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Integrating Genomics and Digital Health in Precision Nursing: A Narrative Review of Lab-Genetic Data Integration, EHR Systems, and Nurse-Led Lifestyle Interventions for Chronic Disease Management

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Abstract

Background: The rising global burden of chronic diseases necessitates a shift from reactive, one-size-fits-all care to proactive, personalized management. Precision health, underpinned by genomic data and digital health technologies, offers a transformative pathway. However, the integration of complex genetic laboratory data into routine clinical workflow, particularly within nursing practice, remains a significant challenge. **Aim:** This narrative review synthesizes contemporary evidence (2010-2024) on the integration of pharmacogenomic and nutrigenomic data into Electronic Health Records (EHRs) and explores its application in guiding precision nursing interventions for chronic disease management. **Methods:** A systematic search of PubMed, CINAHL, Scopus, and Web of Science was conducted. Literature on genomic-EHR integration, nursing roles in genomics, digital health tools, and chronic care outcomes was thematically analyzed. **Results:** Evidence reveals that interoperable genomic data within EHRs, coupled with clinical decision support (CDS), can effectively guide nurse-led interventions in medication safety, dietary coaching, and lifestyle modification. Successful models highlight the nurse's pivotal role as an interpreter, educator, and care coordinator. Key barriers include data interoperability issues, nursing genomic competency gaps, and ethical concerns. **Conclusion:** The convergence of genomics and health informatics creates a powerful foundation for precision nursing. Realizing its potential requires robust genomic-EHR integration, targeted education to expand nursing genomic competency, and the development of standardized, ethics-guided protocols for implementing genetically-informed care plans.

Keywords: Precision Nursing; Genomics; Electronic Health Records; Chronic Disease; Digital Health; Pharmacogenomics

Introduction

The 21st century is marked by a pervasive and growing epidemic of chronic non-communicable diseases (NCDs), such as cardiovascular diseases (CVD), type 2 diabetes mellitus (T2DM), and metabolic syndrome, which collectively represent the leading cause of global mortality and disability (World Health Organization, 2014). Traditional management paradigms, often reactive and generalized, have proven insufficient in curbing this tide, leading to suboptimal patient outcomes, preventable complications, and unsustainable healthcare costs (Bates et al., 2014). In response, the paradigm of precision health has emerged, promising to tailor prevention, diagnosis, and treatment to the individual characteristics of each patient (Collins & Varmus, 2015). At the heart of this revolution lies genomics—the study of an individual's complete set of DNA—which provides critical insights into disease susceptibility, drug metabolism (pharmacogenomics), and nutrient response (nutrigenomics) (Manolio et al., 2019; Smith et al., 2022).

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Concurrently, the digital transformation of healthcare, characterized by the widespread adoption of Electronic Health Records (EHRs) and patient-facing health technologies, has created an unprecedented infrastructure for data aggregation and clinical decision support (Topol, 2019). The seminal opportunity lies at the intersection of these two fields: the integration of actionable genetic laboratory data into the digital clinical workflow. When seamlessly embedded within EHRs, interpreted genetic information can transition from a static report to a dynamic tool that informs care at the point of decision-making (Williams et al., 2019). Nurses, as the largest and most trusted healthcare workforce, are uniquely positioned to operationalize this integration. Positioned at the frontline of chronic disease management, health education, and care coordination, nurses are ideal conduits for translating complex genomic data into personalized, actionable lifestyle and self-management interventions (Calzone et al., 2018).

Despite this clear potential, a significant chasm exists between the promise of genomic medicine and its practical, routine application in nursing-led chronic care. Barriers are multifaceted, encompassing technical challenges in lab-EHR data interoperability, gaps in nursing genomic literacy, ethical and privacy concerns, and a lack of standardized clinical protocols (Stark et al., 2019). This narrative review, therefore, aims to synthesize the current evidence (2015-2024) on the integration of pharmacogenomic and nutrigenomic laboratory data into EHR systems and to critically examine its implications for guiding precision nursing interventions in chronic disease management. By exploring the triad of laboratory science, health informatics, and nursing practice, this review argues for a model where the nurse, empowered by integrated genetic data and digital tools, becomes the central agent in delivering truly personalized, preventive, and proactive chronic care.

