



Bridging Physiological Health Gaps through Data Equity and Digital Inclusion in Sub-Saharan Africa

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ABSTRACT

Digital health technologies are reshaping primary healthcare delivery globally; however, their benefits are distributed inequitably with populations in Sub-Saharan Africa disproportionately excluded from digital health systems. This review examines how data inequity and digital exclusion translate into measurable physiological harm across cardiovascular, metabolic, respiratory, neuroendocrine, and maternal health domains, and evaluates evidence on interventions that address this gap. A systematic search of PubMed, HINARI, Scopus, and African Journals Online (AJOL) identified 57 peer-reviewed studies and health reports published between 2016 and 2026. Evidence consistently demonstrates that digitally excluded populations exhibit poorer physiological markers, including elevated blood pressure, deregulated cortisol, impaired glycemic control, and reduced pulmonary function, while communities with equitable digital health access experience measurably better primary care outcomes. The review advances a novel mechanistic framework linking digital exclusion to physiological harm through three pathways: diagnostic delay, treatment adherence attenuation, and chronic neuroendocrine stress loading. Targeted recommendations are offered for policymakers, healthcare providers, and academic institutions across Sub-Saharan Africa.

Keywords: Data Equity; Digital Inclusion; Human Physiology; Primary Healthcare; Sub-Saharan Africa; mhealth; Digital Divide; Physiological outcomes

INTRODUCTION

The twenty-first century has witnessed an unprecedented digital transformation in healthcare delivery, ranging from wearable biosensors capable of continuously monitoring cardiac rhythms to artificial intelligence algorithms that can predict clinical deterioration before symptoms become apparent. These innovations have revolutionized the collection, analysis, and application of health data, creating new opportunities for disease prevention, diagnosis, and management. However, embedded within this technological revolution is a striking paradox: the populations that bear the greatest burden of disease are often those least able to benefit from these advances. This challenge is particularly evident in low- and middle-income countries (LMICs),

especially across Sub-Saharan Africa, where significant barriers continue to limit access to digital health technologies [1].

As healthcare systems become increasingly data-driven, the concepts of data equity and digital inclusion have emerged as critical determinants of health outcomes. Data equity refers to the fair collection, utilization, and governance of health-related data across all population groups, while digital inclusion encompasses not only access to digital technologies but also the skills, resources, and opportunities required to use them effectively. Together, these principles are increasingly recognized as foundational components of universal health coverage and equitable healthcare delivery [2-3].

The importance of these concepts extends beyond technology itself and into the realm of human physiology. Human physiology, the study of the biological and functional processes that sustain life, does not operate independently of social and environmental influences. Rather, physiological systems are continuously shaped by the conditions in which individuals live and access healthcare. Processes such as blood pressure regulation, glucose homeostasis, respiratory function, immune response, and neuroendocrine signaling are influenced not only by biological factors but also by access to health information, diagnostic services, preventive care, and monitoring platforms which are increasingly mediated through digital technologies [4-5].

This relationship is particularly significant in Sub-Saharan Africa, where the rising burden of Non-communicable diseases (NCDs) coexists with persistent infectious disease challenges. In this context, digital health inequities have far-reaching implications for both individual physiological health and population-level disease outcomes. Limited access to digital health services can delay diagnosis, reduce opportunities for preventive intervention, and hinder long-term disease management, thereby exacerbating existing health disparities.

Nigeria being the most populous country in Africa with over 220 million inhabitants, exemplifies these challenges. Although mobile phone penetration has surpassed 65%, meaningful access to digital health services remains below 30%, with pronounced disparities between urban and rural communities (ITU, 2023). Such inequalities have tangible physiological consequences, including delayed diagnosis and treatment of conditions such as hypertension, diabetes mellitus, and chronic obstructive pulmonary disease (COPD), poorer treatment adherence, and the cumulative physiological effects of prolonged exclusion from healthcare services.

Against this backdrop, this review examines the intersection between digital health equity and human physiology in Sub-Saharan Africa. Specifically, it synthesizes current evidence on how digital health inequities contribute to adverse physiological outcomes and explores how inclusive digital health strategies can generate measurable physiological benefits at the primary healthcare level. By highlighting these connections, the review underscores the importance of equitable digital transformation as a pathway toward improved health outcomes and reduced health disparities across the region.

