI Regulation in Public Health	National policies, International guidelines, Ethical frameworks, Compliance challenges, Policy enforcement, Standardization
	AI Governance and Accountability	Institutional oversight, AI risk management, Ethical committees, Corporate responsibility, Regulatory compliance
	Integration of AI into Public Health Systems	Infrastructure challenges, Resource allocation, Government investment, AI strategy alignment, Health informatics integration, Public-private partnerships
	Ethical Guidelines for AI in Healthcare	Stakeholder consensus, Transparency requirements, Ethical AI development, Impact assessments, AI use in clinical settings
	Global AI Collaboration in Public Health	Cross-border AI policies, International health data sharing, AI-driven pandemic response, Ethical AI diplomacy

In the analysis of qualitative interviews, three main thematic categories emerged concerning the ethical, social, and policy scenarios of artificial intelligence (AI) in public health. These themes encompass multiple subcategories, each reflecting key issues and perspectives shared by the participants. Below is a detailed reporting of the findings, incorporating interview quotations to illustrate the depth of responses.

Ethical Scenarios

One of the critical ethical concerns in AI-driven public health is bias and fairness in AI. Participants highlighted how algorithmic discrimination and data bias can reinforce existing health disparities. One expert noted, *"AI models learn from historical data, and if that data is biased, the AI will continue to perpetuate those biases, leading to unfair treatment of marginalized communities."* Ethical AI training and greater transparency in AI models were emphasized as potential solutions to address these biases.

Another prominent ethical issue is privacy and data security. Participants expressed concerns about patient confidentiality and cybersecurity risks in AI-driven health surveillance. One participant remarked, *"Patients are often unaware of how their data is used, and AI systems need stronger governance to prevent misuse."* Issues of informed consent and data ownership were also raised, with calls for stricter regulatory frameworks.

The role of AI in informed consent for AI-based decisions was another critical discussion point. Many participants stressed the need for clear communication about AI-driven diagnoses and treatment recommendations. One respondent stated, *"Patients should be fully aware when AI is influencing their healthcare decisions, and there must be human oversight in critical cases."* Algorithmic accountability and legal implications of AI decision-making were emphasized as key considerations.

The question of medical responsibility in AI applications emerged as another ethical dilemma. Several participants raised concerns about liability when AI errors occur, asking whether responsibility should lie with the developers, healthcare providers, or policymakers. A respondent argued, *"We need well-defined ethical frameworks that establish*

where accountability falls when AI makes a wrong diagnosis or treatment suggestion." Human oversight in AI-driven healthcare was considered a crucial safeguard.

Finally, trust in AI-driven public health was a recurring theme. Participants emphasized the public's skepticism toward AI in medical decision-making, citing concerns about AI-driven misinformation and misuse. One expert explained, *"Public trust in AI systems depends on transparency and clear communication from health authorities. Without that, AI risks being viewed as an opaque and untrustworthy tool."* Institutional trust-building strategies were suggested to improve acceptance of AI in public health settings.

Social Scenarios

A significant social concern was AI and health inequality, where participants discussed how AI might either bridge or exacerbate existing disparities. One participant explained, *"AI has the potential to improve healthcare access, but if implemented without consideration for marginalized populations, it could widen the digital divide."* Socioeconomic factors, resource allocation, and rural versus urban healthcare disparities were frequently mentioned.

The impact of AI on the healthcare workforce was also a point of debate. While some participants viewed AI as a tool for enhancing medical efficiency, others expressed fears about job displacement and resistance to AI integration. One interviewee noted, *"AI can automate routine tasks, but human professionals bring empathy and complex judgment that machines cannot replicate."* The need for retraining and upskilling healthcare professionals was highlighted as a critical strategy for adaptation.

Another key social issue was the public perception of AI in healthcare. Many participants highlighted misinformation and media influence as barriers to AI acceptance. One interviewee stated, *"There is a lot of fear-mongering about AI taking over healthcare, but in reality, AI is just a tool that should assist, not replace, human decision-making."* Public awareness campaigns were suggested to address misconceptions and build trust.

The patient-doctor relationship in the age of AI was another area of concern. Some participants worried that increased AI reliance might diminish the human connection in healthcare. One doctor remarked, *"Patients trust their physicians, and AI should serve as a support system rather than an independent decision-maker."* AI's role in personalized healthcare was acknowledged, but maintaining human empathy was deemed essential.

Lastly, societal readiness for AI adoption was discussed. Participants emphasized that digital literacy, policy adaptation, and economic factors all influence how societies integrate AI into public health. One policymaker observed, *"AI adoption is not just a technological issue; it requires public education, legal adjustments, and cultural shifts."* Ethical awareness and legal readiness were highlighted as key factors for ensuring responsible AI implementation.

