

Editorial



Digital epigenetics: At the crossroads of data, the epigenome, and artificial intelligence

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In recent decades, traditional epidemiology, which emphasizes the systematic collection of clinical and questionnaire-based data, has significantly transformed in response to a remarkable influx of large-scale digital data, social network analytics, and sensor-based information.^{1,2} This transformation, known as digital epidemiology, has changed the landscape of identifying disease trends and tracking public health.

In parallel, epigenetics—a field that combines molecular biology and epidemiology to elucidate the impact of environmental factors on gene expression—has become increasingly important in the realms of public health research and precision medicine.³ Population-based epigenetic studies, or epigenetic epidemiology, offer a profound understanding of how environmental, social, and behavioral exposures shape disease risk. Advanced molecular techniques such as epigenome-wide association studies (EWAS) have been established to assess and interpret epigenetic markers at scale.⁴⁻⁶

In this editorial, we present a forward-looking vision for epigenetics, drawing upon a synthesis of significant literature in digital epidemiology, epigenetics, and artificial intelligence (AI). Our central thesis is that the field must move beyond isolated approaches and explicitly promote the integration of large-scale digital data with population-level epigenetic profiles via advanced AI. We assert that this is not solely an incremental step, but an essential convergence to unveil previously unattainable insights into gene–environment interactions and evolving exposure patterns, influencing the future direction of this emerging field.

The convergence of these two domains—scalable digital data and molecular epigenetic signals—promises the advent of a novel discipline that we may call digital epigenetics. This emerging field seeks to generate large data sets that encompass environmental, neurobiological, and epigenetic data, collected from a wide variety of digital sources including electronic health records, real-time monitoring via wearable devices such as smartwatches, and large omics databases, all analyzed through advanced

Author's Biosketch

Morteza Ghojzadeh is a distinguished epidemiologist and a leading figure in the emerging field of Digital Epidemiology. His interdisciplinary research program sits at the intersection of artificial intelligence, evidence-based medicine, and neurosciences, with a specialized focus on fMRI applications.



A prolific scholar, Ghojzadeh has authored over 300 peer-reviewed articles and is consistently ranked among the world's top 2% most-cited scientists (Stanford University/Elsevier). His work is characterized by a rigorous methodological approach, heavily utilizing systematic reviews and meta-analyses to synthesize complex evidence and drive the field forward.

computational models.⁷ Such integration could uncover novel behavioral and environmental drivers of epigenetic changes, while simultaneously advancing predictive applications in precision medicine.²

AI plays a crucial role in this transformation. Machine learning and deep learning models have demonstrated their capacity to utilize epigenome-centered data for disease risk prediction, molecular status classification, and the discovery of complex gene–environment interaction patterns.⁸ Recent studies and systematic reviews suggest that applying AI to epigenetic data not only enhances predictive accuracy but also facilitates the identification of new biomarkers and the interpretation of multidimensional datasets.⁹

Several key opportunities define the landscape of digital epigenetics:

1. Integrating wearable, environmental, and electronic health data digitally recorded enables dynamic modeling of temporal relationships between exposures and epigenetic modifications.²
2. AI models trained on multimodal datasets (clinical, behavioral, and epigenetic) can guide earlier and more targeted interventions.¹⁰
3. Large-scale digital data can reveal fine-grained environmental or behavioral patterns (e.g., sleep



disruption or urban exposure) often missed by traditional studies, thus supporting hypothesis generation in molecular epidemiology.¹¹

However, the promise of digital epigenetics is accompanied by considerable challenges that must not be overlooked: ensuring the quality and interoperability of digital data; safeguarding genomic and health privacy; preventing population-level algorithmic bias; and maintaining biological interpretability of complex AI models.¹² In order for digital epigenetics to deliver trustworthy and ethically sound benefits to public health, it is crucial to establish transparent frameworks for data governance, standardized model evaluation, and robust ethical and legal oversight.¹³

Finally, advancing this vision requires a coordinated scientific and policy agenda involving investment in privacy-preserving data-sharing infrastructures, the promotion of longitudinal studies that combine digital and molecular data collection, and the formation of multidisciplinary teams that bridge the fields of epigenetics, data science, and bioethics.¹⁴ Equally important is educating researchers and policymakers regarding both the potentials and limitations of AI in epigenetic research. Once these prerequisites have been met, digital epigenetics may well represent the next frontier of data-driven health science, poised to transform both biomedical research and clinical practice.¹⁵