Scholarly Contribution

This review makes four distinct scholarly contributions. Firstly, it establishes a mechanistic, physiologically grounded framework linking digital exclusion to specific biological harm pathways; an advance beyond existing reviews that described digital health equity largely in access or systems terms without engaging the underlying physiology. Secondly, it centres Sub-Saharan African

evidence within a physiological science framework, providing contextually specific synthesis that global reviews have not offered. Thirdly, it advances the concept of algorithmic physiological bias as an active harm mechanism distinct from passive digital exclusion, with direct implications for clinical practice and health technology regulation in Africa. Fourthly, it disaggregates evidence by gender and geography, revealing differential physiological vulnerability pathways that have significant implications for maternal health programming and rural primary care design.

Conceptual and Theoretical Framework

This review is grounded in an interdisciplinary conceptual framework that integrates human physiology, Social Determinants of Health (SDH), and digital health equity. Guided by the foundational principles of physiological regulation described by Guyton and Hall (2016), and the structural perspective on health articulated by the WHO Commission on Social Determinants of Health the framework conceptualizes physiological health outcomes as the result of dynamic biological processes operating within social environments that are increasingly influenced by digital infrastructure and technological access [3].

At the core of this framework is the concept of allostasis, which describes the body's ability to maintain physiological stability through adaptive responses to changing environmental demands [6]. While allostasis is essential for survival, persistent exposure to adverse social conditions can result in allostatic load. In settings characterized by inequitable digital access, limited connectivity, and restricted access to digital health resources, vulnerable populations may experience heightened allostatic load. This burden can manifest physiologically through dysregulated blood pressure, elevated cortisol levels, impaired immune function, metabolic disturbances, and other adverse health outcomes [4].

To better understand the complex relationship between digital inequity and physiological health, the review focuses on four complementary theoretical perspectives. Firstly, Social Determinants of Health Framework posits that structural inequalities, including disparities in digital access, contribute directly to inequitable health and physiological outcomes [3]. Secondly, Bronfenbrenner's Bioecological Systems Theory Bronfenbrenner & Morris, situates individual physiological functioning within interconnected social, environmental, and technological systems, emphasizing the influence of broader contextual factors on health [7]. Thirdly, the Health Belief Model, as applied to digital health behavior, provides insight into how limited digital literacy, perceived barriers, and low technological self-efficacy can reduce engagement with available digital health interventions [8]. Finally, Algorithmic Fairness Theory highlights how biases embedded within digital health technologies can

perpetuate or even worsen existing health disparities when algorithms are trained on non-representative datasets [2].

The relevance of algorithmic fairness to physiological health is increasingly evident in clinical practice. A notable example is the documented tendency of pulse oximeters to overestimate oxygen saturation levels in individuals with darker skin pigmentation, potentially delaying recognition and treatment of hypoxaemia and contributing to adverse clinical outcomes [9]. Such findings illustrate that digital health inequities are not merely technological concerns; they can directly influence physiological assessment, clinical decision-making, and ultimately health outcomes.

Together, these theoretical perspectives provide a comprehensive framework for understanding how digital inclusion and data equity shape physiological health across populations. They underscore the need to view digital health not simply as a technological innovation but as a critical determinant of equitable physiological well-being, particularly within resource-constrained settings such as Sub-Saharan Africa.

METHODOLOGY

This review employed a systematic review methodology guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 framework [10]. A comprehensive literature search was conducted across multiple electronic databases, including PubMed/MEDLINE, Google Scholar, HINARI, Scopus, and African Journals Online (AJOL). The search strategy was informed by the Population-Concept-Context (PCC) framework to ensure a structured and comprehensive identification of relevant studies.

Search terms were developed using combinations of keywords related to digital health equity and physiological outcomes, including “digital health,” “mHealth,” “data equity,” “digital inclusion,” “digital divide,” “physiological outcomes,” “blood pressure,” “HbA1c,” “respiratory function,” “cortisol,” “Sub-Saharan Africa,” and “primary care.” These terms were combined using appropriate Boolean operators to maximize retrieval of relevant literature. To ensure contemporary relevance, the search was restricted to English-language publications published between January 2016 and June 2026.

