



Nursing and Health Informatics Contributions to Monitoring Nursing Workload and Staffing Optimization

Mulfi Azam Ashwan Alhazmi^{1*}, Nouf Ayed Alanazi², Dalal Qaleb Alrawili³, Aminah Mohammad N Alrawili⁴, Norah Jatli Gasham Alshammari⁵, Aljazi Muteb Mari Alruwaili⁶, Mofareh Mutlaqh Albaqami⁷, Ayad Rubayyi A Alhawiti⁸, Alshehri, Raed Abdullah A⁹, Alsufyani Ahmed Abed¹⁰, Ali Abdallah Ali Albothah¹¹

¹Nursing Technician – Ministry of Health, Compliance Administration – Arar – Northern Borders Region – Saudi Arabia
* Corresponding Author Email: mulfia@moh.gov.sa - ORCID: 0000-0002-0247-7990

²Nurse Specialist – Northern Borders Health Cluster – Arar – Northern Borders Region – Saudi Arabia
Email: noaalanazi@moh.gov.sa - ORCID: 0000-0002-0147-7000

³Nursing Specialist – Northern Borders Health Cluster – Arar – Northern Borders Region – Saudi Arabia
Email: md_3433@icloud.com - ORCID: 0000-0002-2147-7100

⁴Nursing Technician – Ministry of Health (General Medical Commission) – Arar – Northern Borders Region – Saudi Arabia
Email: amalrawili@moh.gov.sa - ORCID: 0000-0002-3147-7200

⁵Nursing Specialist – Ministry of Health, Forensic Medicine Department (Hail Branch) – Hail – Hail Region – Saudi Arabia
Email: Neidah2018@gmail.com - ORCID: 0000-0002-4147-7300

⁶Nursing Technician – Asfan Health Center, Al Jouf Health Cluster – Dumat Al-Jandal – Al Jouf Region – Saudi Arabia
Email: Osm72e@gmail.com - ORCID: 0000-0002-5147-7400

⁷Health Informatics Specialist – East Hawiyah Health Center, Taif Health Cluster – Taif – Makkah Region – Saudi Arabia
Email: mofareh13m@hotmail.com - ORCID: 0000-0002-6147-7500

⁸Health Information Technician – King Fahad Specialist Hospital, Tabuk – Tabuk – Tabuk Region – Saudi Arabia
Email: aralhawiti@moh.gov.sa - ORCID: 0000-0002-7147-7600

⁹Health Information Technician – King Fahad Specialist Hospital, Tabuk – Tabuk – Tabuk Region – Saudi Arabia
Email: raabalshehri@moh.gov.sa - ORCID: 0000-0002-8147-7700

¹⁰Health Informatics Specialist – King Abdulaziz Specialist Hospital, Taif Health Cluster – Taif – Makkah Region – Saudi Arabia
Email: ahmed503010@hotmail.com - ORCID: 0000-0002-9147-7800

¹¹Health Informatics Technician – King Saud Hospital, Unaizah – Unaizah – Qassim Region – Saudi Arabia
Email: alooli_6@hotmail.com - ORCID: 0000-0002-9947-7900

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Abstract:

Nursing and health informatics play a pivotal role in monitoring nursing workload and optimizing staffing levels, ultimately enhancing patient care and outcomes. By harnessing advanced data analytics and electronic health records (EHRs), healthcare facilities can assess real-time workload indicators, such as patient-to-nurse ratios, time spent on various tasks, and patient acuity levels. These insights allow nurse managers to make informed decisions about staffing, ensuring that sufficient personnel are available to meet patient needs while reducing the risk of burnout among healthcare providers. Furthermore, the integration of clinical decision support systems within nursing workflows empowers nurses to effectively prioritize their tasks, thus improving overall efficiency and satisfaction. In addition to real-time monitoring, nursing and health informatics facilitate long-term staffing optimization by identifying trends and patterns in workload data over time. By analyzing historical data, organizations can predict peak

demand periods, such as flu season or post-operative care phases, enabling proactive staffing adjustments. The use of telehealth services and remote patient monitoring also allows nurses to manage larger patient populations without compromising care quality. Ultimately, leveraging informatics in nursing not only streamlines operations but also fosters a culture of continuous improvement, where data-driven decisions enhance the quality of patient care, nurse well-being, and operational efficiency.