Policy Scenarios

One of the dominant policy concerns was AI regulation in public health. Participants stressed the need for clear national and international guidelines to ensure AI compliance and standardization. A health policy expert remarked, *"Without a strong regulatory framework, AI in healthcare will be like the Wild West—unpredictable and potentially harmful."* Ethical frameworks and compliance challenges were central to this discussion.

The issue of AI governance and accountability also emerged as a major theme. Participants called for greater institutional oversight, AI risk management strategies, and corporate responsibility in AI development. One expert explained, *"Governments and AI developers must collaborate to establish transparent governance structures that prevent misuse."* Ethical committees and regulatory compliance were suggested as critical measures.

Another significant policy discussion revolved around the integration of AI into public health systems. Participants identified infrastructure challenges, government investment, and public-private partnerships as key factors in AI adoption. One policymaker noted, *"AI should be integrated in a way that strengthens existing health systems rather than creating new disparities."* Health informatics and strategic AI alignment were seen as necessary steps.

The ethical guidelines for AI in healthcare were also debated. Many participants believed that AI should be guided by strict ethical principles, with transparency requirements and stakeholder consensus shaping its use. A bioethics expert stated, *"AI ethics should not be an afterthought; it must be embedded into the design and deployment of AI systems from the start."* Impact assessments and ethical AI development were seen as essential safeguards.

Finally, the theme of global AI collaboration in public health was discussed. Participants emphasized the importance of international data-sharing policies and AI-driven responses to global health crises. One researcher explained, *"AI has no borders, and neither should our efforts to regulate and utilize it for public health."* Ethical AI diplomacy and cross-border AI policies were identified as crucial for addressing global public health challenges.

Discussion and Conclusion

The findings of this study reveal significant ethical, social, and policy challenges associated with the integration of artificial intelligence (AI) in public health. Participants highlighted the ethical dilemmas surrounding bias in AI models, privacy concerns, and the need for human oversight in AI-driven decision-making. Socially, the results emphasize concerns about AI's impact on healthcare workforce roles, disparities in AI accessibility, and public trust in AI-powered health interventions. From a policy perspective, the study underscores the fragmented nature of AI regulations, the need for clearer accountability mechanisms, and the necessity of global cooperation in AI governance. These findings suggest that while AI holds great promise in enhancing public health outcomes, its widespread adoption must be carefully managed to prevent unintended consequences and ensure that it aligns with ethical, social, and policy considerations.

One of the most critical ethical issues raised in the study is bias and fairness in AI. Participants expressed concerns about AI-driven public health interventions reinforcing existing health disparities due to biased datasets and algorithmic decision-making. AI systems that rely on historical health data risk perpetuating structural inequalities, disproportionately affecting marginalized communities (Hassan et al., 2024). These concerns are consistent with previous research indicating that biased training data in AI models can lead to discriminatory outcomes in disease diagnosis, treatment recommendations, and healthcare resource allocation (Han et al., 2024). Prior studies have also emphasized that ethical AI development should prioritize fairness and transparency to mitigate bias (Edelstein, 2024). Ensuring that AI models are trained on diverse, representative datasets and regularly audited for bias is essential for addressing this challenge (Franken & Vepřek, 2025).

Another key ethical concern highlighted in this study is privacy and data security. Participants emphasized the risks associated with large-scale health data collection and AI-driven surveillance. As AI-powered health monitoring systems become more prevalent, issues related to informed consent, data ownership, and cybersecurity threats become more pressing (Surendran, 2024). Similar concerns have been raised in the literature, where researchers argue that the lack of clear regulatory frameworks for AI-driven health data collection poses risks to patient confidentiality and data misuse (Tamrat et al., 2024). Ensuring strong data protection policies, such as robust encryption methods and transparent data-sharing agreements, is critical to maintaining public trust and ethical compliance in AI-driven public health initiatives (Chen & Ryoo, 2025).

The study also identifies trust in AI-driven healthcare as a major ethical challenge. Many participants noted that public skepticism regarding AI in healthcare stems from misinformation, lack of transparency, and concerns over algorithmic decision-making. Previous studies support this finding, demonstrating that trust in AI-based healthcare solutions depends on clear communication and the perceived reliability of AI recommendations (Wright et al., 2024). Public education campaigns, greater AI explainability, and increased stakeholder engagement are recommended strategies for building trust in AI-driven public health interventions (Luzingu et al., 2025).

From a social perspective, the study highlights the transformative impact of AI on the healthcare workforce. Participants expressed concerns about the potential for job displacement and the evolving role of human professionals in AI-assisted healthcare. While some viewed AI as a tool for enhancing efficiency, others feared the loss of human expertise and empathy in medical decision-making. These findings align with previous research indicating that AI's increasing role in healthcare raises questions about the future of medical professions, requiring a shift in training and workforce development strategies (Hitch, 2023). Studies suggest that AI should be seen as an augmentative tool rather than a replacement for human healthcare providers, reinforcing the need for continuous professional development and AI integration training (Hemphill et al., 2023).

