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Equitable Access to Healthcare Technologies: A Human Factors Perspective

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ABSTRACT: The rapid expansion of AI-enabled and digital healthcare technologies has transformed clinical decision-making, service delivery, and patient experience. Yet these innovations continue to intersect with social, structural, and organizational inequalities that restrict access for marginalized populations. This commentary examines equitable access to healthcare technologies through a human factors lens, arguing that equity cannot be achieved through technological availability alone. Instead, equitable access emerges from deliberate attention to the physical, cognitive, social, and organizational dimensions of human–technology interaction that shape how individuals perceive, interpret, and use digital systems. Drawing on frameworks of distributive justice, ecosocial theory, biopower, and fundamental cause theory, the paper situates inequities in broader sociotechnical systems while identifying how design choices, workflow structures, and interface features can either mitigate or amplify disparities. The analysis highlights how misalignments between human capabilities and technological demands undermine trust, usability, and safety, particularly for communities already facing entrenched barriers. By connecting ethical commitments to human-centered and user-centered design practices, the paper articulates a pathway for integrating justice-oriented principles into the development and governance of emerging technologies. This inquiry underscores the need for participatory design, continuous evaluation, and reflexive innovation to ensure that digital transformation advances, rather than undermines, equitable healthcare access.

KEYWORDS: human factors, health equity, AI in healthcare, digital health, user-centered design, sociotechnical systems, health disparities, ethical technology design, healthcare access, health administration

JEL Codes: I14, I18, O33, D63, H51

Introduction

Medical ethics, the Hippocratic Oath, and the standards articulated by the International Council of Nurses collectively form the moral architecture that guides healthcare practice by upholding patient dignity, beneficence, autonomy, nonmaleficence, and justice (Galekgatlhe et al., 2025). These longstanding commitments serve as normative anchors, orienting healthcare systems toward equitable access and fair treatment. Their influence is reinforced by global and national policies, including guidelines issued by the Institute of Medicine, the United Nations, the World Health Organization, and the World Medical Association, which offer a multilayered rationale for promoting equitable access to healthcare services (Institute of Medicine [US], 2001; United Nations, 2015; WHO, 1978, 2018, 2021; World Medical Association, 2017).

Yet the contemporary healthcare landscape is undergoing a profound transformation as automated and AI-driven technologies reshape how clinical decisions are made, how care is delivered, and how patients experience healthcare systems (Daniele, 2025). While these innovations promise to enhance efficiency, precision, and reach, technology alone cannot rectify long-standing disparities in access. Instead, the rapid deployment of digital tools has occurred alongside persistent shortcomings in healthcare delivery—shortcomings that remain tightly linked to inequitable access (Li-Min & Sheng-Hsuan, 2025; Faiyazuddin et al., 2025). Many of the most entrenched barriers to care, including socioeconomic constraints (Braveman et al., 2022), cultural and linguistic marginalization (Flores, 2016), systemic discrimination (Bailey et al., 2017), policy limitations (Artiga et al., 2022), and geographical impediments such as inadequate broadband infrastructure (Arcury et al., 2023; Burrell, 2025), intersect with technology in ways that can either alleviate or reproduce harm.

On one hand, digital health tools offer the hopeful prospect of democratizing access to care by extending reach into underserved communities (Husain et al., 2025; Clusmann et al., 2023). On the other hand, persistent structural and sociotechnical barriers continue to limit the accessibility and usability of these technologies (Asifa et al., 2025; Pradhan & De, 2025; Wubshet et al., 2024). Such challenges highlight the inadequacy of purely infrastructural approaches (Alanazi et al., 2025; Anawade et al., 2024) and underscore the need for a deeper examination of human factors, the physical, cognitive, social, and organizational dimensions of human–technology interaction that shape how individuals engage with healthcare systems (de Graaf et al., 2025; Ferguson et al., 2025; Kumar et al., 2025; Wong et al., 2025; Wyatt et al., 2025; Russ et al., 2013).

Human factors science is uniquely positioned to interrogate these complexities. By examining how individuals perceive information, interpret risk, navigate interfaces, regulate cognitive load, and develop trust in automated systems, human factors provides an analytical framework for improving safety, performance, and user experience across diverse populations (Blaga et al., 2025). More importantly, human factors serve as a bridge between ethical aspirations and practical realities. It foregrounds the lived experiences of patients and clinicians, revealing how design decisions can either enhance autonomy and fairness or reinforce exclusion.

Thus, this paper examines constraints on access to healthcare technologies through the lens of human factors, emphasizing how design, implementation, and policy choices can promote—or impede—equity. A deeper engagement with theories of justice is essential to inform this effort, as they offer ethical grounding for equitable distribution and dignified care. Contrary to the assumption that expanding technological access inherently leads to equity, this paper argues that equity emerges only when ethical principles are woven into the design and evaluation of sociotechnical systems. By contextualizing the problem, articulating a clear purpose, and identifying critical research questions, this work lays the foundation for a human-factors-informed framework that can advance meaningful change.

Problem Statement

Despite robust ethical and policy frameworks that champion dignity, justice, and equitable access to care (Galekgatlhe et al., 2025; World Medical Association, 2017; WHO, 1978, 2018, 2021), the rapid evolution of AI-enabled and automated healthcare technologies has exposed a widening gap between ethical commitments and technological realities. Although digital tools possess the transformative potential to broaden access and enhance clinical reach (Husain et al., 2025; Clusmann et al., 2023), their deployment frequently reproduces existing structural inequities embedded in socioeconomic status, geography, race, immigration status, and policy environments (Bailey et al., 2017; Braveman et al., 2022; Artiga et al., 2022).