1. Introduction

The contemporary healthcare landscape is characterized by unprecedented complexity, rising patient acuity, and relentless financial pressures. Within this challenging environment, the nursing workforce serves as the fundamental backbone of patient care delivery, safety, and outcomes. However, a persistent and critical challenge threatening the stability and efficacy of healthcare systems globally is the accurate assessment of nursing workload and the subsequent optimization of staffing. Inadequate staffing, often a direct result of flawed or retrospective workload measurement, is inextricably linked to detrimental consequences, including nurse burnout, increased medical errors, higher patient mortality rates, and elevated hospital readmission rates [1, 2]. Traditional methods of determining staffing needs, frequently reliant on simplistic patient-to-nurse ratios or historical volume averages, have proven insufficient. These methods fail to capture the multidimensional nature of nursing work, which encompasses not only direct patient care tasks but also indirect care, unit coordination, documentation, and communication activities. This gap between simplistic measurement and complex reality creates a vulnerable system where both nurses and patients are at risk [3].

It is within this critical juncture that health informatics emerges as a transformative discipline. Health informatics, defined as the interdisciplinary field that uses information technology to organize and analyze health records to improve healthcare outcomes, offers powerful tools and methodologies to revolutionize how nursing workload is understood, measured, and managed [4]. By leveraging data captured through Electronic Health Records (EHRs), predictive analytics, real-time location systems, and sophisticated algorithms, health informatics shifts the paradigm from reactive, volume-based staffing to proactive, acuity-driven, and outcome-oriented workforce optimization [5].

2. The Evolution of Nursing Workload Measurement:

Understanding the current informatics-driven approaches necessitates a brief review of the

evolution of nursing workload measurement. Historically, nursing workload was often conceptualized through an industrial lens, focusing on the quantifiable tasks performed. Tools like the Nursing Activities Score (NAS) or the Therapeutic Intervention Scoring System (TISS) attempted to catalog and assign weights to specific patient care activities [3, 4]. While these represented an advancement over simple ratios, they often remained limited. They were typically applied retrospectively, provided a static snapshot in time, and struggled to account for the cognitive load, emotional labor, and continuous surveillance that constitute a significant portion of nursing work. The fundamental limitation was the treatment of workload as merely the sum of discrete tasks, ignoring the dynamic and interconnected nature of healthcare environments.

The paradigm began to shift with the adoption of complexity science principles in nursing. This perspective views patient care units as complex adaptive systems where interactions between patients, nurses, technology, and the environment are nonlinear and constantly evolving [5]. A patient's condition is not static; a stable patient can deteriorate rapidly, necessitating a sudden and significant increase in nursing attention and intervention. Similarly, the admission, discharge, and transfer (ADT) process creates constant flux. Traditional task-based tools, often completed once per shift, cannot capture this dynamism. Furthermore, they fail to incorporate crucial contextual factors such as nurse skill mix and expertise, unit geography and layout, and the quality of interprofessional collaboration, all of which significantly influence the actual workload experienced. This recognition of complexity created the essential demand for a more sophisticated, data-rich, and real-time measurement approach, setting the stage for health informatics to provide the necessary tools [6].

3. The Foundational Role of the Electronic Health Record (EHR) as a Data Reservoir

The widespread adoption of the Electronic Health Record (EHR) represents the most significant infrastructural development enabling advanced workload analytics. Far more than a digital replacement for paper charts, the modern EHR is a

comprehensive, integrated data reservoir that captures a vast array of structured and unstructured information relevant to patient acuity and nursing work [4]. Every clinical documentation entry, medication administration record, vital sign flow sheet, diagnostic test result, and nursing note contributes to a rich digital footprint of both patient needs and nursing actions. This continuous data stream allows for the move beyond periodic assessments to near-continuous monitoring of factors that drive nursing workload [6].

Informatics systems can be designed to extract and synthesize EHR data in real-time to generate patient acuity scores that are far more nuanced than traditional diagnosis-related groups (DRGs). These acuity algorithms can incorporate a multitude of variables: the number and frequency of medications (especially high-risk IV medications), the complexity of wound care requirements, the need for physiological monitoring, the frequency of required assessments, the presence of behavioral health issues, and the intensity of patient and family education needs [7, 8]. For instance, a patient post-cardiac surgery on multiple vasoactive drips, with chest tube management, and requiring hourly neurological checks generates a quantifiably higher acuity score than a patient recovering from uncomplicated surgery. By aggregating these individual patient acuity scores at the unit level, nurse leaders can obtain a real-time, data-driven picture of the total required nursing care intensity for their cohort of patients. This moves staffing decisions from being based on a simple census count ("we have 30 patients") to being based on a weighted acuity index ("we have 30 patients with a cumulative acuity score equivalent to 40 average patients"), which is a fundamentally more accurate reflection of demand [9].

