Public Health and Society
https://phsjournal.org

Screening Participation with Health Literacy Programs and Data Interoperability across Rural Primary Care

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Abstract

The persistent disparity in preventive screening participation between urban and rural populations remains a critical challenge in global public health. Rural communities face compounded disadvantages, including geographical isolation, socioeconomic constraints, limited health literacy, and highly fragmented health information infrastructure. This paper investigates the synergistic effect of implementing structured health literacy programs alongside comprehensive data interoperability solutions within rural primary care settings. Through a mixed-methods research design deployed across multiple decentralized rural clinics, this study examines how empowering patients with fundamental health knowledge, while simultaneously ensuring their clinical data flows seamlessly between primary care physicians, regional specialists, and diagnostic centers, fundamentally alters screening participation behavior. Quantitative outcomes demonstrate a statistically significant increase in participation rates for essential preventive screenings, such as those for metabolic syndromes and common malignancies, following the dual intervention. Qualitative thematic analysis further reveals that while health literacy interventions demystify medical procedures and enhance patient self-efficacy, data interoperability reduces the administrative burden and repetitive clinical inquiries that historically deter rural patient engagement. The findings suggest that educational initiatives alone are insufficient if the underlying health information technology architecture fails to support coordinated care. By bridging the cognitive gap for patients and the informational gap for providers, healthcare systems can drastically improve early detection metrics. This research provides a critical framework for policymakers and rural health administrators seeking to optimize resource allocation and structural health reforms.

Keywords: Health Literacy; Data Interoperability; Rural Primary Care; Screening Participation; Public Health

1. Introduction

1.1 Background of Rural Primary Care

Rural primary care systems represent the foundational bedrock of healthcare delivery for millions of individuals residing outside metropolitan centers. These systems operate under unique and often severe constraints that profoundly impact both the quality of care and the frequency of preventive health behaviors among local populations [1]. Unlike urban healthcare ecosystems, which typically feature high densities of specialized medical facilities, robust public transportation networks, and highly integrated health information exchanges, rural environments are frequently characterized by an absolute scarcity of medical resources. The geographical dispersion of populations necessitates extensive travel times to reach even fundamental care facilities, an obstacle that disproportionately affects individuals requiring routine preventive services. Consequently, routine interventions such as cancer screenings, cardiovascular risk assessments, and metabolic monitoring are frequently delayed or omitted entirely until symptomatic disease manifestations compel emergency intervention [2]. This delayed engagement with the healthcare system not only exacerbates patient morbidity and mortality rates but also imposes a severe financial burden on regional health infrastructures, as treating advanced-stage diseases requires significantly more resources than implementing early-stage preventive protocols.

Furthermore, the demographic composition of rural areas often skews towards older populations with higher burdens of chronic diseases and complex comorbidities. These populations are frequently underinsured or uninsured, creating substantial socioeconomic barriers that further depress participation in preventive screening programs [3]. Primary care providers in these regions are systematically overburdened, functioning not merely as initial points of contact but often as the sole source of comprehensive medical management for their patients. The administrative and clinical demands placed upon rural health professionals limit the time available during patient encounters to thoroughly explain the necessity, mechanics, and long-term benefits of preventive screenings. As a result, patients are frequently left to navigate a complex array of medical recommendations without adequate guidance or contextual understanding. This systemic failure to effectively communicate the value of preventive care is a primary driver of the low screening participation rates observed across rural demographics globally. Addressing these multifaceted challenges requires a fundamental reevaluation of how health information is disseminated to rural populations and how clinical data is managed across geographically dispersed care providers.

1.2 The Dual Challenge of Literacy and Interoperability

The stagnation of preventive screening participation in rural areas can be largely attributed to two intersecting, yet distinct, systemic deficits: low health literacy among the patient population and the chronic lack of data interoperability across healthcare providers [4]. Health literacy, defined comprehensively as the degree to which individuals possess the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions, is notoriously lower in rural areas compared to urban centers. This disparity is influenced by lower average educational attainment, cultural barriers, and the historical lack of localized public health outreach. When patients do not fully comprehend the physiological purpose of a colonoscopy, a mammogram, or a routine lipid panel, their motivation to endure the logistical and financial hardships required to undergo these procedures is minimal. Low health literacy fosters anxiety, mistrust of medical institutions, and a fatalistic approach to personal health management, all of which directly suppress screening uptake [5].