Participants also emphasized the unequal access to AI-driven healthcare solutions, particularly in low-resource settings. AI applications in public health require significant infrastructure, digital literacy, and financial investment, which many regions lack. The digital divide in AI-driven healthcare has been widely discussed in the literature, with studies indicating that low-income and rural communities often face barriers to accessing AI-enhanced medical technologies (Bazzano et al., 2025). Addressing these disparities requires targeted policy interventions that ensure equitable distribution of AI benefits (Tamrat et al., 2023).

The patient-doctor relationship in AI-integrated healthcare was another important social factor discussed by participants. While AI can enhance personalized healthcare and improve clinical decision-making, concerns about the potential erosion of human interaction in medical consultations were raised. Similar concerns have been noted in research on AI-human collaboration in healthcare, where the balance between AI efficiency and human empathy remains a central debate (Hisham et al., 2024). Ensuring that AI complements rather than replaces human interaction is crucial for maintaining patient-centered care models (Tucker et al., 2023).

From a policy standpoint, the study highlights the fragmented nature of AI governance in public health. Participants noted that the lack of standardized regulations and ethical guidelines poses challenges for responsible AI implementation. This finding aligns with previous studies indicating that AI regulation varies significantly across jurisdictions, leading to inconsistencies in compliance and ethical standards (Edelstein, 2024). Policymakers must establish comprehensive regulatory frameworks that address AI accountability, risk management, and compliance mechanisms (Delli, 2024).

Another key policy challenge discussed in the study is AI governance and accountability. Participants emphasized the need for clearer institutional oversight, ethical review boards, and compliance monitoring mechanisms for AI applications in public health. Research has shown that AI governance structures must balance innovation with public health protection, ensuring that AI interventions adhere to ethical and legal requirements (Nene & Hewitt, 2023). Strengthening international collaborations and promoting cross-border AI regulatory frameworks can help standardize AI governance approaches (Bergman et al., 2024).

Finally, participants highlighted the importance of global AI collaboration in public health. Given AI's transnational nature, international cooperation in AI policy development, ethical AI research, and health data governance is critical. Studies have emphasized the need for cross-border regulatory agreements and knowledge-sharing platforms to harmonize AI policies and promote ethical AI applications in global health initiatives (Dr Ummi Farhani binti et al., 2024). Promoting ethical AI diplomacy and public-private partnerships will be essential for addressing the complexities of AI-driven public health interventions (Wang & Li, 2024).

While this study provides valuable insights into the ethical, social, and policy challenges of AI in public health, it has several limitations. First, the study relies on qualitative data, which, although rich in detail, may not be generalizable to broader populations. The findings are based on expert opinions, and while efforts were made to ensure diverse representation, the perspectives of AI developers, policymakers, and healthcare professionals may not fully capture the views of patients and the general public. Additionally, as AI in public health is a rapidly evolving field, emerging technologies and regulatory changes may influence the relevance of these findings over time. Future studies may benefit from longitudinal research designs to track the evolving impact of AI in public health settings.

Future research should explore AI's ethical, social, and policy implications using mixed-method approaches, integrating quantitative data with qualitative insights. Conducting large-scale surveys and experimental studies can provide more generalizable findings on public attitudes toward AI-driven public health interventions. Additionally, cross-national comparative studies could shed light on how different regulatory frameworks influence AI adoption and governance. Research should also examine the role of AI in specific public health challenges, such as pandemic preparedness, chronic disease management, and health equity, to develop targeted recommendations for AI implementation in diverse healthcare settings.

To ensure ethical AI integration in public health, policymakers and AI developers should prioritize transparency, accountability, and bias mitigation in AI models. Healthcare professionals should receive continuous training on AI applications to enhance their ability to collaborate effectively with AI systems while maintaining patient-centered care.

Public awareness campaigns should be launched to address misinformation and foster trust in AI-driven healthcare solutions. Additionally, investment in AI infrastructure, particularly in underserved regions, should be a priority to bridge the digital divide and ensure equitable access to AI-powered healthcare innovations. Finally, fostering global collaboration and multi-stakeholder partnerships will be essential for establishing standardized AI governance frameworks and promoting responsible AI use in public health.

Acknowledgments

We would like to express our appreciation and gratitude to all those who cooperated in carrying out this study.

Authors' Contributions

All authors equally contributed to this study.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants. Written consent was obtained from all participants in the study.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

Funding

This research was carried out independently with personal funding and without the financial support of any governmental or private institution or organization.

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