Studies were considered eligible for inclusion if they met the following criteria:

- (a) Peer-reviewed research articles or reports published by the World Health Organization (WHO) and other recognized regional health authorities;
- (b) Investigations addressing digital health equity, digital inclusion, or related dimensions of healthcare access
- (c) Studies reporting at least one measurable physiological outcome

(d) Research conducted within primary healthcare or community health settings.

Studies were excluded if they consisted solely of editorials, commentaries, conference abstracts without accompanying full-text manuscripts, or if they failed to report physiological outcome measures relevant to the review objectives.

The initial search yielded 3,847 records. Following the removal of duplicates and the application of predefined screening and eligibility criteria, 57 studies were retained for final analysis. These included 47 peer-reviewed original research articles, six systematic reviews, and four WHO or regional health authority reports, collectively representing more than 284,000 participants from 23 countries across Sub-Saharan Africa and comparable low- and middle-income settings.

To ensure methodological rigor and assess the quality of included evidence, critical appraisal was conducted using the Mixed Methods Appraisal Tool (MMAT) Version 2018 for primary studies and the AMSTAR-2 tool for systematic reviews [11-12]. The use of these validated appraisal instruments strengthened the reliability of the evidence synthesis and supported robust interpretation of the review findings.

RESULTS

Cardiovascular Physiology and Digital Health Access

Twenty-one studies examined blood pressure as a physiological outcome. Across 14 trials, mHealth-based hypertension interventions produced a weighted mean systolic blood pressure reduction of 5.1 mmHg compared to standard care, a finding consistent with the meta-analysis by reporting a 4.4 mmHg reduction (95% CI: 2.7-6.1 mmHg) [13]. Three longitudinal cohort studies from Nigeria, Kenya, and Ghana found hypertension prevalence 28-41% higher in communities without mobile health access after controlling for socioeconomic confounders, suggesting an independent physiological harm attributable to digital exclusion beyond socioeconomic factors alone [14-16].

Metabolic Physiology

Eighteen studies addressed glycaemic outcomes. A multi-site randomised controlled trial across four Sub-Saharan African countries demonstrated that an SMS-based diabetes self-management intervention achieved HbA1c reductions of 0.7 percentage points at 12 months, associated with approximately 25% reduced microvascular complication risk [17]. Critically, participants with low digital literacy showed 54-62% lower mHealth adherence and correspondingly attenuated HbA1c improvements establishing a direct physiological dose-response relationship between digital literacy and metabolic physiological outcomes [11]. The IDF (2021) estimated that over 60% of the 24 million Africans living with diabetes

remain undiagnosed which is a diagnostic gap with devastating long-term physiological consequences.

Respiratory Physiology

Nine studies addressed pulmonary outcomes. Digital spirometry implementation in community settings in Uganda, Ethiopia, and Nigeria improved COPD case detection rates by 34-47% when community health workers were equipped with digital respiratory tools [18]. A systematic review by Maddock, found rural African communities had access to less than one spirometer per 100,000 populations, with COPD diagnosis delayed 8-10 years after symptom onset compared to 3-5 years in urban settings producing correspondingly greater irreversible FEV₁/FVC ratio decline. Telemonitoring for asthma significantly improved peak expiratory flow rate variability but only in settings with adequate mobile connectivity [19-20].

Neuroendocrine Physiology and Digital Stress

Seven studies examined neuroendocrine outcomes. Three cross-sectional studies from South Africa, Nigeria, and Cameroon found significantly elevated morning salivary cortisol levels in individuals with high health-related digital access barriers after adjusting for socioeconomic confounders [21]. While causality cannot be established cross-sectionally, the finding is physiologically plausible: chronic frustration with inaccessible health systems activates the hypothalamic-pituitary-adrenal (HPA) axis, producing sustained cortisol elevation, sympathetic nervous system arousal, suppressed natural killer cell activity, shortened telomere length, and increased inflammatory cytokine production, well-documented allostatic load consequences [4,6].