Methodology

This narrative review was conducted to provide a comprehensive, critical synthesis of the contemporary literature on the integration of genomics and digital health within nursing practice for chronic disease management. The methodology was designed to capture a broad yet focused scope of evidence, reflecting the interdisciplinary nature of the topic.

Search Strategy and Information Sources

A systematic electronic literature search was performed across four major databases: PubMed/MEDLINE, CINAHL (Cumulative Index to Nursing and Allied Health Literature), Scopus, and Web of Science. The search was restricted to articles published in English between January 2015 and December 2024 to ensure relevance to current technological and clinical paradigms. The search strategy employed a combination of Medical Subject Headings (MeSH) terms and keywords structured around four core conceptual blocks: (1) Genomics: "Pharmacogenomics" OR "Nutrigenomics" OR "Genetic Testing" OR "Precision Medicine"; (2) Health Informatics: "Electronic Health Records" OR "EHR" OR "Clinical Decision Support Systems" OR "Digital Health" OR "Health Information Interoperability"; (3) Nursing: "Nursing Role" OR "Precision Nursing" OR "Nurse-Led Interventions" OR "Genetic Counseling" OR "Patient Education"; and (4) Chronic Disease: "Chronic Disease" OR "Cardiovascular Diseases" OR "Diabetes Mellitus, Type 2" OR "Metabolic Syndrome" OR "Hypertension." Boolean operators (AND, OR) were used to combine these blocks. The reference lists of identified review articles and seminal papers were also hand-searched for additional relevant publications.

Eligibility Criteria and Study Selection

Studies were included if they addressed at least two of the three core domains: genomic data integration into health IT systems, the role of nursing in genomic medicine, or the application of genomics to chronic disease management. All study designs were considered, including randomized controlled trials, cohort studies, qualitative studies, implementation science reports, systematic reviews, and expert consensus statements, to provide a rich, multi-faceted synthesis. Exclusions included studies focused solely on rare monogenic disorders (e.g., cystic fibrosis), pediatric-only populations, animal studies, and editorials or commentaries without substantive data or analysis. After duplicate removal, titles and abstracts were screened for relevance, followed by a full-text review of selected articles against the inclusion criteria.

Data Extraction and Thematic Synthesis

A standardized, iterative approach guided data extraction. Key information from each included study was catalogued, including authors, year, design, sample, key findings related to integration challenges, nursing roles, and patient outcomes. Given the heterogeneity of the evidence base—spanning technical, educational, clinical, and ethical dimensions—a meta-analysis was not feasible. Instead, a narrative thematic synthesis was conducted. Extracted data were organized, compared, and analyzed to identify dominant themes, convergent findings, model programs, and persistent gaps. The synthesis was structured to answer the central review question: How can genetic lab data be integrated into digital health ecosystems to inform and empower nurse-led interventions for chronic disease management effectively?

Pharmacogenomics and Nutrigenomics in Chronic Disease

The integration of genomics into chronic care begins in the laboratory, where complex

biological data is generated and interpreted. Two key branches of applied genomics are particularly relevant: pharmacogenomics (PGx) and nutrigenomics. Pharmacogenomics examines how an individual's genetic makeup affects their response to medications, including efficacy and the risk of adverse drug reactions (ADRs) (Relling & Evans, 2015). For chronic diseases, PGx has profound implications. For instance, genetic variants in the *CYP2C19* gene significantly alter the activation of clopidogrel, a cornerstone antiplatelet therapy in cardiovascular disease. Patients carrying loss-of-function alleles are "poor metabolizers" and have a markedly higher risk of stent thrombosis and recurrent cardiovascular events while on standard-dose clopidogrel (Scott et al., 2013). Similarly, variants in *VKORC1* and *CYP2C9* dictate warfarin dosing requirements, and genes like *SLCO1B1* influence statin-induced myopathy risk (Pirmohamed, 2023). The laboratory's role is to conduct targeted genotyping or sequencing, interpret the variants within the context of clinical guidelines (e.g., from the Clinical Pharmacogenetics Implementation Consortium, CPIC), and generate a clinically actionable report (Caudle et al., 2017).