4. Predictive Analytics and Modeling for Proactive Staffing

Building upon the real-time data from EHRs, health informatics contributes its most powerful tool for optimization: predictive analytics. Predictive analytics uses historical data, statistical algorithms, and machine learning techniques to identify the likelihood of future outcomes. In the context of nursing workload and staffing, this translates to forecasting patient inflow, acuity, and specific care demands hours or even days in advance. This capability enables a shift from reactive staffing—where managers scramble to call in staff after a sudden surge—to proactive, strategic workforce planning [7].

Predictive models integrate data from multiple sources beyond the EHR. They analyze patterns in

historical ADT data, seasonal illness trends (e.g., influenza season), scheduled elective surgery volumes, and even local event calendars to forecast patient admissions and discharges [10, 11]. More advanced models incorporate real-time emergency department wait times and ambulance diversion status to predict impending admissions to inpatient units. By forecasting the "when" and "what" of patient arrivals, these tools allow managers to align scheduled staff hours with predicted demand, minimizing both overstaffing (which is costly) and understaffing (which is dangerous). Furthermore, predictive analytics can forecast individual patient risks, such as the likelihood of a fall, a pressure injury, or clinical deterioration [12]. Identifying high-risk patients allows for the pre-emptive assignment of appropriate resources, such as more frequent rounding or placement in rooms closer to the nurses' station, thereby optimizing the distribution of nursing attention and potentially preventing adverse events that would create even greater workload.

5. Real-Time Location Systems and Workflow Analysis

While EHR data reveals the "what" of patient condition, understanding the "how" and "where" of nursing work requires different informatics tools. Real-Time Location Systems (RTLS), often using radio-frequency identification (RFID) or infrared badges, track the movement of nurses, equipment, and sometimes patients throughout a facility. This technology provides objective, granular data on nursing workflow patterns, time-motion, and non-value-added activities that are invisible to traditional measurement or self-report [11].

RTLS data can quantify the distance nurses walk per shift, the time spent in patient rooms versus at medication stations or decentralized charting areas, and the frequency and duration of interruptions [13, 14]. This analysis reveals inefficiencies in unit design or supply location that contribute to indirect workload and fatigue. For example, if data shows nurses are making excessive trips to a central supply room for common items, workload can be reduced by implementing well-stocked supply carts on the unit. Similarly, analysis of communication patterns and interruption frequency can lead to structured handoff protocols or "quiet zones" for medication preparation, reducing cognitive load and error risk. By optimizing the physical and logistical environment, informatics directly contributes to reducing the burden of indirect care, freeing up nursing time for direct patient interaction and more complex clinical reasoning. This form of industrial engineering, powered by informatics

data, is a crucial component of holistic workload management [14].

6. Automated Documentation and Clinical Decision Support:

A substantial and often-cited component of nursing workload is documentation. The burden of manual, repetitive, and sometimes redundant charting contributes significantly to cognitive fatigue and time away from the bedside. Health informatics addresses this through automated documentation and integrated Clinical Decision Support (CDS) systems. Interoperable medical devices—such as vital signs monitors, infusion pumps, and ventilators—can now interface directly with the EHR, automatically populating flowsheets with accurate, time-stamped data. This not only saves time and reduces transcription errors but also ensures a more complete and continuous patient record [15].

More profoundly, CDS systems embedded within the EHR and other clinical software can streamline workflow and reduce cognitive load. Alerts for medication interactions, reminders for evidence-based care bundles (e.g., for sepsis or ventilator-associated pneumonia), and condition-specific documentation templates guide nurses through complex processes, ensuring thoroughness and adherence to protocols [16]. While poorly designed alerts can cause alarm fatigue, well-designed, context-sensitive CDS acts as a cognitive aid. It helps organize and prioritize information, reducing the mental effort required to remember all steps of a protocol or to constantly cross-reference guidelines. By managing information flow and providing just-in-time knowledge, these informatics tools mitigate a key dimension of workload: the cognitive and clerical burden, allowing nurses to focus their expertise on assessment, judgment, and compassionate care [16].

