Perceptions of Cognitive Load and Workload in Nurse Handoffs

Benjamin J. Galatza; Liang Shan; Elizabeth A. Johnson; Patricia A. Patrician

Perceptions of Cognitive Load and Workload in Nurse Handoffs: A Comparative Study Across Differing Patient-Nurse Ratios and Acuity Levels

Abstract

Medical errors, often resulting from miscommunication and cognitive lapses during handoffs, account for numerous preventable deaths and patient harm annually. This research examined nurses' perceived workload and cognitive load during handoffs on hospital units with varying patient acuity levels and patient-nurse ratios. Conducted at a southeastern U.S. medical facility, the study analyzed 20 handoff dyads using the NASA TLX to measure perceived workload and cognitive load. Linear regressions revealed significant associations between patient-acuity levels, patient-nurse ratios, and NASA TLX subscales, specifically mental demand ($p=.007$) and performance ($p=.008$). Fisher's exact test and Wilcoxon rank sum test showed no significant associations between these factors and nurses' roles ($p>0.05$). The findings highlight the need for targeted interventions to manage workload and cognitive load, emphasizing standardized handoff protocols and technological aids. The study underscores the variability in perceived workload and cognitive load among nurses across different units. Medical-Surgical units showed higher cognitive load, indicating the need for improved workload management strategies. Despite limitations, including the single-center design and small sample size, the study provides valuable insights for enhancing handoff communications and reducing medical errors.

Keywords: Nurse handoffs, Cognitive load, Nurse-patient ratios, Workload, nursing Informatics, Patient safety.

Medical errors are responsible for an estimated 210,000-400,000 preventable deaths and patient harm each year.[1 2] The primary root causes of these errors are miscommunication and cognitive lapses.[3-5] These lapses and miscommunications, particularly during handoffs, lead to delayed diagnosis and interventions, delayed or omitted tests, and medication errors.[6-9] These issues often result in adverse patient outcomes, including direct patient harm, hospital-associated infections, and extended hospitalizations.[10 11]

As evident in the potential adverse events, nursing handoffs play a pivotal role in ensuring the continuity, safety, and quality of patient care. The transition of care communication or handoff is the process of transferring responsibility for and care of the patient and communicating critical patient information from one nurse to another, often involving the synthesis and transfer of complex patient information.[3 6 12] The mental effort involved in this process, or 'cognitive demand', challenges both the sender and the receiver due to the intricate details necessary for patient safety. [13] The cognitive demand during handoffs can be affected by various factors, such as the patient-nurse ratio, the complexity of patient cases, and the dynamics of the healthcare unit. 'Cognitive load', however, specifically refers to the mental resources needed to understand and utilize the information exchanged during handoffs. This load is shaped by intrinsic factors like the severity of the patient's condition and extraneous factors such as the staffing levels.[14 15]

The nursing units within a healthcare facility provide care to patients with varying levels of illness severity and care demands. An intensive care unit (ICU) provides care to critically ill patients requiring highly specialized and focused care, while a general medical-surgical unit provides care to patients with a wide-range of medical issues which are not immediately life-threatening. In addition to acuity levels, nurse-patient ratios are often indicative of the workload of a nurse and vary across nursing units. Units with a high patient-to-nurse ratio indicate that the nurse is responsible for a larger number of patients, potentially increasing the volume and complexity of information to be communicated during handoff. With a lower patient-to-nurse ratio, the nurse is responsible for fewer patients, but often the patient acuity is higher, and the complexity of the cases is greater, also affecting the handoff process. These variances in patient acuity levels and nurse-patient ratios could lead to differing degrees of information complexity that a nurse must convey during handoffs, potentially affecting the nurse's perceived workload and cognitive load.

Understanding the nurse's perception of the workload and cognitive load of the handoff process is essential in improving the quality of care and patient safety. A consistently high level of perceived cognitive load and workload can lead to a negative impact on the nurse's sense of well-being, burnout, fatigue, and job satisfaction.[16-19] In addition to nurse well-being, a consistently perceived high level of workload and cognitive load can impact patient safety, quality of care, and workflow efficiency.[16 18 19] The aim of this study was to examine the Registered Nurse's (RN's) perception of the workload and cognitive load of the handoff process on three different units with varying degrees of nurse-patient ratios and patient acuity level. The two main research questions were:

1) What is the perceived workload and cognitive load of both the sender and receiver during the change of shift handoff, as measured by the NASA TLX? 2) How do varying patient acuity levels and patient-nurse ratios affect the perceived workload and cognitive load, as measured by the NASA TLX, during the change of shift handoff?

