Contents lists available at ScienceDirect

Digital Chinese Medicine

journal homepage: http://www.keaipublishing.com/dcmed

Editorial

Bridging tradition and innovation: phenomics of traditional Chinese medicine 2.0 as a catalyst for the development of integrated holistic precision medicine

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Traditional Chinese medicine (TCM) with its millennia-old wisdom rooted in the principles of holistic Yin-Yang balance and "Bianzheng Lunzhi" [辨证论治, Zhenghou (证候) differentiation and treatment], has long offered a unique lens to understand human health and disease. However, the modern scientific interpretation of TCM remains at the stage of "knowing that it works, but not knowing why it works". Over the past few decades, TCM's modernization has faced a pivotal challenge: how to translate its subjective, experience-driven paradigms—such as tongue diagnosis and pulse palpation—into the objective, data-driven language of contemporary science. This gap is by no means a mere technical issue; it has hindered the integration of TCM into the global modern medical system and restricted the ability to accurately address complex, multifactorial diseases defined by TCM—conditions that often leave single-target western treatment approaches powerless.

Against this backdrop, the paper "Phenomics of traditional Chinese medicine 2.0: integration with digital medicine" [1] published by DUAN and his team emerges as a landmark contribution. This study does not simply extend the existing research framework of the narrative TCM phenomics; instead, it redefines it. The paper deeply integrates advanced digital medicine tools, including artificial intelligence (AI), wearable sensors, medical digital twins (MDTs), and high-throughput phenotyping analysis, with the fabric of TCM's holistic theory. The authors propose a "TCM phenomics 2.0" pattern that successfully bridges tradition and innovation. This work is more than a technical review; it is a roadmap for transforming TCM from an "empirical practice" to a "data science", while preserving its core strength and advantage—focusing on Zhenghou, the earliest clinical phenome defined in medicine.

1 From TCM phenomics 1.0 to 2.0: overcoming the dilemma of TCM modernization

As a key discipline in the post-genomic era, phenomics is dedicated to the systematic study of all macroscopic, mesoscopic, and microscopic phenotypic characteristics of organisms in different environments, promoting multi-dimensional integration from the macro to the micro level [2]. Its holistic and systematic research philosophy is highly consistent with TCM's concepts of holism, Zhenghou differentiation and treatment, and "preventing diseases before they occur (治未病)" [3, 4]. The proposal of "TCM phenomics 1.0" in 2008 marked a crucial first step. By leveraging multi-omics (genomics, metabolomics, metagenomics) and large-scale cohort studies, it aimed to decipher the molecular mechanisms of Zhenghou and Fufang (复方, Chinese herbal formulas) [4, 5]. This gradually enabled TCM phenomics to develop into an important interdisciplinary field for solving scientific problems in TCM and advancing the modernization and internationalization of TCM [3, 5-9]. For instance, the

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Peer review under the responsibility of Hunan University of Chinese Medicine.

DOI: 10.1016/j.dcmed.2025.09.001

Citation: CONG B. Bridging tradition and innovation: phenomics of traditional Chinese medicine 2.0 as a catalyst for the development of integrated holistic precision medicine. Digital Chinese Medicine, 2025, 8(3): 279-281.

authors highlight studies linking colorectal cancer-associated "Pixu Shire" (脾虚湿热) phenome to 12 distinct metabolites [10]. TCM phenomics has also played a leading role in cardiovascular disease phenomics and precision medicine in the post-Coronavirus Disease 2019 (COVID)-19 era [11], and diabetes syndromes are associated with genomics [12], phenomics [13, 14], gut microbiota [15], and multi-omics characteristics [15]. These findings have laid the foundation for establishing the scientific credibility of TCM, but they have also exposed limitations: scattered and fragmented data sources, difficulty capturing dynamic Zhenghou transitions, and the "curse of dimensionality" when analyzing massive high-volume phenomic data.

The emergence of digital medicine has addressed these bottlenecks. As elaborated by DUAN's team, TCM phenomics 2.0 is not a simple addition of technologies, but a paradigmatic innovation [1]. Wearable devices and subcutaneous sensors transform intermittent TCM diagnostic methods, such as tongue coating observation, into real-time, dynamic data streams. AI technologies, ranging from Bayesian networks to graph neural networks, can integrate these data with multi-omics features to map knowledge graphs of causal relationships between Zhenghou subtypes and molecular pathways [e.g., linking "Qi deficiency (气虚)" to abnormal energy metabolism]. MDTs can simulate the long-term regulatory effects of Fufang or acupuncture on Zhenghou, reducing the costs and risks of preclinical research. In short, digital tools do not "replace" TCM's holistic view; instead, they quantify it, endowing TCM with verifiability, axiomatic nature, and computability, making its insights testable, reproducible, and scalable [1].