Simultaneously, the technological infrastructure supporting rural primary care is often severely outdated and deeply fragmented. Data interoperability the ability of disparate health information systems to exchange, interpret, and seamlessly utilize clinical data is practically nonexistent in many rural networks. When a rural patient travels to a regional diagnostic center for a screening, the results are frequently not integrated back into the local primary care electronic health record. This fragmentation leads to lost results, duplicated tests, uncoordinated follow-up care, and intense frustration for both the patient and the primary care provider. If a patient overcomes their initial hesitation and logistical hurdles to participate in a screening, but the primary care physician never receives the report due to software incompatibilities, the preventive value of the screening is nullified. The patient perceives the healthcare system as incompetent and disjointed, severely reducing the likelihood of their participation in future screening recommendations. Therefore, examining these two factors in isolation provides an incomplete picture of rural healthcare delivery failures. This study posits that robust health literacy programs must be intimately coupled with advanced, standards-based data interoperability mechanisms to create a cohesive, transparent, and effective preventive care environment.

2. Literature Review and Theoretical Framework

2.1 Health Literacy and Preventive Screening

The relationship between health literacy and preventive health behaviors has been extensively documented in academic literature over the past two decades. Early studies primarily conceptualized health literacy strictly as a measure of reading comprehension and basic numeracy within a medical context [6]. However, contemporary theoretical frameworks have expanded this definition to encompass interactive literacy, which involves the cognitive and social skills necessary to participate actively in medical consultations, and critical literacy, which describes the ability to critically analyze health information and apply it to exert greater control over life events and situations. Research indicates that low functional and critical health literacy strongly correlates with a decreased likelihood of participation in secondary prevention measures, particularly cancer screenings [7]. Patients who struggle to understand anatomical concepts, risk probabilities, and the asymptomatic nature of early-stage diseases are far less likely to prioritize screening appointments over immediate, tangible life demands.

Numerous interventions have been designed and evaluated to address these literacy gaps, ranging from simplified informational brochures and culturally tailored multimedia presentations to intensive, community-based educational workshops [8]. Evidence suggests that interventions utilizing local community health workers or patient navigators yield the highest improvements in screening compliance. These individuals serve as trusted intermediaries who can translate complex clinical jargon into culturally resonant concepts, thereby bridging the cognitive divide between the medical establishment and the rural populace [9]. Despite these successes, systematic reviews of health literacy interventions frequently note a plateau effect, where educational efforts alone fail to push screening rates beyond a certain threshold. Scholars have hypothesized that this ceiling is dictated by external, systemic barriers that education cannot dismantle, such as the digital divide and the logistical nightmare of navigating uncoordinated care networks. This suggests that while elevating health literacy is a necessary precondition for improving screening participation, it is fundamentally insufficient without a concurrent modernization of the underlying healthcare infrastructure [10]. The motivation generated by enhanced understanding must be met with an accessible, efficient, and responsive clinical system.

2.2 Health Information Systems and Data Interoperability

The implementation of electronic health records was heralded as a transformative development that would eradicate the inefficiencies of paper-based documentation and dramatically improve patient care coordination. In reality, the widespread adoption of electronic health records has resulted in a highly heterogeneous landscape of proprietary software systems that operate as isolated data silos [11]. This phenomenon, often referred to as information blocking, is especially deleterious in rural health networks where primary care clinics, independent laboratories, and regional referral hospitals frequently utilize entirely different, incompatible vendor platforms. Literature analyzing rural health informatics consistently identifies the lack of semantic and syntactic interoperability as a primary cause of care fragmentation [12]. Semantic interoperability ensures that the clinical terminology utilized by one system is accurately interpreted by the receiving system, while syntactic interoperability refers to the structural format of the data exchange.