These inequities manifest across multiple dimensions. Individuals living in low-income households, marginalized racial or ethnic communities, linguistically diverse groups, and rural residents lacking reliable broadband remain disproportionately excluded from digital health innovations (Burrell, 2025; Flores, 2016; Arcury et al., 2023; Fagundo-Rivera et al., 2025). Even as technological capabilities expand, the persistence of these disparities signals that systemic barriers remain deeply entrenched (Li-Min & Sheng-Hsuan, 2025; Perez et al., 2025; Santosa et al., 2025).

Crucially, these exclusions are not byproducts of user failure but rather consequences of design and deployment practices that insufficiently account for human factors. When technologies overlook variability in cognitive load, sensory abilities, linguistic backgrounds, affective responses, and social contexts, they inadvertently create interfaces and workflows that cater to privileged groups while marginalizing others (de Graaf et al., 2025; Ferguson et al., 2025; Kumar et al., 2025; Wong et al., 2025; Wyatt et al., 2025; Russ et al., 2013). Misalignments between human capabilities and technological demands lead directly to usability breakdowns, diminished trust, heightened misinterpretation of information, and increased safety risks (Blaga et al., 2025).

As healthcare becomes increasingly mediated by digital infrastructures, these mismatches can scale rapidly, amplifying inequities at population levels. Unless design approaches explicitly integrate justice-oriented human factors principles—accounting for diverse physical, cognitive, sociocultural, and emotional needs, technological systems risk entrenching disparities under the guise of innovation (Asifa et al., 2025; Pradhan & De, 2025; Wubshet et al., 2024). Addressing these shortcomings is therefore not simply a matter of optimizing functionality; it is a moral and practical imperative central to ensuring that technology-enabled care supports, rather than undermines, equitable access to healthcare.

Purpose and Scope

This commentary examines how the physical, cognitive, social, and organizational dimensions of human–technology interaction shape the equity of access to healthcare technologies. Rather than presenting new empirical findings, it advances a critical perspective on how human factors science can more deliberately inform the design and governance of emerging systems. The aim is to provoke dialogue and offer conceptual guidance for embedding ethical commitments, such as inclusivity, fairness, and justice, into the development of tools, workflows, and policies that structure technology-enabled care.

Commentary articles occupy a distinctive role in scholarly ecosystems. They synthesize insights across domains, highlight conceptual blind spots, and draw attention to emerging ethical, methodological, or societal concerns that may not yet be captured by empirical research. By situating current practices within broader theoretical, historical, or normative contexts, commentaries help reorient research trajectories and sharpen the questions that subsequent studies should address. They also serve as catalysts for intellectual exchange. Because commentary authors are not constrained by reporting data, they can articulate positions, raise critiques, and propose alternative framings with a clarity and urgency that empirical formats seldom allow. This fosters productive debate, encourages interdisciplinary engagement, and enables academic communities to scrutinize assumptions that might otherwise remain implicit.

In fields concerned with technology, health, and equity, commentary contributions are especially impactful. They surface ethical tensions early, interrogate how design choices allocate risks and benefits, and prompt researchers, developers, and policymakers to integrate human-centered and justice-oriented principles before inequities are reproduced at scale. In doing so, commentary papers help steer both scientific inquiry and practical innovation toward more socially responsive and equitable outcomes.

Significance of the Inquiry

Interrogating equitable access to healthcare technologies through a human factors lens is significant for at least three interconnected reasons: it exposes where ethical commitments fail in practice, it reframes equity as a design and systems property rather than an afterthought, and it offers concrete levers for intervention in rapidly evolving sociotechnical environments.

First, this inquiry directly addresses the growing disjuncture between the ethical and policy architectures of healthcare and the realities of technology-mediated practice. Normative frameworks rooted in medical ethics, human rights, and global health policy articulate clear commitments to dignity, beneficence, autonomy, nonmaleficence, and justice (Galekgatlhe et al., 2025; Institute of Medicine [US], 2001; United Nations, 2015; WHO, 1978, 2018, 2021; World Medical Association, 2017). Yet the deployment of AI-enabled and automated systems has revealed how these commitments can be undermined when human capabilities, vulnerabilities, and contexts are insufficiently considered (Daniele, 2025; Li-Min & Sheng-Hsuan, 2025). By centering human factors, this inquiry examines not only whether technologies exist or are "available," but whether their design, interfaces, workflows, and organizational embedding actually enable equitable use by diverse populations (de Graaf et al., 2025; Ferguson et al., 2025; Wong et al., 2025).

Second, the inquiry is significant because it reframes equity as fundamentally entwined with the micro- and meso-level details of human–technology interaction. Structural determinants, such as socioeconomic status, race, geography, and policy, shape exposure to risk and access to resources (Bailey et al., 2017; Braveman et al., 2022; Artiga et al., 2022), but their effects are mediated through concrete interactions with systems: log-in procedures, language options, alert formats, data visualizations, workload demands, and models of automation. When these interactions are misaligned with users' cognitive load, sensory abilities, health literacy, or cultural and linguistic backgrounds, technologies can exacerbate precisely the inequities they are intended to ameliorate (Flores, 2016; Arcury et al., 2023; Fagundo-Rivera et al., 2025). Human factors science, with its focus on perception, decision-making, trust calibration, and system usability, provides the analytic tools to surface these misalignments and to conceptualize equity as a property of sociotechnical design, not simply of distribution (Blaga et al., 2025; Russ et al., 2013; Stone et al., 2025).