Maternal and Reproductive Physiology

Eleven studies examined maternal physiological outcomes. mHealth antenatal platforms improved blood pressure control in preeclampsia, maternal haemoglobin levels, and neonatal birth weight. However, women in Sub-Saharan Africa are 26% less likely to own a smartphone

and 36% less likely to use mobile internet than men (GSMA, 2020). Three intervention studies found that fewer than 40% of eligible pregnant women could independently access mHealth antenatal platforms in contexts of marked female digital exclusion, significantly limiting population-level physiological benefit [22-23]. Given that Sub-Saharan Africa accounts for approximately 66% of global maternal deaths (WHO, 2023), this gendered digital exclusion constitutes a physiological emergency.

Immunological Physiology

Seven studies addressed vaccine-related immunological outcomes. Communities with digital vaccine information access had 2.3 times higher measles immunisation completion rates than those relying on physical outreach alone [18]. Studies across Nigeria, South Africa, and Kenya during COVID-19 documented lower population seroprevalence of vaccine-induced antibody titres in digitally underserved communities, illustrating that digital exclusion impairs not only healthcare access but active immunological physiological protection at the population level [24].

DISCUSSION

This review establishes that data equity and digital inclusion are physiological health imperatives, not merely technological considerations. Across all physiological systems examined, a consistent pattern emerges: digital exclusion produces measurable physiological harm; digital inclusion, contextually delivered, produces clinically meaningful physiological benefit.

Comparative Synthesis Across Physiological Domains

To fulfil the review's synthesis mandate, Table 1 juxtaposes the six physiological domains examined in this review against study volume, predominant evidence design, and the direction and magnitude of the reported association. This comparative arrangement reveals a graded hierarchy of evidentiary strength that domain-by-domain narrative reporting alone does not convey.

Physiological Domain	Studies (n)	Predominant Evidence Design	Key Quantitative Finding	Causal Inference Strength
Cardiovascular	21	RCTs; longitudinal cohorts	SBP reduction 4.4–5.1 mmHg; hypertension prevalence 28–41% higher without access	Strong
Metabolic	18	Multi-country RCT	HbA1c reduction 0.7 percentage points; 25% lower microvascular risk; literacy dose-response	Strong

Respiratory	9	Systematic review; implementation study	COPD detection +34–47%; diagnosis delayed 8–10 vs 3–5 years	Moderate
Maternal/Reproductive	11	Intervention studies; population survey	<40% of eligible women reached; 26–36% gender gap in device/internet access	Moderate
Immunological	7	Ecological/population-level	2.3× higher immunisation completion; lower vaccine seroprevalence	Moderate
Neuroendocrine	7	Cross-sectional survey	Elevated morning salivary cortisol under high digital access barriers	Weak–moderate

Table 1: Comparative synthesis of evidence strength and quantitative findings across the six physiological domains reviewed.

Evidence quality is not uniform across domains. The metabolic and cardiovascular domains rest on the strongest causal footing, since intervention trials, cluster-randomised designs, and independent longitudinal cohorts converge on effects of similar direction and comparable magnitude across multiple countries. The dose-response gradient linking digital literacy to HbA1c improvement is the review's clearest example of a temporally ordered, biologically graded relationship, features that support a causal rather than a merely associative interpretation [11]. By contrast, the neuroendocrine domain relies exclusively on cross-sectional survey designs; the elevated cortisol findings are physiologically plausible and theoretically anchored in allostatic load theory, but they cannot exclude reverse causation, in which pre-existing physiological stress reduces engagement with digital health tools rather than the converse [20].

Expressed on a common clinical-significance scale, the magnitude of digitally mediated benefit varies considerably across domains. A 4.4 – 5.1 mmHg systolic blood pressure reduction approaches the effect size of a single first-line antihypertensive agent, whereas the 0.7 percentage point HbA1c reduction is smaller in absolute terms yet is nonetheless associated with a 25% reduction in microvascular complication risk over time [13,17]. The 2.3-fold difference in measles immunisation completion and the 28 – 41% differential in hypertension prevalence represent population-level rather than individual-level effect metrics, complicating direct numerical comparison across domains [14-16,18]. Nonetheless, the consistent direction of effect, worse physiological outcomes under digital exclusion across six independently studied systems, constitutes a form of triangulation that strengthens the review's overall inference despite the heterogeneity of underlying study designs.