Methods

Design

The research utilized the Nurse-to-Nurse Transition of Care Communication Framework to structure the study. This framework serves as a tool to analyze the handoff communication between nurses when a patient experiences a transition of care either intrahospital or interhospital.[10] The study employed a quantitative descriptive design to investigate nurses' perceived workload of performing the handoff on three different units with varying degrees of patient acuity levels and patient-nurse ratio. This study was part of a larger mixed methods research project concerning the change of shift handoff communication.

Setting

The study was conducted at a major medical facility in the southeastern United States, known for its comprehensive academic, clinical research, and referral services. The units selected for this study were based on their differing patient-nurse ratios and patient acuity levels, including a cardiovascular ICU, a step-down trauma unit, and a general medical-surgical unit. The cardiovascular ICU (CICU) had a 1 RN to 1-2 patient ratio for both day and night shifts, representing a low patient-nurse ratio and high acuity level. The step-down trauma unit had a 1 RN to 3-4 patient ratio for day shift and a 1 RN to 4-5 patient ratio for nights, indicating a medium patient-nurse ratio and medium acuity level. The medical-surgical unit had a 1 RN to 6-7 patient ratio on day shift and a 1 RN to 7-9 patient ratio on night shift, reflecting a high patient-nurse ratio and low acuity level. These categorizations highlight the unique characteristics of each unit under the study setting and underscore the varying demands on nurse workload and cognitive load during handoffs.

Definition and Impact of Patient Acuity. Patient acuity is defined as the complexity and severity of patients' conditions, requiring varying levels of nursing care and resources.[20 21] According to the Easley-Storfjell Patient Classification Instrument and Holzemer's Outcomes

Model for Health Care Research, patient acuity is considered a structure of care that can influence nursing processes and outcomes, such as workload distribution, patient safety, and quality of care.[20] The patient acuity for the three units involved in the study was categorized as high for the CICU, moderate/medium for the step-down unit, and medium/low for the general medical-surgical units.[21] We acknowledge that acuity levels can fluctuate on any given unit, but these categories align with the critical nature of each unit.

Handoffs took place face-to-face at the bedside, away from the bedside, or a combination of both. Notably, all three units lacked a standardized handoff tool. Nurses used their own personal handoff template (brainsheet); the electronic health record was not used. Approval for the study was obtained from both the Institutional Review Board of the organization and the academic institution.

Recruitment and Sample

The participants in the study consisted of RNs responsible for conducting the handoff. The study aimed to include 60 RNs and 30 handoffs. The sample size was determined through information power analysis, taking into account the focused and specific objectives of the study, the characteristics of the participants (RNs involved in the handoffs), the application of a defined theoretical framework, the quality of the dialogue, and the strategic analytical methods employed.[22 23] The researchers employed a convenience sampling method to identify eligible participants, and no advertising was used for this study. To be eligible for participation, the RNs needed to fulfill the following inclusion criteria: 1) Work full-time on the designated unit or be a traveler/agency RN assigned to that unit. 2) Possess a minimum of three months' experience on the unit, having completed their orientation or be a traveler/agency RN assigned to the unit. 3) Be proficient in speaking and reading English. 3) Had provided care or were continuing to provide care for a patient that had experienced a Clinical Event (CE). A critical criterion for participant in this study was that the patient must have experienced a CE during the current shift, before the nursing shift change, and continued to receive care on the unit. A Clinical Event (CE) is identified by occurrences such as fever, alterations in bodily outputs (e.g., urine, stool, vomit), changes in consciousness levels, instances of bleeding, pain, or shifts in respiratory conditions.[24] These incidents are unexpected during patient treatment, necessitating immediate medical response and carrying the potential to escalate into sentinel events if not managed promptly. The occurrence of a clinical event was a key factor in this study, providing a lens through which to investigate the conveyance of critical patient information during the handoff, as well as to assess the cognitive demands and perceived workload associated with the handoff process.

To mitigate any potential bias or distortion of results, each nurse participant was permitted to take part in the study only once. The sample size for this study was 20 handoff dyads, involving the three units. A handoff dyad comprised at least one RN sending the handoff (sender) and one RN receiving the handoff (receiver). The total RN sample size was N=41 including 20 RNs sending and 21 RNs receiving the handoff communication. One of the handoff dyads consisted of three RNs, with one sending and two receiving the handoff.