7. The Emergence of Artificial Intelligence and Machine Learning

The frontier of health informatics in workload optimization lies in the application of Artificial Intelligence (AI) and Machine Learning (ML). These technologies move beyond rules-based predictive models to discover complex, non-linear patterns within vast datasets that may elude human analysts. In staffing optimization, AI algorithms can process a staggering array of variables—including nuanced EHR data, local weather patterns, community disease prevalence, and even staff sentiment analysis from anonymized feedback—to generate highly refined staffing

recommendations with unprecedented accuracy [17, 18].

Machine learning models can be trained to predict not just patient acuity, but specific nursing-sensitive outcomes based on staffing patterns. They can learn, for example, the precise relationship between nurse skill-mix, patient turnover, and the risk of hospital-acquired infections on a specific unit type. This allows for precision staffing aimed at mitigating specific risks. Furthermore, Natural Language Processing (NLP), a branch of AI, can analyze unstructured data in nursing notes and progress reports to extract themes related to workload, patient complexity, or safety concerns that are not captured in structured fields [19]. This can provide a qualitative, narrative layer to the quantitative acuity scores, offering a more holistic view of unit pressure. AI-powered scheduling software can also optimize staff deployment by matching nurse competencies, preferences, and fatigue levels with patient needs, creating fairer and more efficient schedules that improve job satisfaction and retention [20].

8. Outcomes and Impact: Linking Informatics-Driven Staffing to Quality

The ultimate test of any informatics intervention is its impact on tangible outcomes. A growing body of evidence links the use of informatics-driven, acuity-based staffing systems to improvements in both nurse and patient outcomes. For nurses, these systems are associated with reduced subjective workload and burnout, as staffing more closely matches actual demand [21]. More objective scheduling and fairer distribution of difficult assignments, facilitated by data transparency, can improve morale and reduce turnover intention [22]. Perhaps most critically, when nurses are not stretched beyond safe limits, they can practice at the full scope of their education and experience, leading to greater professional satisfaction.

For patients, the benefits are measured in safety and quality metrics. Studies have demonstrated correlations between the use of predictive acuity-based staffing and reductions in patient falls, medication errors, hospital-acquired pressure injuries, and catheter-associated urinary tract infections [23, 24]. Furthermore, by enabling optimal nurse-to-patient ratios tailored to actual need, these systems contribute to better patient surveillance, earlier detection of complications, and more timely interventions, which are key drivers of reduced mortality and failure-to-rescue rates [25, 26]. From a system perspective, optimized staffing leads to greater operational efficiency, reducing costs associated with overtime, temporary agency

staff, and adverse event-related penalties. It also enhances capacity management, allowing hospitals to care for more patients safely by ensuring nursing capacity is dynamically aligned with patient needs [27].

9. Challenges, Ethical Considerations, and Future Directions

Despite its transformative potential, the integration of health informatics into nursing workload and staffing is not without significant challenges. The initial financial investment in software, hardware, and IT infrastructure can be substantial [28]. The success of these systems is entirely dependent on data quality; incomplete documentation or inaccurate data entry leads to a "garbage in, garbage out" scenario, producing faulty acuity scores and recommendations [29]. There is also a risk of technological determinism, where the algorithm's output is followed uncritically. Nurse leaders must maintain their professional judgment, using informatics as a decision-support tool, not an autocratic decision-maker. The "black box" nature of some advanced AI models can create transparency issues, where the rationale for a staffing recommendation is not easily interpretable, potentially eroding trust among nursing staff [30]. Ethical considerations are paramount. Continuous tracking via RTLS raises legitimate concerns about privacy and surveillance, potentially creating a culture of mistrust if not implemented with nurse input and clear policies on data use [31]. Algorithms themselves can perpetuate existing biases if they are trained on historical data that reflects inequities in care delivery or documentation [32]. It is crucial that these systems are developed and validated with interdisciplinary teams including nurses, ethicists, and data scientists. The future direction of this field lies in developing more explainable AI, creating seamless interoperability between different health IT systems to provide a unified data view, and integrating patient-reported outcome measures (PROMs) into acuity models to capture the holistic needs of the individual [33, 34]. Furthermore, the next generation of systems may focus on predictive resilience, forecasting not only patient needs but also nursing team stress levels and recommending targeted interventions like resilience huddles or support resources [35].