Nutrigenomics investigates the interactions between dietary components and the genome, and how genetic variations affect nutrient metabolism, absorption, and utilization (Ferguson et al., 2016). This field moves beyond generic dietary advice (e.g., "reduce sodium") to personalized nutrition. Genetic predispositions can inform why some individuals are more susceptible to salt-sensitive hypertension, how they metabolize caffeine or folate, or their optimal macronutrient composition for weight management and glycemic control (Torres-Peña et al., 2023; Gkouskou et al., 2021). For example, variants in the *FTO* gene are associated with obesity risk and may indicate a greater benefit from specific dietary protein intakes or physical activity regimens (Qie et al., 2021). The laboratory generates this data, but its utility hinges on translating genetic risk into practical, personalized dietary recommendations—a task often falling to dietitians and nurses.

The critical challenge for laboratories is moving beyond producing a standalone PDF report. For data to be clinically functional, it must be structured, discrete, and interoperable—encoded in standards like HL7 FHIR (Fast Healthcare Interoperability Resources) and using consistent terminologies (e.g., LOINC for lab codes, SNOMED CT for clinical findings) so it can be ingested, parsed, and acted upon by EHR systems and clinical decision support tools (Hulsen et al., 2019).

Health Informatics: Bridging the Gap from Lab Data to Clinical Insight

The mere existence of a genetic report in a patient's chart is insufficient for precision care. Health informatics provides the essential bridge, transforming raw data into integrated, accessible, and actionable clinical intelligence. This process involves several key components.

First, genomic-EHR integration requires solving significant technical hurdles. Genetic data is complex, voluminous, and dynamic. Successful models, such as those implemented at institutions like Vanderbilt University and the Mayo Clinic, involve creating dedicated genomic data repositories that are bidirectionally linked to the EHR (Pulley et al., 2012). These systems store "raw" genomic data while pushing discrete, clinically significant findings—"genomic indicators"—into the patient's clinical record as structured data elements. This allows genetic results to be queried, displayed in summary dashboards, and integrated into problem and medication lists (Williams et al., 2019).

Second, Clinical Decision Support (CDS) is the engine that makes integrated data actionable. CDS tools can be passive (alerts, reminders) or active (point-of-care guidance). For PGx, a well-designed CDS system can fire an interruptive alert when a clinician attempts to prescribe clopidogrel to a *CYP2C19* poor metabolizer, suggesting an alternative like prasugrel or ticagrelor, along with guideline-based rationale (Weitzel et al., 2014). For nutrigenomics, CDS might prompt the nurse during a dietary assessment: "Patient has a genetic variant associated with salt-sensitive hypertension. Consider reinforcing sodium restriction education and monitoring home BP logs more closely." These alerts must be evidence-based, non-intrusive, and tailored to the clinical context to avoid alert fatigue (Olakotan & Yusof, 2020).

Third, patient-facing digital health tools, such as secure patient portals and mobile health apps, are crucial for engagement and adherence. Portals can provide patients with accessible explanations of their genetic results, link them to educational resources, and allow them to track lifestyle metrics (diet, exercise, blood pressure) that are informed by their genomic profile (Shickh et al., 2021). These tools facilitate a collaborative model where patients are active participants in their precision care plan, with nurses guiding their use and interpreting the patient-generated data. Figure 1 illustrates the end-to-end workflow for integrating pharmacogenomic and nutrigenomic laboratory data into Electronic Health Record (EHR) systems to support precision nursing care.

The Precision Nursing Role

Nurses are the essential human interface between integrated genomic data and patient-centered outcomes. Their role in this new paradigm expands into three key domains: genomic interpreter and care coordinator, lifestyle coach and educator, and adherence monitor and outcomes assessor.