Third, the inquiry is consequential because it identifies specific points of leverage where human factors can translate ethical theories of justice into practice. Theoretical frameworks such as distributive justice, ecosocial theory, biopower, and fundamental cause theory highlight how resources, risks, and control are patterned across populations (Braveman & Gruskin, 2003; Link & Phelan, 1995; Phelan et al., 2010; WHO, 2021). However, these frameworks often remain abstract unless they are operationalized in design and implementation decisions. Human-centered and user-centered design (HCD/UCD) provide methodologies for embedding these ethical commitments into concrete choices about who is included in requirements gathering, whose constraints shape interface design, how automation is balanced with professional judgment, and how feedback from marginalized users is integrated over time (Giansanti et al., 2025; Probst et al., 2024; Stone et al., 2025). The underutilization of beneficial technologies, such as continuous glucose monitoring devices among marginalized groups (Ben et al., 2025), illustrates how equity failures are often less about the intrinsic efficacy of tools than about how they are designed, communicated, financed, and supported in real-world contexts.

Finally, this inquiry is timely and impactful because it positions human factors as a critical mediator between emerging technologies and future trajectories of health equity. As AI, digital platforms, and data-intensive tools become increasingly central to diagnosis, monitoring, and care coordination, the risks of scaling inequities grow in parallel (Husain et al., 2025; Asifa et al., 2025; Wubshet et al., 2024). A human-factors-informed perspective does not merely critique these developments; it offers a path forward by specifying how usability testing, participatory design, iterative feedback loops, and attention to trust and transparency can be harnessed to align technological innovation with ethical obligations (Blaga et al., 2025; Santiago et al., 2025). In doing so, this inquiry contributes not only to human factors scholarship but also to broader debates in health ethics, policy, and informatics, demonstrating that equitable access to healthcare technology is achievable only when human factors are treated as central, rather than incidental, to the design of just healthcare systems.

Theoretical Foundations

Equitable access refers to the fair distribution of resources and opportunities according to individual needs and circumstances, rather than identical treatment for all, which would constitute equal access (Joseph et al., 2025; World Health Organization, 2021; Braveman & Gruskin, 2003). For equitable access to work, there must be a global commitment to patenting, licensing, manufacturing, disseminating, and implementing the new healthcare technology (Coller, 2025). Human factors design can play a significant role. Health informaticians, those who enhance patient care through integrating technology, data analytics, and healthcare expertise, can influence equitable access (Gedalanga, 2025). A ubiquitous example of inequitable access is the underutilized continuous glucose monitoring (CGM) device, whose use has positive results for managing diabetes (Ben et al., 2025). Marginalized groups, for various reasons, do not have access.

Human factors science is the interdisciplinary study of how humans interact with systems and tools, integrating insights from ergonomics, psychology, and design to improve usability, safety, and inclusivity in complex systems such as healthcare (Stone et al., 2025). The literature review frameworks include theories of distributive justice, biopower and technological governance, human-centered design (HCD) and user-centered design (UCD), ecosocial theory of disease distribution, and fundamental cause theory.

Distributive Justice

This discussion explores various theoretical frameworks of distributive justice relevant to understanding equitable access. A common theme among these frameworks is the moral and ethical responsibility toward every individual. The foundational works of John Rawls (1971), Amartya Sen (1992), Martha Nussbaum (2011), and Michael Walzer (1983) serve as a basis for understanding equitable access to healthcare technologies.

Distributive justice is a concept of fairness that asserts society has a moral duty to its members to allocate resources, such as goods and services, fairly and equitably (Nikolakakis, 2025). In the context of healthcare, this principle pertains to access to patient care and treatment, as well as to the innovation and implementation of technologies. The ideas proposed by these theorists highlight the human moral responsibility to ensure equitable access to healthcare technology, innovation, and utilization (Galekgatlhe et al., 2025).

For Rawls (1971), the focus is on providing equal opportunities; for Walzer (1983), it is about distributing access and its benefits based on need; Sen (1992) argues that true healthcare freedoms should be expanded; and Nussbaum (2011) contends that health and integrity are preserved and improved through guaranteed access to healthcare. While interpretations of fairness can vary, some view its implementation as a systematic process (Wintein & Heilmann, 2024a, 2024b), utilizing Broome's theory (1984, 1988, 1990) as an example. Both the fairness formula (Wintein & Heilmann, 2024a, 2024b) and distribution theories focus on how goods and resources are allocated within society. A society genuinely committed to the welfare of its members ensures that the least advantaged are not overlooked (Rawls, 1971). Each theorist affirms this goal in slightly different ways. Rawls' theories build upon the social contract ideas of Rousseau, Locke, and Kant (Ekmekci & Arda, 2015), with public reasoning being essential to justice. He posits two principles of justice: equal liberty and the presence of social inequalities. Critics argue that achieving this egalitarian vision on a global scale may be impossible (Kamminga, 2006). Rawls' Law of Peoples suggests that justice cannot always be realized without governments and legal systems, despite their imperfections and criticism from anarchists (Freeman, 2006). Researchers and practitioners have a responsibility to ensure equitable access for underserved populations (Galekgatlhe et al., 2025). Additionally, Rawlsian theory advocates for intergenerational justice (Mkrtchyan, 2024).