Instrument

The National Aeronautics and Space Administration Task Load Index (NASA TLX) mobile application[25] was used to evaluate the RNs' perceived workload and cognitive load associated with the nursing handoff. The NASA TLX was completed through a mobile application on an iPad programmed specifically for the study. It was originally developed for the aviation industry to assess perceived workload after completing a task.[26-28] The NASA TLX has since been used in a variety of applications, including computer science, nursing[29], medicine, and military.[27 28 30]

The NASA TLX contains six subscales: mental demand (cognitive effort required), physical demand (physical effort required), temporal demand (time pressure felt), performance (satisfaction with one's performance), effort (overall exertion required), and frustration (stress and irritation experienced).[31] This instrument has demonstrated high construct validity when used to assess workload of nurses working in the ICU setting, pediatric ICU, and neonatal ICU[29], and high criterion (concurrent) validity when assessing the workload of anesthesiologists [28]. The NASA TLX has demonstrated moderate to good reliability with an intraclass correlation coefficient range of 0.71 to 0.81[30], and an interrater reliability range of 0.77 to 0.83.[26 32]

Data Collection

The primary investigator (PI) and two trained research assistants (RAs) followed a systematic data collection protocol. All data and informed consent were obtained by either the PI or the RAs. To identify RN handoff dyads meeting the inclusion criteria, the PI or RAs arrived on the unit one hour before the next shift start. The PI or RAs engaged in a discussion with the off-going RN to ascertain if any patient had experienced a CE during that shift. Once an eligible patient was identified, the PI or RAs individually approached the out-going and in-coming RNs assigned to that patient to assess eligibility, provide a study explanation, and obtain consent. The PI and RA emphasized that participating in the study was voluntary and would not impact job status. They also assured that all identifiers such as those of patients, families, RNs, and other healthcare personnel would be removed.

The PI created the study as per the NASA TLX user guide in the online mobile application using the research iPads.[33] The PI or RAs entered the study name, study group, and subject ID (for example, ICU01031722).[33] After the handoff was completed, the RN participant completed the NASA TLX on the research iPad in a private location of their choosing. Additionally, demographic information for each participant was collected prior to the completion of the NASA TLX. As an expression of gratitude and compensation for their time and involvement, all participants were offered a $25 dollar Visa gift card. This procedure was followed with each dyad until the data collection phase was concluded. The data was collected over four-month period.

Data Management

The data from each completed online questionnaire were downloaded as a CSV file to the PI's password-protected laptop for additional data processing. Upon completion of the study, all data on the iPad app were deleted, and all NASA TLX data transferred to the PI's secured institution-provided and managed Box drive (secure cloud storage with user and password-controlled access).

Data Analysis

The demographic and NASA TLX data were analyzed using IBM SPSS Statistics (Version 28) and R (Version 4.3.1). The demographic data were analyzed and evaluated using descriptive statistics. To examine whether and how the two factors (patient-nurse ratio and patient acuity level) and NASA TLX subscales differentiate between roles of the nurses (Sender vs Receiver), Fisher's exact test was used. This test explored the association between the role and categorical variables (e.g., different units). The Wilcoxon rank sum test compared the means between the two roles, given the relatively small sample size. To explore how the factors (patient-nurse ratio and patient acuity level) are associated with the NASA TLX subscales and test whether these associations differ by the role of nurses, linear regression models were used. Initially, these models tested for any interaction effect between the role of nurses and the factors(patient-nurse ratio and patient acuity level); however, no interaction effect was found to be significant. Subsequently, separate linear regression models were run for each NASA TLX subscale as the outcome variable, with the factors (patient-nurse ratio and patient acuity level) as predictors, controlling for the role of the nurses.

Results

Demographics

The total sample size was 41 RNs/20 handoff dyads with the following breakdown from each unit: Cardiovascular ICU (n = 18), Step-down trauma (n = 12), and Medical-Surgical (n = 11). The sample consisted of 80.5% female nurses. A majority of the sample were Caucasian non-Hispanic (75.6%). The highest education level of the participants was Baccalaureate of Science in Nursing (63.4%). The mean years of experience of the participants was 5.51 years. The mean years of experience on the unit was 2.44 years. Table 1 provides a detailed breakdown of the demographics.