10. The Imperative of Interoperability and Data Standardization

A critical technical hurdle that underpins many of the advanced applications discussed is the lack of seamless interoperability between disparate health

information systems. Nurses often navigate multiple, non-integrated platforms for EHR documentation, medication dispensing, laboratory results, and staffing scheduling. This fragmentation creates data silos, hinders the comprehensive view needed for accurate workload assessment, and adds to cognitive burden as nurses must manually reconcile information [36, 37]. True optimization requires a holistic data ecosystem. Efforts towards adopting common data standards, such as those promoted by Health Level Seven (HL7) International and the integration of nursing-specific terminologies like the Nursing Interventions Classification (NIC) into system architectures, are essential [38]. When systems can communicate effortlessly, the data reservoir deepens, allowing predictive models to incorporate a wider array of variables—from pharmacy data on medication complexity to bed management systems on pending transfers—resulting in even more precise and actionable staffing intelligence.

11. Human Factors and Change Management: The Crucial Human Element

The most sophisticated informatics system will fail if the human element is neglected. Nurses, nurse managers, and administrators are the end-users who must interpret, trust, and act upon system outputs. Therefore, the principles of human factors engineering and robust change management are not ancillary but central to successful implementation. System interfaces must be intuitive and designed with nurse input to fit naturally into clinical workflow, not disrupt it [39]. Transparency in how acuity scores or staffing recommendations are generated is vital to foster trust; nurses are more likely to support a system they understand. Comprehensive, ongoing education is required to transition staff from a mindset of fixed ratios to one of dynamic, data-informed resource allocation. Leaders must champion these tools as support mechanisms for clinical judgment, not replacements for it, and be prepared to address concerns about surveillance or perceived devaluation of experiential knowledge. The goal is to create a collaborative human-technology partnership where informatics amplifies nursing expertise [40].

12. Economic Modeling and Return on Investment

Justifying the significant investment in health informatics for staffing optimization requires clear demonstration of return on investment (ROI). Beyond the direct quality and safety benefits,

economic modeling is a powerful tool. Informatics-driven systems can generate substantial cost savings by reducing excessive overtime expenditures, minimizing the use of high-cost temporary agency staff, and decreasing turnover-related recruitment and training expenses [40]. Furthermore, by optimizing staffing levels, hospitals can improve throughput, reducing length of stay and increasing capacity to generate revenue from additional patient care. Perhaps most significantly, these systems provide a powerful defense against the far greater costs associated with adverse events, such as hospital-acquired conditions that are no longer reimbursed under value-based payment models and the potential legal costs of preventable errors [41]. Articulating this full spectrum of financial benefits—from cost avoidance to revenue enhancement—is crucial for securing organizational commitment and funding for these transformative technologies, ensuring that the virtuous cycle of investment, improvement, and further investment can be sustained.

13. Conclusion

The challenge of accurately monitoring nursing workload and optimizing staffing is a complex, high-stakes problem at the heart of healthcare quality and safety. Traditional, simplistic methods have proven inadequate in capturing the dynamic, multifaceted nature of nursing work in complex adaptive systems. Health informatics provides the essential toolkit to bridge this gap, offering a data-driven, sophisticated, and proactive approach to workforce management. From the foundational data of the EHR to the predictive power of analytics, the workflow insights from RTLS, the cognitive support of CDS, and the advanced pattern recognition of AI, informatics technologies are revolutionizing the field.

These contributions enable a shift from staffing based on historical patient counts to staffing dynamically aligned with real-time and predicted patient acuity. The outcomes of this shift are profound: enhanced patient safety through reduced adverse events, improved nurse well-being through mitigated burnout, and greater healthcare system efficiency. However, realizing this potential requires mindful implementation that addresses challenges of cost, data integrity, algorithmic bias, and ethical surveillance. It necessitates a collaborative partnership where nursing expertise guides the development and application of technology, ensuring that informatics serves as a powerful ally to the nursing profession. In this synergy between nursing science and health informatics lies the most promising path toward

creating sustainable, safe, and effective healthcare environments for both those who provide care and those who receive it. The ongoing integration and refinement of these tools will undoubtedly remain a central focus in the pursuit of the quintuple aim: improving patient experience, population health, care team well-being, cost-effectiveness, and health equity.

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