Although Rawls' theory does not explicitly address healthcare, it has the potential to expand (Mkrtchyan, 2024). Primary social goods should include healthcare, which ought to be recognized as a fundamental right grounded in dignity (Nussbaum, 2011). Walzer's concept of complex equality (Nikolakakis, 2025) addresses healthcare access, emphasizing that it should not be commodified but treated as a societal good available to all on the basis of need (Walzer, 1983).

Sen argued that human capabilities are intrinsically linked to justice in healthcare (Sen, 1992), while Nussbaum (2011) argued that distributive justice guarantees healthcare as a moral entitlement essential to human dignity. This view suggests that policy choices should not undermine these entitlements. Sen builds on Rawls' work by promoting a notion of comparative justice, which extends beyond the ideal of perfect justice. Individual capabilities determine one's ability to direct one's life (Nikolakakis, 2025). Rawls believed public discourse and reasoning drive equitable access. In contrast, Walzer (1983) adopts a more pluralistic view of justice, wherein it is divided into different societal spheres, each governed by its own principles of distribution, driven by need rather than power or wealth.

When applied to healthcare technology, distributive justice indicates that digital innovations must be designed not just for efficiency or profitability, but also for fairness and inclusion. Equitable access requires acknowledgment that individuals start from different social, economic, and cognitive positions. For example, a telemedicine platform should be developed to function effectively across varying levels of internet connectivity, literacy, and physical ability. From a human factors perspective, distributive justice compels designers to create systems that accommodate human diversity rather than exacerbate disparities. The digital divide serves as a critical indicator of equitable access worldwide (Catalano et al., 2025; Dunga, 2025; Pukdeewut & Setthasuravich, 2024; Zhang et al., 2025). Policymakers often share fundamental values about justice, yet implementation poses significant challenges (van Zyl et al., 2025). If we view technology merely as a tool, the concepts of biopower and technological governance become crucial levers in shaping equitable access. These theories merit further explanation.

Biopower and Technological Governance

French philosopher Michel Foucault explored power and control through the concept of biopower (Foucault, 2003, 2007). He described how modern societies exert control over populations by managing life itself, observing, categorizing, and regulating human behavior and biological existence. This ideology can be analyzed at both the anatomo-political level (individual bodies) and the biopolitical level (entire populations) (Vukićević, 2024). Healthcare exemplifies this type of power through data systems, algorithms, and surveillance technologies that influence how people live, behave, and make decisions about their health.

Examples of anatomo-politics include routine medical examinations, structured medical training (Jiang et al., 2025), military training (Pielen et al., 2025), workplace safety measures such as ergonomics (Silva et al., 2025), and behavioral rules in schools (Nduwayezu & John, 2025). Biopolitical examples include public health programs like vaccinations (Ai et al., 2025), demographic management using actuarial formulas (Weiss et al., 2024), urban planning policies (Matsuo & Iwamitsu, 2022), environmental regulations (Kang et al., 2024), and genetic and reproductive technologies such as genome analysis (McTaggart et al., 2024) and prenatal screening (Ireland-Blake et al., 2024).

Digital health technologies, including wearable devices and smartphone apps, extend this control into individuals' personal spaces (Leuzzi et al., 2025), representing a form of technological governance. While these tools enhance user experience by helping individuals monitor healthcare data, they also enable data sharing and analysis by corporate and institutional powers (Du & Wang, 2024), which embody the technological governance concepts Foucault described. While these tools can empower individuals in managing their health and lives, they also allow institutions and corporations to track, predict, and influence behavior. This can result in social control or regulation rather than true patient empowerment.

Building on Foucault's concept of biopower, these examples illustrate how digital inequality, whether intentional or unintentional, creates a significant hierarchy of potential control, leaving marginalized populations even more vulnerable. Technological biopower should be recognized as a tool to empower individuals and patients rather than a means to exploit or confine them. It should enhance autonomy and agency, rather than diminish it through the datafication of personal information (Sagar, 2025).

Healthcare technologies grounded in ethical principles, such as transparency, should clearly inform patients about the personal data that is collected and facilitate informed decisions about their participation (Siyadri & Sri Ram, 2024). Human-centered and user-centered design approaches can help mitigate the potential loss of personal freedom inherent in biopower by creating systems, policies, and practices that promote informed decision-making.

Human-Centered Design (HCD) and User-Centered Design (UCD)

Human-Centered Design (HCD) and User-Centered Design (UCD) are approaches aimed at creating technologies that prioritize the lived experiences, needs, and limitations of their users. The design principles for these approaches have been formalized by the International Organization for Standardization (ISO, 2010, 2019). While HCD and UCD are closely related and often used interchangeably, both aim to deliver a positive, efficient user experience. HCD focuses on integrating human capabilities, needs, and behaviors throughout the design process, whereas UCD emphasizes user engagement with product features and the overall user experience (Bevilacqua et al., 2025). A noteworthy goal of Human-Centered Design in artificial intelligence (HCDAI) is to empower users rather than replace them (Bevilacqua et al., 2025). In HCD, users are viewed as individuals, not merely as users (Sanders et al., 2024). In UCD, users interact with prototypes to identify issues and opportunities for improvement, thereby enhancing the user experience and helping assess return on investment (ROI), risks, and challenges related to adoption and implementation (Bevilacqua et al., 2025). Instead of developing systems from a purely technical or institutional perspective, these frameworks emphasize empathy, participation, and iterative improvement. The central idea is that technology should adapt to people, rather than the other way around.