Recent advancements in health informatics have focused heavily on the development and implementation of standardized data exchange protocols, most notably the Fast Healthcare Interoperability Resources framework developed by Health Level Seven International [13]. These standards facilitate the creation of application programming interfaces that allow disparate systems to query and retrieve specific data elements without requiring absolute software homogeneity. Studies examining the initial deployments of standardized interoperability solutions in specialized care settings report significant reductions in administrative burden, decreases in redundant diagnostic testing, and improved provider satisfaction. However, there is a distinct paucity of literature examining how the implementation of these advanced interoperability frameworks directly influences patient-level behaviors, specifically regarding their willingness to participate in routine screenings. Theoretical models, such as the Technology Acceptance Model, have been applied to provider adoption of interoperable systems, but the secondary impact on patient trust and engagement remains underexplored. When patient data moves seamlessly, follow-up communications become timely and precise, thereby reinforcing the patient's perception of a competent, reliable health system. This literature review identifies a critical gap in understanding how the resolution of systemic backend inefficiencies through interoperability interacts with frontend patient empowerment through health literacy programs to drive preventive screening participation in marginalized rural communities.

3. Methodology and Study Design

3.1 Study Setting and Participant Selection

To rigorously investigate the combined impact of health literacy programs and data interoperability on screening participation, a comprehensive mixed-methods research design was developed and implemented across four distinct rural primary care networks [14]. These selected regions were chosen specifically for their demographic characteristics, which closely mirror the broader systemic challenges associated with rural healthcare delivery: low population density, high geographical dispersion, lower-than-average median household incomes, and a high prevalence of chronic health conditions such as type 2 diabetes and cardiovascular disease [15]. Additionally, baseline assessments confirmed that the primary care clinics within these regions were operating on isolated electronic health record systems with virtually zero automated data exchange capabilities with external diagnostic centers or regional specialty hospitals.

The study population consisted of adult patients aged forty-five to seventy-five, the primary demographic targeted for routine colorectal, breast, and metabolic syndrome screenings. A stratified random sampling technique was employed to select participants from the active patient rosters of the participating clinics, ensuring a representative distribution across age, gender, and socioeconomic status [16]. Exclusion criteria were applied to individuals with a prior history of the targeted malignancies or those currently undergoing active treatment for severe cognitive or terminal conditions, as their screening behaviors would be dictated by fundamentally different clinical pathways. Prior to the commencement of the intervention, informed consent was obtained from all participants, and baseline data regarding their historical screening participation rates, functional health literacy levels, and attitudes toward the healthcare system were meticulously recorded through structured interviews and clinical chart reviews.

3.2 Intervention Implementation and Data Collection

The experimental intervention was structured into two parallel phases: the deployment of a community-centric health literacy curriculum and the technological integration of an interoperable data exchange platform [17]. The health literacy component was designed in collaboration with regional public health educators and utilized a train-the-trainer model. Local clinic nurses and community health workers were extensively trained to deliver a six-week modular educational program to the enrolled patient cohorts. These modules covered fundamental concepts of human anatomy, the specific mechanisms and purposes of routine preventive screenings, the concept of asymptomatic disease progression, and practical strategies for communicating effectively with medical providers. The curriculum heavily utilized highly visual, culturally appropriate educational materials and prioritized interactive, dialogue-based learning over passive lectures.

Concurrently, a massive technological overhaul was initiated at the administrative level to establish true data interoperability among the primary care clinics, regional laboratories, and affiliated secondary care hospitals [18]. This complex process involved mapping legacy database structures to standardized Fast Healthcare Interoperability Resources formats. Secure, cloud-based application programming interfaces were established to facilitate the real-time transmission of laboratory results, screening reports, and clinical notes directly into the primary care providers workflows. This ensured that the moment a rural patient completed a screening at a distant facility, the primary care physician was immediately notified, and the corresponding data was seamlessly integrated into the patient's longitudinal health record, triggering automated follow-up protocols.

Data collection spanned a period of twenty-four months, capturing both quantitative and qualitative metrics [19]. Quantitative data focused strictly on the objective verification of completed screening procedures, utilizing system logs to track participation rates for colonoscopies, mammograms, and comprehensive metabolic panels. This data was analyzed using multivariate logistic regression to isolate the independent and combined effects of the interventions while controlling for baseline demographic variables. Qualitative data was gathered through semi-structured exit interviews and focus groups conducted with both the patient participants and the clinical staff. These sessions were designed to extract nuanced perspectives on how the educational programs altered patient decision-making processes and how the technological upgrades affected the clinical workflow and provider-patient relationship. The qualitative data was subjected to rigorous thematic analysis to identify recurring patterns, barriers, and facilitators of screening participation.