Roles

No statistical significance ($p > 0.05$) was found between different roles of handoffs regarding the unit type (CICU, step-down trauma, and medical-surgical) and the six NASA TLX subscales. However, receivers perceived a higher average physical demand (31 vs. 18) with a modest p-value ($p = 0.055$) and a medium effect size (Cohen's d = 0.63), see table 2.

Workload and Cognitive Load among the Three Units

The results show that most of the NASA TLX subscales do not differ by different units, after controlling for the nurses' roles. However, the average mental demand is statistically significantly different among the three units after controlling for the nurses' roles, as does the average performance. Table 3 provides the mean scores for mental demand, performance, and frustration level. Specifically, there are no significant differences in the average mental demand between CICU (low patient-nurse ratios and high acuity) and step-down trauma (medium patient-nurse ratios and medium acuity) units (p=0.98), but medical-surgical (high patient-nurse ratios and low acuity) units exhibit significantly higher mental demand than the rest (p=0.01, CICU vs. medical-surgical difference 24.29 (7.87), step-down trauma vs. medical-surgical difference 25.50 (8.63)). Note that the p-values are obtained after multiple testing adjustment by the Tukey method. The performance subscale showed no difference between the CICU (low patient-nurse ratio and high acuity) and medical-surgical (high patient-nurse ratio and low acuity) units (p=0.96). However, the step-down trauma (medium patient-nurse ratio and medium acuity) unit has significantly higher mean performance loads than the other two units (p=0.01, step-down trauma vs CICU difference 13.34 (4.46); p=0.02, step-down trauma vs medical-surgical difference 14.50 (5.18)).

In summary, the medical-surgical unit has significantly higher mental demand workload, whereas the step-down trauma unit has significantly higher performance loads. These differences highlight the unique demands and challenges faced by each unit type. The estimated means of the mental demand and performance for each unit are summarized in Table 2.

Discussion

The present study investigated the variance in perceived workload and cognitive load across three different hospital units: Medical-Surgical, ICU (CICU), and Step-down Trauma, with a focus on the handoff process. The research sought to uncover the perceived workload and cognitive load experienced during the handoff, with a specific emphasis on how the units with different patient-to-nurse ratios and patient acuity levels may influence these dynamics, including the roles of the sender and receiver.

The study observed no significant differences in temporal demand and effort across the units, suggesting that the time constraints and physical exertions associated with handoffs are perceived consistently, regardless of the unit type. This indicates that the duration and physical strain of handoff procedures are perceived similarly across departments. Furthermore, it suggests that the processes and time allocations for handoffs are fairly standardized across the different units.

A significant divergence emerged in the mental demand aspect of the NASA TLX, with Medical-Surgical units experiencing a notably higher cognitive load (mean=65.5) compared to CICU and Step-down Trauma units. This finding aligns with the complex nature of Medical-Surgical units where staff may deal with a higher patient-nurse ratio and a greater variety of patient conditions, leading to an increased demand on the nurse's mental and cognitive processing.[34] The differences in mental demand between Medical-Surgical and Step-down Trauma, as well as Medical-Surgical and CICU, underscore the potential influence of higher patient-to-nurse ratios on workload demands and cognitive load on the nurse. Intriguingly, this finding is further reinforced by the lack of significant variation in mental demand between the CICU and the Step-down Trauma unit, despite the higher levels of patient acuity. The nurse-patient ratios for these units were 1 RN to 2 patients in the CICU, 1 RN to 3-4 patients in the Step-down unit compared to 1 RN to 6-7 patients on the Medical-Surgical unit. The significant discrepancies between Medical-Surgical and the other two units underscore the need for targeted strategies to manage cognitive load in the Medical-Surgical settings, possibly by adding nursing staff or shifting the RNs workload to other healthcare workers. The consequences of increased patient-to-nurse ratios, as reported by others, include cognitive overload, burnout, communication errors, and adverse patient outcomes.[16, 18]