2 A "new language" for integrated medicine

One of the most profound contributions of this paper is its clarification of how the TCM phenomics 2.0 pattern enriches the connotation of precision medicine. For a long time, western medicine has relied on single phenotypes (such as tumor size and blood glucose levels) to define diseases and guide treatment—a pattern that has shown limited effectiveness in addressing conditions like chronic pain, metabolic syndrome, and post-COVID-19 sequelae. This is because such "diseases" are complex aggregates composed of a series of interrelated factors. In contrast, TCM defines diseases through "Zhenghou", which, as clinical phenomes, integrate multiple elements including symptoms, signs, environment, and constitutions. However, without digital tools, TCM Zhenghou has always remained abstract concepts.

TCM phenomics 2.0 has changed this situation by establishing a "common language" between TCM and western medicine. For example, Table 1 in the paper [1] clearly contrasts the differences between the two medical systems: western medicine classifies diseases based on anatomical or molecular phenotypes, while TCM uses Zhenghou as the "blueprint" of phenomes. Digital technology transforms this "blueprint" into actionable practice: an AI model trained on tongue image data and metabolomics data can not only diagnose the "Yin deficiency (阴虚)" Zheng but also predict which Fufang [e.g., Liuwei Dihuang Pill (六味地黄丸)] can restore metabolic balance. This represents a reimagining of precision medicine—it integrates the rigor of molecular interactions in western science with the holistic view of TCM.

3 Challenges and the path forward

DUAN's team did not shy away from the hurdles ahead and future challenges. Data standardization remains an urgent pressing issue to be resolved: the lack of unified standards for TCM phenomics data, such as pulse rhythm and intensity, as well as tongue coating color and thickness, has hindered cross-institutional collaboration. There is also a shortage of interdisciplinary talents—very few researchers possess both a solid understanding of TCM theory and the ability to conduct AI-driven data analysis. Ethical issues cannot be ignored either, ranging from patient privacy concerns related to data collection by wearable devices to the transparency of AI diagnostic models, all of which require the improvement of data governance systems.

The vision outlined in this paper is both promising and feasible. The study calls for the establishment of a national TCM phenomics data-sharing platform to integrate datasets, suggests that universities offer courses to cultivate "TCM-digital interdisciplinary" talents, and advocates for policymakers to update the ethical framework for digital TCM research. These initiatives are not optional; they are essential prerequisites for unlocking the potential of TCM phenomics 2.0. Consider its potential application scenarios: rural clinics in China obtaining AI-driven syndrome diagnoses through smartphone-based tongue diagnosis scanners; global teams using MDTs to test TCM compound formulas for Alzheimer's disease; and the World Health Organization (WHO) conducting collaborative validation of "TCM phenome coding" with the 12th Revision of the International Classification of Diseases (ICD-12). These are not distant dreams—with the framework proposed by DUAN's team, they are within reach.

4 Conclusion: TCM phenomics 2.0 pattern, a catalyst for global holistic precision medicine

The medical field has gradually recognized the limitations of the "one-size-fits-all" treatment approach. TCM phenomics 2.0 timely reminds us that treatment needs to focus on the "whole person" rather than just symptoms.

The research by DUAN's team is not only an academic achievement but also a call to action. It urges TCM researchers to embrace digital innovation while staying true to their roots, encourages western scientists to recognize the value of TCM's holistic view and TCM phenomics, and appeals to policymakers to invest in integrated medical solutions to leverage the advantages of both medical traditions.

The modernization of TCM does not mean making TCM "more like western medicine", but rather using modern research paradigms and tools to uncover the scientific principles behind the timeless wisdom of TCM [16]. With TCM phenomics 2.0, we stand at a crossroads in a new era of medicine—an era where tradition and innovation converge, bringing about more precise, personalized, and people-centered medical services. While challenges lie ahead, as strongly demonstrated by this paper [1], the future is also filled with boundless possibilities. For the sake of global health, we must walk together and move forward hand in hand.

Competing interests

The authors declare no conflict of interest.

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