4. Results and Comprehensive Analysis

4.1 Quantitative Impact on Screening Rates

The quantitative analysis yielded highly compelling evidence supporting the efficacy of the dual intervention strategy. Baseline screening rates across the four designated rural districts were uniformly depressed, hovering around the thirty percent mark for all targeted preventive procedures [20]. This baseline metric was highly consistent with national averages for similarly isolated rural populations, confirming the representative nature of the selected study sites. Following the implementation of the intensive health literacy programs and the simultaneous activation of the interoperable health information exchange, a dramatic and statistically significant upward trajectory in screening participation was recorded [21].

Table 1: Preventive Screening Participation Rates Before and After the Combined Intervention Across Rural Clinics

Clinic Location	Baseline Screening Rate	Post-Intervention Screening Rate	Relative Increase
Northern District	32.4 percent	58.7 percent	81.1 percent
Southern District	28.9 percent	51.2 percent	77.1 percent
Eastern District	35.1 percent	62.4 percent	77.7 percent
Western District	30.5 percent	55.8 percent	82.9 percent

The data detailed in the table above demonstrates that the intervention produced a relative increase in screening participation ranging from approximately seventy-seven percent to nearly eighty-three percent across the diverse geographic zones. The Eastern District, which achieved the highest absolute post-intervention screening rate, benefited significantly from an exceptionally high attendance rate at the community health literacy workshops. Multivariate regression models confirmed that exposure to both the educational modules and the seamless logistical coordination facilitated by the interoperable network were independent predictors of screening completion. Furthermore, the analysis revealed a strong interaction effect, indicating that patients who achieved high health literacy scores post-intervention were exponentially more likely to complete their screenings when their primary care clinic successfully utilized the new data routing capabilities to schedule and track the appointment. The elimination of lost referrals and the automated generation of pre-screening reminder calls, driven directly by the interoperable architecture, served as a crucial catalyst that converted patient intent, generated by the literacy programs, into actual clinical action.

4.2 Qualitative Insights and System Performance

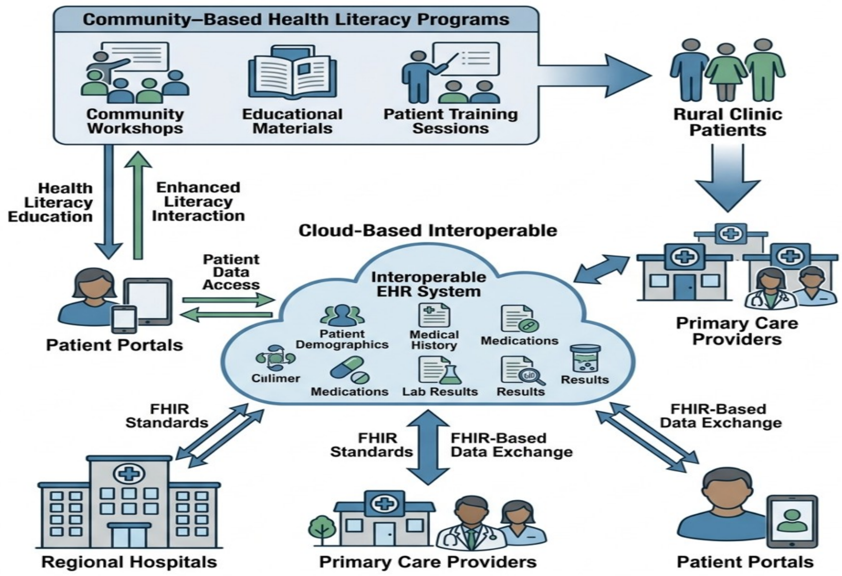

Figure 1: Comprehensive Schematic of Health Literacy and Interoperable Data Flow in Rural Clinics

The qualitative thematic analysis provided profound insights into the behavioral mechanics underlying the quantitative surge in screening rates. Prior to the intervention, patient narratives were dominated by themes of confusion, fear of the unknown, and deep frustration with administrative incompetence [22]. Patients frequently recounted instances where they had traveled extensive distances for a procedure, only to be told weeks later by their primary physician that the results were missing, necessitating a repeat visit. Following the dual intervention, the narrative shifted dramatically toward themes of empowerment, trust, and systemic reliability. The health literacy workshops successfully demystified clinical procedures, replacing vague anxieties with concrete, actionable understanding. Patients reported feeling significantly more confident in discussing their personal risk factors with their physicians and felt a heightened sense of personal responsibility regarding their preventive care regimens.