Competing Interests

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References

- Fallatah DI, Adekola HA. Digital epidemiology: harnessing big data for early detection and monitoring of viral outbreaks. *Infect Prev Pract*. 2024;6(3):100382. doi: [10.1016/j.infpip.2024.100382](https://doi.org/10.1016/j.infpip.2024.100382).
- Salathé M, Bengtsson L, Bodnar TJ, Brewer DD, Brownstein JS, Buckee C, et al. Digital epidemiology. *PLoS Comput Biol*. 2012;8(7):e1002616. doi: [10.1371/journal.pcbi.1002616](https://doi.org/10.1371/journal.pcbi.1002616).
- Yu W, Drzymalla E, Gyorfy MF, Khoury MJ, Sun YV, Gwinn M. Navigating epigenetic epidemiology publications. *Epigenetics Commun*. 2023;3(8). doi: [10.1186/s43682-023-00023-3](https://doi.org/10.1186/s43682-023-00023-3).
- Bakulski KM, Fallin MD. Epigenetic epidemiology: promises for public health research. *Environ Mol Mutagen*. 2014;55(3):171-83. doi: [10.1002/em.21850](https://doi.org/10.1002/em.21850).
- Tahir M, Norouzi M, Khan SS, Davie JR, Yamanaka S, Ashraf A. Artificial intelligence and deep learning algorithms for epigenetic sequence analysis: a review for epigeneticists and AI experts. *Comput Biol Med*. 2024;183:109302. doi: [10.1016/j.combiomed.2024.109302](https://doi.org/10.1016/j.combiomed.2024.109302).
- Hamamoto R, Komatsu M, Takasawa K, Asada K, Kaneko S. Epigenetics analysis and integrated analysis of multiomics data, including epigenetic data, using artificial intelligence in the era of precision medicine. *Biomolecules*. 2019;10(1):62. doi: [10.3390/biom10010062](https://doi.org/10.3390/biom10010062).
- Mumtaz H, Riaz MH, Wajid H, Saqib M, Zeeshan MH, Khan SE, et al. Current challenges and potential solutions to the use of digital health technologies in evidence generation: a narrative review. *Front Digit Health*. 2023;5:1203945. doi: [10.3389/fgdh.2023.1203945](https://doi.org/10.3389/fgdh.2023.1203945).
- Campagna MP, Xavier A, Lechner-Scott J, Maltby V, Scott RJ, Butzkueven H, et al. Epigenome-wide association studies: current knowledge, strategies and recommendations. *Clin Epigenetics*. 2021;13(1):214. doi: [10.1186/s13148-021-01200-8](https://doi.org/10.1186/s13148-021-01200-8).
- Rauschert S, Raubenheimer K, Melton PE, Huang RC. Machine learning and clinical epigenetics: a review of challenges for diagnosis and classification. *Clin Epigenetics*. 2020;12(1):51. doi: [10.1186/s13148-020-00842-4](https://doi.org/10.1186/s13148-020-00842-4).
- Nishitani S, Smith AK, Tomoda A, Fujisawa TX. Data science using the human epigenome for predicting multifactorial diseases and symptoms. *Epigenomics*. 2024;16(5):273-6. doi: [10.2217/epi-2023-0321](https://doi.org/10.2217/epi-2023-0321).
- Rozek LS, Dolinoy DC, Sartor MA, Omenn GS. Epigenetics: relevance and implications for public health. *Annu Rev Public Health*. 2014;35:105-22. doi: [10.1146/annurev-publhealth-032013-182513](https://doi.org/10.1146/annurev-publhealth-032013-182513).
- Fahim YA, Hasani IW, Kabba S, Ragab WM. Artificial intelligence in healthcare and medicine: clinical applications, therapeutic advances, and future perspectives. *Eur J Med Res*. 2025;30(1):848. doi: [10.1186/s40001-025-03196-w](https://doi.org/10.1186/s40001-025-03196-w).
- Golub Y, Wulff A, Plösch T. From haze to horizon: epigenetic research and artificial intelligence in child and adolescent psychiatry. *Eur Child Adolesc Psychiatry*. 2025;34(4):1245-8. doi: [10.1007/s00787-025-02686-w](https://doi.org/10.1007/s00787-025-02686-w).
- Lvovs D, Creason AL, Levine SS, Noble M, Mahurkar A, White O, et al. Balancing ethical data sharing and open science for reproducible research in biomedical data science. *Cell Rep Med*. 2025;6(4):102080. doi: [10.1016/j.xcrm.2025.102080](https://doi.org/10.1016/j.xcrm.2025.102080).
- Mostafavi Abdolmaleky H, Nohesara S, Zhou JR, Thiagalingam S. Epigenetics in evolution and adaptation to environmental challenges: pathways for disease prevention and treatment. *Epigenomics*. 2025;17(5):317-33. doi: [10.1080/17501911.2025.2464529](https://doi.org/10.1080/17501911.2025.2464529).