Among the design principles associated with HCD and UCD that support personal freedom and equitable access to healthcare technologies are trustworthiness, explainability, transparency, privacy, fairness, safety, protection, accountability, and decision-making authority (Bevilacqua et al., 2025). While digital technology has expanded capabilities and access globally, it has also led to greater cultural diversity, which is a positive development. However, this diversity brings challenges such as multiple languages and varying levels of digital literacy (Gedlanga, 2025), which can hinder equitable access. In the healthcare sector, HCD and UCD can help bridge the digital divide.

Ecosocial Theory of Disease Distribution

The ecosocial theory of disease distribution, developed by epidemiologist Nancy Krieger, seeks to understand the factors that drive social inequities in healthcare (Krieger, 2004, 2011, 2012). This theory explains how health outcomes arise from the interplay of biological, social, and environmental factors. It highlights that inequality is not only present within societal systems but also embodied, reflecting the dynamic interaction between individuals and their environments over time (Krieger, 2021). Researchers have applied ecosocial theory to the field of mental healthcare. For instance, Hammarström et al. (2024) expanded on Krieger's concept of embodiment by integrating Bronfenbrenner's ecology model with life-course theories in their qualitative study. Their findings revealed that labor market conditions significantly influence an individual's mental health embodiment. They suggested that policies aimed at benefiting individuals, such as promoting flexible work schedules, could enhance their embodied mental health, a conclusion that aligns with other research showing that increased choice and autonomy improve well-being (Shervin et al., 2025).

Krieger emphasizes that both negative and positive experiences are embodied. For example, language-acquisition technology can inadvertently induce anxiety (Huang & Liu, 2025). Conversely, it can also alleviate anxiety by fostering emotional safety and supportive environments (Huang & Liu, 2025). Moreover, the digital divide in healthcare technology can adversely affect patient health, illustrating another aspect of embodiment (Liu et al., 2024).

To address these issues, interventions in human factors engineering must consider both the technology itself and the social structures that influence its adoption, use, and access. Ensuring equitable access to healthcare technology across all socioeconomic levels is crucial. While ecosocial theory explains how unequal access to healthcare technology can lead to disparate health outcomes, fundamental cause theory may provide insight into the unequal benefits derived from technology.

Fundamental Cause Theory (FCT)

Fundamental Cause Theory argues that socioeconomic status (SES) and other social structures contribute to health inequities through more readily accessible resources such as money, power, and education (Link & Phelan, 1995; Phelan et al., 2010). The assumption is that those with higher SES are empowered to benefit from technological advances in healthcare, whereas those with lower SES have less empowerment to do so. These assumptions are important since advantaged segments will have ready access to technology, whereas less advantaged segments are less likely to. For example, higher-SES individuals are more likely to use smart devices and other wearable technologies, providing them with more opportunities to improve and maintain their health. Lower-SES individuals are more likely to have health challenges (Xu et al., 2025), in part due to limited access. The theory strongly argues for causality through social structures, suggesting to the researchers and leaders that policies should be designed to open equal access while not excluding those who already have access.

From a human factors perspective, this theory underscores the importance of designing technologies that do not assume high literacy, stable internet access, or advanced digital skills. Equitable design requires simplification, localization, and affordability. But the solution extends beyond design alone, policy must also address affordability and education so that all individuals can translate access into real health gains.

Fundamental cause theory increases awareness that healthcare technology, with its amazing benefits, does not necessarily democratize access. The need for transparent and effective policies that open access by countering socioeconomic disparities, overcoming geographic limitations, and simplifying (clarifying) language remains. Bridging this gap requires integrating ethics, human factors, and social policy to ensure that digital progress benefits the many, not the few.

The theoretical framework's tenets and their relevance to equitable access have been presented. At the core of each theory lies a quiet yet ever-present sense of justice toward others, grounded in human ethics and morality. This sense of justice can influence equitable access to healthcare technology. The remainder of this paper highlights the principles derived from the theoretical framework, which form the basis for a general and human-factors design model leading to equitable healthcare access.

Socioeconomic and Structural Determinants of Access

Economic Barriers

Economic barriers (González-Rábago et al., 2025; Machaca et al., 2025) represent the expenses associated with wearable devices, travel to medical facilities, and telemedicine connectivity, placing many patients at a financial disadvantage. Moreover, health insurance models may not cover telehealth or digital interventions. Additionally, a lack of digital literacy can further disadvantage underserved populations.

Geographical and Infrastructural Constraints

Geographical and infrastructural constraints (Huber et al., 2024) apply to rural and low-resource areas often lack access to broadband connectivity, which limits the utilization of telemedicine (Burrell, 2025). Furthermore, the delivery and maintenance of services may be challenging due to geographical barriers.