Surprisingly, the study found no significant disparities in frustration levels among the units. The Step-down Trauma unit experienced the highest levels (mean=35), followed by Medical-Surgical (mean=23) and CICU (mean=15.26), yet these differences were not statistically significant. This finding was unexpected given the assumption that higher patient-to-nurse ratios and varying patient acuity levels would lead to higher frustration levels, particularly in less experienced nurses. Based on the demographics of this sample, the Step-down Trauma unit has a higher acuity level than the Medical-Surgical unit and a higher patient-nurse ratio than the CICU, while also being on average the least experienced. It was anticipated that the combination of these factors would result in significant differences in frustration, reflecting the additional cognitive and emotional stressors faced by nurses in units with higher patient loads and complexity. The lack of significant variation suggests that factors other than patient-to-nurse ratios and acuity levels, such as team dynamics, support systems, and individual coping mechanisms, might play a critical role in mitigating frustration across different units. Additionally, it may indicate that nurses, regardless of unit, have developed effective strategies to manage their workload and maintain a consistent level of frustration.[13, 19]

Furthermore, the study did not find significant differences between the roles of the sender and receiver in the handoff process, indicating that the cognitive load and workload are perceived similarly regardless of whether the nurse is giving or receiving the handoff. This finding is important because it highlights that interventions aimed at reducing cognitive load during handoffs should be holistic and universal, addressing the needs of both senders and receivers equally. Since there is no significant difference in the perceived cognitive load between the roles, interventions should focus on the overall handoff process to ensure that both roles are supported.

Limitations

While providing valuable insights into nurse-to-nurse handoff communications and associated workload, this study is subject to several limitations that merit consideration. The potential bias in this study primarily relates to single-center nature of the research and the sample selection method. Firstly, the research design was descriptive and quantitative, which, while beneficial for identifying statistical relationships, does not allow for the exploration of causality. The setting of the study in a single, major-medical facility in the southeastern United States may also constrain the generalizability of the results. The facility’s specific operational practices, cultural context, and patient demographics might differ significantly from those of other regions or institutions. The sample size of 20 handoff dyads/41 RNs is relatively small. A larger sample size could provide a more robust analysis and a more reliable representation of the nurse population. Additionally, the study did not assess the nurses' baseline comfort level with clinical events, which could influence their perceived workload and frustration levels. To mitigate potential bias and enhance the robustness of the findings, future research should address these limitations through methodological diversification, larger and more varied samples, and multi-site studies to enhance the external validity and applicability of the results.

Implications for Practice and Research

Implications for Practice

Given the observed differences in mental demand across units, with Medical-Surgical units showing higher cognitive load compared to ICU and Step-down Trauma units, several key points should be considered by healthcare administrators and policymakers. We recommend focusing research and practice efforts on workload management, standardization of handoffs, and cognitive load reduction. For instance, standardized handoff tools and training programs should be designed to enhance the efficiency and accuracy of the handoff process as a whole, ensuring that all nurses are equipped to manage the cognitive demands effectively. Evidence-based strategies to manage workload more effectively include the use of technological tools to augment nurse judgment and recall, staffing decision tree protocols, and support staff roles.

Future Research Directions

Although we did not find significant differences between sender and receiver roles in the handoff process, our findings do reveal important unit-based differences. Future research should include prospective studies to quantify the impact of varying patient-to-nurse ratios on nurse performance, cognitive workload, and patient outcomes. Additionally, future studies should include larger, more diverse samples across multiple healthcare settings to enhance the generalizability of the findings. Standardization of handoffs should be implemented, including formalizing time allocations and procedural steps to ensure a consistent approach across all units. Additionally, future studies should examine the effects of standardized handoff protocols across different units to understand their impact on cognitive load and nurse satisfaction. In addition to standardization and nurse-patient ratios, interventions aimed at reducing cognitive load, such as technological cognitive-aid tools, structured communication tools, and training programs, should be further examined.

Conclusion

The critical nature of handoff communication within nursing practice cannot be overstated, especially given its direct relationship with patient safety and quality of care. This study has underscored the variability in perceived workload and cognitive load among nurses across different acute care units, highlighting the influence of nurse-patient ratios and the complexity of patient conditions on these perceptions. While temporal demands and physical efforts of handoffs appeared consistent across units, the mental demand showed significant variation, with Medical-Surgical units experiencing higher cognitive loads. These findings are a testament to the intricate balance required in nurse staffing and handoff communication strategies during transitions of patient care. The implications of this study are twofold. For clinical practice, there is a clear need for targeted strategies to manage cognitive load, particularly in units with higher patient-to-nurse ratios. For research, these results highlight areas for further investigation, such as the development and implementation of technological interventions aimed at optimizing handoff processes and evaluating the impact of such interventions on patient outcomes.