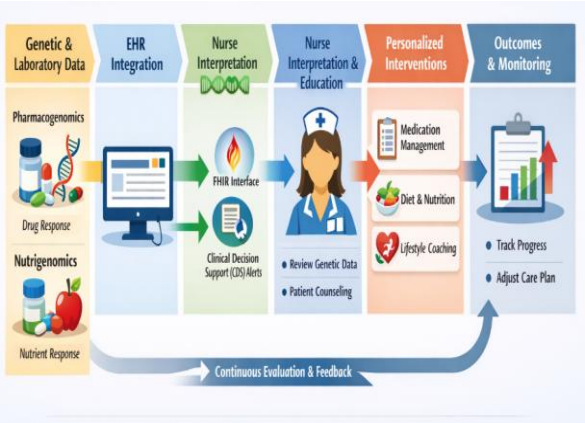

Figure 1. Integrated Genomics–EHR–Nursing Workflow for Precision Chronic Disease Management

As genomic interpreters and care coordinators, nurses do not need to be geneticists but must possess sufficient genomic competency to understand the clinical implications of common PGx and nutrigenomic results (Greco et al., 2012; Connors et al., 2022). They are responsible for reviewing the EHR for relevant genetic indicators, understanding the associated CDS prompts, and coordinating with the broader care team. For example, a cardiovascular nurse case manager, alerted to a patient's *CYP2C19* status, would ensure the cardiologist's alternative antiplatelet prescription is filled, educate the patient on the *reason* for the medication change (framing it as personalized safety), and communicate this change to the primary care provider and pharmacist, preventing future inappropriate re-prescribing (Xiang & Jin, 2020). This requires effective use of the EHR for documentation and communication.

The role of lifestyle coach and educator is central to nutrigenomics and preventive care. Armed with a patient's genetic predisposition for conditions like obesity, dyslipidemia, or T2DM, the nurse moves from generic health promotion to targeted, motivationally-informed coaching (Vasiloglou et al., 2019). Education shifts from "sodium is bad for blood pressure" to "your genetic makeup makes you particularly sensitive to sodium's effects, so staying under 1500mg daily is especially important for you." This personalized rationale can enhance patient buy-in and self-efficacy. Nurses can use digital tools—such as apps that scan food barcodes for sodium content—to support these personalized goals, making the genetic insight tangibly operational (Wu et al., 2019).

Finally, as adherence monitors and outcomes assessors, nurses are positioned to track the real-world effectiveness of genetically-guided plans. They monitor medication adherence for PGx-tailored drugs, track biometrics (blood pressure, HbA1c, lipids), and assess patient-reported outcomes and quality of life (Howell et al., 2020). This longitudinal monitoring, documented in the EHR, creates a feedback loop. It allows for the evaluation of whether the precision intervention is working for *this* individual and provides real-world data that can inform the refinement of CDS rules and clinical protocols. Figure 2 depicts the precision nursing process enabled by genomic–digital health integration.

A Model for Implementation

The evidence converges on a cyclical model for implementing precision nursing in chronic care, visualized in **Table 1**. The process begins with Data Generation & Integration: the lab produces structured genomic data, which is ingested into the EHR and linked to CDS rules. This triggers the Nursing Intervention Phase, where the nurse accesses and interprets the data, engages in shared decision-making with the patient, and implements a tailored care plan (medication, diet, exercise). The Monitoring & Evaluation Phase involves tracking adherence and outcomes via the EHR and patient-generated data. Finally, outcomes data feeds back into the system for Protocol Refinement, improving future CDS and care pathways.