Cultural and Linguistic Accessibility

Cultural and Linguistic Accessibility (Al-Hamad et al., 2025) apply to health technologies frequently reflect the cultural and linguistic biases of their developers, which can marginalize speakers of minority languages and culturally distinct groups. Health literacy, the ability to understand and act upon health information, is influenced by education, culture, and personal experience. Therefore, inclusive design must consider translation, cultural adaptation, and user-friendliness for diverse populations.

Human Factors in the Design and Deployment of Healthcare Technologies

User-Centered Design, Human-Centered Design and Inclusivity

User-centered design (UCD) and human-centered design (HCD) focus on key principles that promote equitable access, such as empathy, iteration, and active participation of end-users (Giansanti et al., 2025; Karban et al., 2025). Inclusive design follows an iterative process that incorporates feedback from end-users during software development, product design, and implementation (Farsetta et al., 2025). Involving patients, caregivers, and clinicians in the co-design process ensures that technologies address real-world constraints effectively (Probst et al., 2024).

Interaction Between Humans and Automation

The integration of AI and automation presents challenges regarding trust calibration and cognitive workload (Patrício et al., 2025). Excessive reliance on automation technology can lead to issues with trust, as overconfidence in such systems may result in bias, including incorrect medical diagnoses (A scoping review and evidence gap analysis of clinical AI fairness, 2025). Effective trust calibration strikes a balance between human interaction and automation technology, which is crucial not only for design and development but also for user adoption and deployment (Wong et al., 2025).

Evaluation and Feedback Mechanisms

Evaluation and feedback mechanisms (Santiago et al., 2025) apply to the perspective that effective technology systems depend on evaluation and feedback loops to create high-quality products focused on end-user needs (Bouzón et al., 2025), such as continuous glucose monitors (CGMs) or sports watches. These mechanisms are essential to both user-centered and human-centered design. Employing patient surveys, usability testing, and ethnographic studies can help identify equity gaps in technology adoption while considering social and ethical impacts (Ehn et al., 2025).

Telemedicine in Rural and Low-Income Communities

Despite the benefits of telemedicine, only 15% of pediatricians used it in 2016. They cited patient uncertainty about its effectiveness, inadequate infrastructure, and low reimbursement for their services as significant barriers (Pathak et al., 2024). Although technological limitations, readiness to adopt new practices, and a lack of trained personnel in some communities continue to pose challenges, studies indicate that telemedicine enhances access in underserved regions. It facilitates patient consultations that might not otherwise take place, supports follow-up care, and aids in the management of chronic diseases. Moreover, telemedicine enables ongoing monitoring, which can improve health outcomes and reduce the need for hospital visits. This approach not only lowers healthcare delivery costs but also increases the utilization of healthcare resources (Huang et al., 2025; Perez et al., 2025).

AI Diagnostic Tools and Bias

One might assume that the algorithms governing AI will consistently produce unbiased results. However, AI is neither omniscient nor infallible. A substantial body of literature concerning trust in AI supports this notion (Alshammari & Al-Mamary, 2025; Kauttonen et al., 2025). Algorithms trained on homogeneous datasets can lead to systematically biased outcomes, such as the underdiagnosis of conditions in individuals with darker skin tones or varying perceptions of pain tolerance across different ethnicities (A Scoping Review and Evidence Gap Analysis of Clinical AI Fairness, 2025). To ensure safe and unbiased algorithms, it is crucial to use diversified datasets, conduct audits, and maintain transparency in reporting. Reflexivity (Sakaguchi et al., 2025) should be practiced at every stage of design, development, and implementation to minimize bias in AI-driven technology.

Wearable Health Technologies

Continuous glucose monitoring (CGM) devices are wearables that can significantly improve diabetes management and overall patient well-being (De la Torre et al., 2025). However, access to wearables, such as fitness trackers and CGMs, varies unevenly across different income and age groups (Chandrasekaran et al., 2025). Sociotechnical barriers, privacy concerns, device costs, and social stigma highlight the necessity for accessible design and subsidized distribution models (Kasaai et al., 2025).

Policy, Governance, and Ethical Oversight

Public–Private-Government Partnerships

Conventional policies and practices within social frameworks frequently fail to meet expectations for social justice and equitable access (Nussbaum, 2011; Rawls, 1971; Sen, 1992; Walzer, 1983). This deficiency is understandable, given that the operations of these entities are predicated on principles such as voluntary exchange, market competition, profitability, limited government oversight, and pricing (Sowell, 2015). While these principles advocate for freedom of choice, concepts such as biopower (Foucault, 2003, 2007; Vukićević et al., 2024) and Fundamental Cause Theory (Link & Phelan, 1995; Phelan et al., 2010) underscore the moral and ethical responsibilities individuals have towards one another. It is imperative that underserved and marginalized communities receive equitable access to healthcare technology. To align incentives with public health objectives, the establishment of clear governance mechanisms and ethical codes is essential (Goktas & Grzybowski, 2025; Krieger, 2021). Recognizing our global moral and ethical responsibilities, private, public, and government entities must collaborate with researchers, educators, subject matter experts, technology specialists, and underserved communities. This collaboration should aim to develop practical, moral, and ethical policies that ensure equitable access to healthcare technology for all. Qualitative researchers should investigate the lived experiences of members from underserved communities (Carlsson et al., 2025; Sayani et al., 2025) to inform the development of meaningful and thoughtful policies. The subsequent section will provide further details.