Healthcare facilities recognize the consequences of cognitive overload, such as burnout and communication errors, and take definitive action to address these issues. The development of standardized handoff tools and the incorporation of technological aids could serve as viable solutions to mitigate the risk of errors and enhance the overall well-being of nurses. In sum, the findings of this study contribute valuable insight to the ongoing efforts to improve handoff communications in nursing. By continuing to refine our understanding of the factors affecting handoff quality, the healthcare industry can make strides toward reducing medical errors and ensuring high standards of patient care.

Reference

1. Makary MA, Daniel M. Medical error-the third leading cause of death in the US. BMJ Quality and Safety 2016;**353**:i2139 doi: 10.1136/bmj.i2139 [published Online First: 2016/05/05].
2. James JT. A New, Evidence-based Estimate of Patient Harms Associated with Hospital Care. Journal of Patient Safety 2013;**9**(3):122-28 doi: 10.1097/PTS.0b013e3182948a69.
3. Orenstein EW, Ferro DF, Bonafide CP, Landrigan CP, Gillespie S, Muthu N. Hidden health IT hazards: A qualitative analysis of clinically meaningful documentation discrepancies at transfer out of the pediatric intensive care unit. JAMIA Open 2019;**2**(3):392-98 doi: 10.1093/jamiaopen/ooz026 [published Online First: 2020/01/28].
4. Joint Commission. Most commonly review sentinel event types. Secondary Most commonly review sentinel event types 2016. https://www.jointcommission.org/assets/1/18/Event_type_2Q_2016.pdf.
5. Joint Commission. Sentinel event data 2022 annual review. Secondary Sentinel event data 2022 annual review 2023. https://www.jointcommission.org/resources/sentinel-event/sentinel-event-data-summary/.
6. Galatzan BJ, Carrington JM. Examining the meaning of the language used to communicate the nursing hand-off. Research in Nursing & Health 2021 doi: 10.1002/nur.22175 [published Online First: 2021/08/18].
7. Galatzan BJ, Carrington JM. Exploring the state of the science of the nursing hand-off communication. Computers, Informatics Nursing 2018;**36**(10):484-93 doi: 10.1097/CIN.0000000000000461 [published Online First: 2018/07/26].
8. Spruce L. Back to basics: Patient care transitions. AORN Journal 2016;**104**(5):426-32 doi: 10.1016/j.aorn.2016.08.014.
9. Johnson C, Carta T, Throndson K. Commuicate with me: Information exchanges between nurses. Canadian Nurse 2015;**3**(2):4.
10. Galatzan BJ, Carrington JM. Communicating data, information, and knowledge in the nursing handoff. Computers, Informatics, Nursing 2022 doi: 10.1097/CIN.0000000000000806 [published Online First: 2021/08/05].
11. Agency for Healthcare Research and Quality. Healthcare-associated infections program. Secondary Healthcare-associated infections program 2017. https://www.ahrq.gov/hai/quality/tools/cauti-ltc/modules/implementation/long-term-modules/module4/mod4-slides.html.
12. O'Rourke J, Abraham J, Riesenberg LA, Matson J, Lopez KD. A Delphi study to identify the core components of nurse to nurse handoff. Journal of Advanced Nursing 2018;**74**(7):1659-71 doi: 10.1111/jan.13565 [published Online First: 2018/03/09].
13. Ahmadi N, Sasangohar F, Yang J, et al. Quantifying Workload and Stress in Intensive Care Unit Nurses: Preliminary Evaluation Using Continuous Eye-Tracking. Human Factors 2022;**0**(0):00187208221085335 doi: 10.1177/00187208221085335.
14. Sweller J, Ayres PL, Kalyuga S. *Cognitive load theory*. New York: Springer, 2011.
15. Sweller J, van Merriënboer JJG, Paas F. Cognitive Architecture and Instructional Design: 20 Years Later. Educational Psychology Review 2019;**31**(2):261-92 doi: 10.1007/s10648-019-09465-5.