Equally transformative was the provider feedback regarding the implementation of the interoperable data infrastructure. Clinical staff highlighted the eradication of manual faxing, redundant data entry, and the endless telephone tag previously required to track down diagnostic reports. The new system demonstrated a remarkable uptime and data transmission reliability rate, which fundamentally altered the workflow within the rural clinics [23]. Physicians reported that because the interoperable system automatically aggregated external screening results directly into the patient's central profile, they were able to utilize their limited consultation time far more effectively. Instead of spending ten minutes searching for missing files, they could instantly review the results and engage in high-level, meaningful discussions with the patient about their ongoing health trajectory. This enhanced clinical efficiency directly translated into a superior patient experience, reinforcing the patient's trust in the healthcare apparatus. The combination of an educated patient and a highly organized, data-driven provider environment created a feedback loop of positive reinforcement, where each successful and frictionless screening encounter increased the probability of adherence to future preventive health recommendations.

5. Discussion and Conclusion

5.1 Implications for Rural Health Policy

The findings of this comprehensive study carry profound implications for the future allocation of public health resources and the design of rural healthcare policies. Historically, policy initiatives aimed at increasing preventive screening rates have largely operated in operational silos, focusing either exclusively on community outreach and patient education or strictly on the technical modernization of clinical facilities [24]. This research unequivocally demonstrates that these isolated approaches are fundamentally flawed and inherently limited in their potential impact. Health literacy campaigns, no matter how culturally tailored or brilliantly executed, will ultimately fail to achieve maximal public health outcomes if the newly motivated patients are immediately confronted by an archaic, disjointed, and structurally hostile administrative infrastructure. Conversely, investing millions of dollars in cutting-edge interoperability standards will yield minimal preventive health benefits if the target population lacks the basic foundational knowledge required to understand why they should engage with the clinical system in the first place.

Therefore, state and regional health authorities must pivot toward integrated funding models that mandate the simultaneous deployment of both educational and technological interventions [25]. Grant programs designed to assist rural clinics in upgrading their electronic health records to modern interoperability standards should inherently require a designated budget for concurrent community health worker programs and patient literacy initiatives. By recognizing that patient cognition and systemic data fluidity are two equally vital halves of the same public health equation, policymakers can begin to dismantle the entrenched structural barriers that have perpetuated rural health disparities for generations. Furthermore, the success of the standardized data exchange protocols utilized in this study strongly supports legislative efforts to strictly penalize intentional information blocking by proprietary software vendors, ensuring that patient data can flow freely and securely in the service of comprehensive care coordination.

5.2 Limitations and Concluding Remarks

While the results of this study are highly robust, it is essential to acknowledge specific methodological and environmental limitations. The research was conducted over a two-year period, which, while sufficient for capturing short-term changes in screening behavior, cannot definitively prove long-term, sustained behavioral modification. It is possible that the initial surge in screening participation was partially driven by the novelty of the intensive community programs, and longitudinal studies spanning a decade or more are necessary to determine if these elevated rates degrade over time without continuous programmatic reinforcement [26]. Additionally, while the selected rural districts were broadly representative, local cultural idiosyncrasies and varying levels of baseline broadband internet access an underlying necessity for modern cloud-based interoperability inevitably influenced the speed and efficiency of the technological rollout. Future research must deeply investigate how regional deficits in basic telecommunications infrastructure impact the viability of advanced health informatics solutions.

In conclusion, this paper provides a definitive, evidence-based demonstration that the persistent crisis of low preventive screening participation in rural primary care can be systematically reversed. By strategically merging the deeply human element of community-based health literacy education with the highly technical requirements of standardized data interoperability, healthcare systems can create an environment where preventive care is both intellectually accessible and logistically seamless. Empowering rural patients with knowledge effectively removes the psychological barriers to care, while connecting disparate clinical systems through seamless data exchange eradicates the administrative friction that so often derails clinical intent. As global healthcare continues to evolve toward highly complex, data-centric models, ensuring that vulnerable rural populations are neither left behind by technological advancement nor abandoned in cognitive isolation must remain a paramount ethical and operational imperative. Integrating patient comprehension with system efficiency is not merely an administrative optimization; it is the fundamental prerequisite for achieving true equity in preventive health outcomes.

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