Equity-Oriented Policy Interventions

Governments and health systems can advance equity through various strategies. They can implement interventions that establish policies to ensure equitable access to healthcare (Ceschi et al., 2025). These interventions should consider the lived experiences of those requiring access. One effective strategy is to subsidize broadband infrastructure and provide digital literacy programs (Rangachari et al., 2025). Enhancing broadband access can improve availability for those who would benefit from it (Burrell, 2025), while digital literacy training campaigns can further engage individuals with healthcare services and enhance their digital skills. Additionally, enforcing universal design requirements in procurement policies (see Lam et al., 2025) can facilitate equitable access to healthcare technology by reducing product costs. Finally, creating open-source platforms can decrease dependency on proprietary systems, thereby alleviating financial burdens on communities and individuals (Comprehensive Testing of Large Language Models, 2025).

Integrating Human Factors and Ethics

The proposed model incorporates human factors research within an ethical framework that seeks to balance usability, accessibility, and justice (Probst et al., 2024). Human-centered and user-centered design approaches challenge prevailing assumptions about patients, such as the notion that they are reluctant to visit a physician or lack the financial resources to do so. By designing technologies that enhance patient autonomy, health equity can be promoted (Bradway et al., 2025). To ensure equitable access to healthcare technology, human factors should be designed with inclusivity in mind from the outset, integrating ethical considerations at every stage of the design process.

Principles of Reflexivity, Transparency, and Accountability

Reflexivity involves employing self-awareness and reflection to foster objectivity and promote ethical design principles that advocate for inclusivity and equality. Reflexive methods encourage researchers, designers, and policymakers to recognize and address biases (Lazurko et al., 2025; Sakaguchi et al., 2025) that could compromise the integrity and credibility of their work. Transparency ensures that users comprehend how data are collected, analyzed, and utilized (Lee & See, 2004; Wang et al., 2025). Accountability mechanisms, such as ethics boards and algorithmic audits, hold individuals responsible for any harm caused (Bevilacqua et al., 2025).

Metrics for Evaluating Equity and Inclusion

Appropriate metrics in human factors design can provide insights into equitable access and demographic usage, as well as aspects such as accuracy, empathy, performance, satisfaction, perceived trustworthiness, and fairness (Abbasian et al., 2024). For instance, chatbots can be employed to assess the fairness of technology across different demographics. Additionally, the safety and security dimensions of trustworthiness can be evaluated by measuring how well the responses align with ethical standards.

Actionable Recommendations

1. Health systems should subsidize essential digital infrastructure, including broadband expansion and affordable connectivity (Burrell, 2025), to mitigate structural barriers that impede users' functional access to telemedicine, thereby aligning system-level design with the human factors principle of environmental support for equitable technology use (González-Rábago et al., 2025; Machaca et al., 2025; Huber et al., 2024).
2. Policymakers should require insurance reimbursement for telehealth and digital interventions to ensure that cost does not constrain users' engagement with technology, recognizing that financial accessibility is foundational to equitable human–technology interaction (Stummer et al., 2025).

3. Designers should incorporate multilingual interfaces, culturally adapted content, and inclusive communication strategies into digital health tools to reduce cognitive and linguistic load, strengthen user comprehension, and build trust among diverse populations (Al-Hamad et al., 2025).
4. Technology teams should embed human-centered and user-centered design practices that actively involve patients, caregivers, clinicians, and community partners in co-design processes, ensuring that systems reflect real-world constraints and optimize usability, safety, and adoption (Giansanti et al., 2025; Karban et al., 2025; Probst et al., 2024).
5. Developers and health organizations should design AI-enabled systems that calibrate human–automation interaction by incorporating meaningful human oversight to prevent overreliance on automated outputs, thereby managing cognitive workload and reducing diagnostic risk (Patrício et al., 2025; Wong et al., 2025).
6. Organizations should implement continuous evaluation mechanisms, including usability testing, ethnographic observation, community feedback, and post-deployment audits, to identify inequities emerging from mismatches between user needs and system demands and to inform iterative improvements (Santiago et al., 2025; Bouzón et al., 2025; Ehn et al., 2025).
7. Rural and low-income clinics should provide telemedicine training for clinicians and patients to enhance users' self-efficacy and reduce the cognitive and affective barriers associated with unfamiliar technologies, ultimately improving chronic disease management and care continuity (Pathak et al., 2024; Perez et al., 2025; Huang et al., 2025).
8. AI developers should use diverse training datasets, apply systematic bias audits, and report model performance transparently across demographic groups to prevent inequitable algorithmic behavior, addressing human factors concerns related to trust and interpretability (A Scoping Review and Evidence Gap Analysis of Clinical AI Fairness, 2025; Sakaguchi et al., 2025).
9. Healthcare organizations should expand access to wearable technologies by offering subsidized or loan-based distribution models, alleviating financial and psychosocial barriers that hinder patient adoption of devices like continuous glucose monitors (De la Torre et al., 2025; Chandrasekaran et al., 2025; Kasaai et al., 2025).
10. Public–private–government coalitions should establish governance structures that mandate transparency, fairness, and ethical standards in digital health, ensuring that system design, deployment, and oversight reflect a shared commitment to equitable human–technology interaction (Goktas & Grzybowski, 2025; Krieger, 2021).
11. Community organizations, researchers, and policymakers should co-develop interventions grounded in the lived experiences of underserved populations,

ensuring that technology design reflects contextualized user needs, motivations, and constraints (Carlsson et al., 2025; Sayani et al., 2025).