16. Iskander M. Burnout, Cognitive Overload, and Metacognition in Medicine. Medical Science Educator 2019;**29**(1):325-28 doi: 10.1007/s40670-018-00654-5.
17. Gillet N, Huyghebaert-Zouaghi T, Réveillère C, Colombat P, Fouquereau E. The effects of job demands on nurses' burnout and presenteeism through sleep quality and relaxation. Journal of Clinical Nursing 2020;**29**(3-4):583-92 doi: https://doi.org/10.1111/jocn.15116.
18. National Academies of Sciences Engineering and Medicine. *Taking Action Against Clinician Burnout: A Systems Approach to Professional Well-Being.* Washington, DC: The National Academies Press, 2019.
19. Harry E, Sinsky C, Dyrbye LN, et al. Physician Task Load and the Risk of Burnout Among US Physicians in a National Survey. The Joint Commission Journal on Quality and Patient Safety 2021;**47**(2):76-85 doi: https://doi.org/10.1016/j.jcjq.2020.09.011.
20. Brennan CW, Daly BJ. Patient acuity: a concept analysis. Journal of Advanced Nursing 2009;**65**(5):1114-26 doi: https://doi.org/10.1111/j.1365-2648.2008.04920.x.
21. Mitra AR, Griesdale DEG, Haljan G, O'Donoghue A, Stevens JP. How the high acuity unit changes mortality in the intensive care unit: a retrospective before-and-after study. Canadian Journal of Anesthesia/Journal canadien d'anesthésie 2020;**67**(11):1507-14 doi: 10.1007/s12630-020-01775-5.
22. Malterud K, Siersma V, Guassora AD. Information power: Sample content and size in qualitative studies. Qualitative research in psychology: Expanding perspectives in methodology and design, 2nd ed. Washington, DC, US: American Psychological Association, 2021:67-81.
23. Malterud K, Siersma VD, Guassora AD. Sample Size in Qualitative Interview Studies:Guided by Information Power. Qualitative Health Research 2016;**26**(13):1753-60 doi: 10.1177/1049732315617444.
24. Carrington JM. Development of a conceptual framework to guide a program of research exploring nurse-to-nurse communication. Computers, Informatics, Nursing 2012;**30**(6):293-9 doi: 10.1097/NXN.0b013e31824af809.
25. Gore B. TLX App. Secondary TLX App 2023. https://humansystems.arc.nasa.gov/groups/tlx/tlxapp.php.
26. Hart SG, Staveland LE. Development of NASA-TLX (Task Load Index): Results of Empirical and Theoretical Research. Human Mental Workload, 1988:139-83.
27. Hudson D, Kushniruk A, Borycki E. Using the NASA Task Load Index to assess workload in electronic medical records. In: Courtney K, Kuo A, Shabestari O, eds. Driving quality in informatics: Fulfilling the promise. Amsterdam: IOS Press, 2015.
28. Said S, Gozdzik M, Roche TR, et al. Validation of the Raw National Aeronautics and Space Administration Task Load Index (NASA-TLX) Questionnaire to Assess Perceived Workload in Patient Monitoring Tasks: Pooled Analysis Study Using Mixed Models. J Med Internet Res 2020;**22**(9):e19472 doi: 10.2196/19472 [published Online First: 2020/08/12].
29. Tubbs-Cooley HL, Mara CA, Carle AC, Gurses AP. The NASA Task Load Index as a measure of overall workload among neonatal, paediatric and adult intensive care nurses. Intensive Crit Care Nurs 2018;**46**:64-69 doi: 10.1016/j.iccn.2018.01.004 [published Online First: 2018/02/17].
30. Devos H, Gustafson K, Ahmadnezhad P, et al. Psychometric Properties of NASA-TLX and Index of Cognitive Activity as Measures of Cognitive Workload in Older Adults. Brain Sci 2020;**10**(12) doi: 10.3390/brainsci10120994 [published Online First: 2020/12/20].

31. Human Performance Research Group. NASA Task Load Index (TLX) v1.0. In: Human Performance Research Group NARC, ed. Moffett Field, California: National Aeronautics and Space Administration, ND.
32. Xiao YM, Wang ZM, Wang MZ, Lan YJ. [The appraisal of reliability and validity of subjective workload assessment technique and NASA-task load index]. Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi 2005;**23**(3):178-81 [published Online First: 2005/08/30].
33. Gore BF, Kim RH. NASA TLX for iOS User Guide v1.0: National Aeronautics and Space Administration, ND.
34. Chen YC, Guo YL, Chin WS, Cheng NY, Ho JJ, Shiao JS. Patient-Nurse Ratio is Related to Nurses' Intention to Leave Their Job through Mediating Factors of Burnout and Job Dissatisfaction. International Journal of Environmental Research and Public Health 2019;**16**(23) doi: 10.3390/ijerph16234801 [published Online First: 20191129].