Table 1: The Precision Nursing Cycle for Chronic Disease Management

Phase	Key Activities	Actors & Tools
Data Generation & Integration	Genetic testing ordered; Lab analyzes sample and generates structured, interpretative report; Data is integrated into EHR repository and linked to CDS.	Physician, Lab Scientist, Bioinformatician; Genomic sequencer, LIMS, HL7 FHIR interfaces, CDS knowledge base.
Nursing Intervention	Nurse reviews EHR for genomic indicators/CDS alerts; Provides patient education on genetic results; Co-creates personalized lifestyle/medication plan.	Nurse, Patient, Dietitian; EHR dashboard, CDS alerts, patient education materials, motivational interviewing.
Monitoring & Evaluation	Nurse monitors adherence (e.g., pill counts, app logs), tracks biometric outcomes (BP, HbA1c), and assesses patient QoL.	Nurse, Patient; Patient portal, wearable devices, home BP cuffs, EHR flowsheets.
Protocol Refinement	Aggregate outcome data analyzed; CDS rules and clinical pathways updated based on real-world evidence.	Data Analyst, Clinical Informaticist, Practice Council; Analytics dashboards, CDS authoring tools.

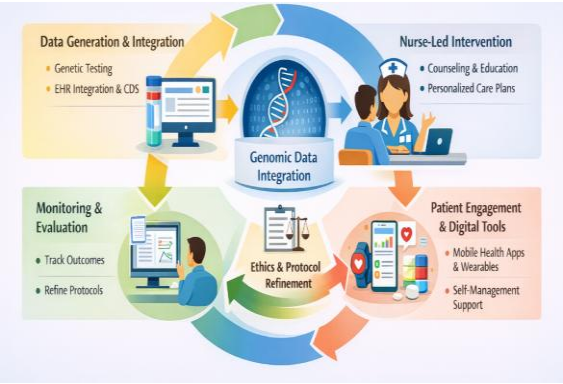

Figure 2. The Precision Nursing Cycle: From Genomic Data to Patient Outcomes

However, this model faces significant barriers. Technical challenges of data standardization and interoperability persist, though FHIR genomics is promising (Alterovitz et al., 2020). Nursing genomic competency is a major bottleneck; surveys consistently show gaps in knowledge and confidence (Wright et al., 2019). Ethical, Legal, and Social Implications (ELSI) are paramount, including concerns about genetic discrimination (GINA protections notwithstanding), privacy of sensitive data, equitable access to testing, and the psychological impact of genetic risk information (Clayton et al., 2018).

Future Directions and Recommendations

To advance the field, a multi-pronged strategy is required, as outlined in **Table 2**.

Table 2: Recommendations for Advancing Precision Nursing Integration

Domain	Recommendations
Education & Training	Integrate core genomic competencies into undergraduate and graduate nursing curricula; Develop and fund continuing education certificates in genomic nursing; Create simulation training using EHRs with genomic CDS.
Health Informatics	Advocate for and adopt HL7 FHIR standards for genomic data exchange; Develop and validate patient-facing app interfaces for lifestyle tracking linked to EHRs; Design CDS that is sensitive to nursing workflow and context.
Policy & Practice	Develop nursing-specific clinical practice guidelines for pharmacogenomic and nutrigenomic interventions; Establish clear institutional protocols for genetic counseling referral pathways; Advocate for insurance coverage for preventive genomic testing in high-risk chronic disease populations.
Research	Conduct implementation science studies on nurse-led precision care models; Investigate patient-reported outcomes and cost-effectiveness of genomics-guided nursing interventions; Explore the use of AI to synthesize genomic and lifestyle data for predictive nursing insights.

Conclusion

The integration of genomics and digital health heralds a new era for chronic disease management, one where care is predictive, preventive, personalized, and participatory. This review demonstrates that the laboratory generation of pharmacogenomic and nutrigenomic data, when effectively integrated into interoperable EHRs with intelligent CDS, provides a powerful evidence base for clinical action. Nurses, as the constant caregivers in the chronic disease journey, are the indispensable agents who can translate this complex data into compassionate, personalized interventions that improve medication safety, optimize lifestyle changes, and ultimately enhance patient outcomes and quality of life. Realizing this vision of precision nursing requires concerted efforts to overcome technical interoperability hurdles, systematically expand genomic literacy within the nursing workforce, and address ethical concerns with robust safeguards. By embracing this convergence, nursing can solidify its leadership role in shaping the future of personalized, effective, and humane chronic care.

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