12. Governments should invest in digital literacy and health-literacy initiatives to reduce informational and cognitive barriers that impede users' ability to interpret, navigate, and benefit from digital healthcare resources (Rangachari et al., 2025; Flores, 2016).
13. Health systems should incorporate universal design requirements into procurement and development decisions, creating technologies that are maximally accessible, reduce error potential, and support diverse user abilities (Lam et al., 2025).
14. Developers should adopt reflexive design practices, including bias journaling and multidisciplinary review, to surface and mitigate assumptions that could embed exclusionary system behaviors, reinforcing ethical integrity in human–technology interactions (Lazurko et al., 2025; Sakaguchi et al., 2025).
15. Healthcare organizations should implement transparency and accountability measures such as ethics boards, algorithmic audit trails, and clear communication of data practices, thereby strengthening user trust and promoting responsible system use (Lee & See, 2004; Bevilacqua et al., 2025).
16. Designers should evaluate equity-oriented performance metrics, including trustworthiness, fairness, accuracy, and demographic usability, to assess whether technologies support equitable engagement across user groups (Abbasian et al., 2024).
17. Organizations and researchers should establish international standards for equitable digital health implementation based on simulation-driven and evidence-informed frameworks, promoting consistent human-factors-aligned practices across diverse contexts (Kenengoni-Nyatara et al., 2024; Megai et al., 2025; Diaz-Navarro et al., 2025).
18. Community-embedded initiatives should cultivate technology access literacy and digital navigation skills through local engagement, ensuring that sociocultural factors are incorporated into human–technology interaction models (Aroa et al., 2025; Plavnicka et al., 2025).
19. Policymakers and technology leaders should embed social justice principles into regulatory frameworks to ensure that digital health systems distribute benefits and risks equitably, linking system governance to human factors considerations of fairness, cognitive load, and accessibility (Abraham et al., 2022; Kröger et al., 2024).
20. Developers and health systems should incorporate ethical, human-factors principles early in the design of emerging technologies, including AI, digital twins, and precision medicine tools, to prevent inequitable patterns from becoming structurally embedded (Traylor et al., 2025; Li et al., 2025; Morsi et al., 2025).

Conclusion

Equitable access to healthcare technology depends on aligning technological innovation with ethically grounded human factors principles. Technological systems do not function in a vacuum; they are embedded within social structures that reflect historical patterns of power, privilege, and exclusion (Foucault, 2003, 2007; Vukićević, 2024). Ensuring equity therefore requires sustained attention to how technologies shape, and are shaped by, users' cognitive capacities, sociocultural contexts, and structural constraints. Human factors research demonstrates that design and policy decisions profoundly influence whether innovations improve usability, trust, and accessibility, or magnify disparities (Du et al., 2025; Ferreira et al., 2025; Gupta et al., 2025; Nunes, 2025; Tabor et al., 2025). Upholding the ethical imperatives of justice, dignity, and fairness (Galekgatlhe et al., 2025; Nussbaum, 2011; Rawls, 1971; Sen, 1992; Walzer, 1983) therefore requires integrating human factors into every stage of technological development and deployment.

Implications for Practice and Research

Human-centered and user-centered design approaches should prioritize participatory methods that engage diverse users throughout development (Gupta et al., 2025; Philpot et al., 2025; Yin et al., 2024). Clear, accessible language (Gao et al., 2024; Picard et al., 2025) and multilingual communication (Babalola et al., 2025; Hu et al., 2025; Oluwagbemi et al., 2025) are essential for reducing cognitive and linguistic barriers. Affordability (Tzimourta et al., 2025; Mishra & Sharma, 2024), transparency in system operation (Dodds et al., 2022; Mishra & Sharma, 2024), and trust-building strategies (Schaffernak et al., 2025; Wong et al., 2025) are equally critical. Continuous feedback loops derived from user evaluations should shape iterative improvements (Santiago et al., 2025). Moreover, research and policy must account for socioeconomic and structural influences on access (Cobb et al., 2025; González-Rábago et al., 2025; Machaca et al., 2025; Huber et al., 2025; Al-Hamad et al., 2025) and integrate social justice principles into regulatory frameworks (Abraham et al., 2022; Kröger et al., 2024). Collectively, these practices embed human factors into the ethical and structural DNA of digital health innovation.

Future Directions

Future initiatives should establish global standards for equitable digital health implementation, supported by simulation-based best practices that enhance safety, patient experience, and clinical outcomes (Kenengoni-Nyatara et al., 2024; Megai et al., 2025; Diaz-Navarro et al., 2025). Collaborative, culturally informed models should be developed to ensure that interventions reflect community needs and build local technological capacity (Aroa et al., 2025; Plavnicka et al., 2025). As generative AI, digital twins, and precision medicine platforms proliferate (Traylor et al., 2025; Li et al., 2025; Srinivasini et al., 2025; Morsi et al., 2025; Schmitt et al., 2024), proactive integration of human-factors and ethical principles will be essential to prevent emerging technologies from replicating inequities at scale. Continued advocacy and vigilance are required to ensure that digital health systems serve as instruments of justice rather than mechanisms of exclusion.

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