The domains also diverge in the structural drivers underlying digital exclusion. Respiratory and cardiovascular exclusion in this evidence base is driven predominantly by infrastructural scarcity, exemplified by the sub-one-spirometer-per-100,000-population ratio reported by Maddock, whereas maternal exclusion is driven predominantly by gendered ownership and usage gaps (GSMA, 2020) that persist independently of infrastructure investment [19]. This distinction carries direct implications for intervention design: infrastructure-driven gaps respond to connectivity and device investment, while gender-driven gaps require targeted digital literacy and ownership programming, a distinction that domain-by-domain reporting alone risks obscuring.

Mechanistic Pathways Linking Digital Exclusion to Physiological Harm

Three mechanistic pathways explain this relationship. Firstly, the diagnostic delay pathway: without digital health platforms or telehealth access, individuals depend on physical facility attendance for physiological monitoring, and conditions are diagnosed at physiologically advanced stages. The 8-10 year diagnostic delay for COPD in rural African settings compared to 3-5 years in urban settings represents irreversible physiological progression measurable in FEV₁ units. Secondly, the treatment adherence pathway: digital tools such as SMS reminders, mHealth education, remote feedback, sustain the behavioral change necessary to achieve physiological treatment targets. The dose-response relationship between digital literacy and HbA1c improvement in diabetes management illustrates this mechanism with precision. Thirdly, the neuroendocrine stress pathway: chronic exclusion from health information and services constitutes a documented psychosocial stressor activating HPA axis and sympathetic pathways, producing the allostatic load sequelae of sustained cortisol elevation, cardiovascular dysregulation, and immune suppression.

Algorithmic Bias as an Active Harm Mechanism

A conceptually significant finding is that digital health inequity does not merely deprive populations of benefit; it actively harms them through algorithmically biased tools. Pulse oximeter racial bias and algorithmic clinical decision support bias (2) demonstrated that digital health systems trained without adequate African population data produce physiologically consequential diagnostic errors for African patients; which are errors that are more dangerous when those patients lack the digital health literacy to question algorithmic outputs [9].

Limitations of the Evidence Base

Limitations of the evidence base include: predominance of urban and peri-urban study settings limiting rural generalisability; reliance on process rather than objective physiological biomarker outcomes in several studies; likely publication bias toward positive results; and scarcity of longitudinal physiological data beyond 12-month follow-up. These gaps define the priority research agenda for the field.

CONCLUSION

Data equity and digital inclusion are not peripheral considerations in primary healthcare; they are fundamental physiological determinants of health outcomes for populations across Sub-Saharan Africa. This review demonstrates across cardiovascular, metabolic, respiratory, neuroendocrine, maternal, and immunological physiology domains that digital exclusion produces measurable and preventable physiological harm, while equitable digital health access, contextually designed and community-ground yields clinically significant physiological benefit. Physiological science must be at the centre of the digital health equity agenda: not merely as a beneficiary of digital inclusion, but as an essential scientific discipline for evaluating, validating, and governing the digital health tools that increasingly determine who receives timely, accurate, and equitable physiological healthcare.

RECOMMENDATIONS

Based on the evidence reviewed, this paper recommends the followings:

For governments and ministries of health

Adopt explicit data equity mandates in national digital health strategies, requiring disaggregated physiological outcome reporting by gender, geography, and income strata. Invest in rural digital connectivity as essential primary care infrastructure, and enact community health data governance legislation that grants populations meaningful rights over the physiological data collected from them.

Primary healthcare providers

Should Prioritize community health worker (CHW) digital empowerment as the most evidence-supported strategy for extending physiologically beneficial digital health to non-digitally-literate communities. Integrate digital physiological monitoring into routine primary care protocols. Exercise caution in using algorithms not validated in African populations, particularly for cardiovascular risk stratification and pulse oximetry.

Academic and research institutions

Should integrate digital health literacy and data equity into human physiology and biomedical science curricula. Develop African physiological reference databases as a research priority, and conduct longitudinal community-based studies on physiological health impacts of digital inclusion in rural African settings.

Technology developers

Should design digital health tools for physiological equity using low-bandwidth compatible, multilingual, and low-literacy accessible platforms. Mandate algorithmic validation across African population subgroups for all tools used in physiological assessment or clinical decision support.

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