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A Systematic Approach Utilizing the System Engineering Initiative for Patient Safety 2.0 Model to Mitigate Fatigue in ER

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Abstract

The focus of the study addresses fatigue among healthcare workers in the Emergency Room (ER), which is vital in delivering health services but is prone to worker fatigue. It evaluates physical and mental fatigue using objective measures like cardiovascular load (%CVL) and the Bourdon Wiersma test. Leveraging the System Engineering Initiative for Patient Safety 2.0 (SEIPS 2.0) model, it comprehensively analyzes fatigue factors. Data collection includes surveys and statistical analysis through Structural Equation Modeling-Partial Least Squares (SEM-PLS). Results show all workers experience fatigue, with physical fatigue affected by age and gender and mental fatigue influenced by workload. The outer model analysis confirms convergent and discriminant validity, as well as the reliability of the constructs. The inner model analysis reveals the work system significantly affects fatigue while the process does not. The study emphasizes the importance of addressing fatigue to improve worker well-being and enhance patient care in the ER, providing actionable insights for healthcare organizations.

INTRODUCTION

Hospitals are vital pillars within the healthcare ecosystem, delivering indispensable health services to communities. Yet, the demanding nature of healthcare environments, particularly in settings like the Emergency Room (ER), can subject healthcare workers to significant fatigue. This physical or mental fatigue poses substantial risks to healthcare professionals' performance and well-being and can ultimately compromise patient care (Søvold, Naslund, Kousoulis, Saxena, Qoronfleh, & Münter, 2021). Physical fatigue manifests as a reduced work capacity, while mental fatigue can impair concentration and attention, ultimately impacting work speed and accuracy (Karim et al., 2024). In light of the complexities presented, it is imperative to confront the issue of fatigue within healthcare environments to safeguard the integrity and quality of care delivered. Consequently, this investigation commits to a concentrated endeavor to amplify the efficacy of health service provision, focusing on the Emergency Room (ER). The research adopts objective methodologies to quantify physical and mental fatigue among healthcare professionals to embark on this initiative. Physical fatigue is measured by assessing cardiovascular load percentage (%CVL), gauging the physiological demands placed on employees (Dias et al., 2023). Concurrently, mental fatigue is appraised via the Bourdon-Wiersma test, which provides a metric for evaluating concentration, attention span,

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and operational tempo (Shwe, Win-Thu, & Mar, 2020). The study utilizes Cardiovascular Load (%CVL) as a scientifically validated measure for assessing physical fatigue, particularly relevant in high-stress environments such as the Emergency Room (ER). CVL is widely recognized in ergonomics and occupational health research as a reliable indicator of physiological strain, reflecting the cardiovascular demands placed on an individual during work activities. This measure allows for quantifying physical workload by analyzing heart rate responses, providing a concrete, objective assessment of fatigue levels. For healthcare workers in ER settings, where rapid physical responses and endurance are critical, CVL serves as a precise tool for understanding the physical demands imposed on staff and highlights areas where interventions may reduce excessive strain.

Additionally, the study incorporates the System Engineering Initiative for Patient Safety 2.0 (SEIPS 2.0) framework into its research design, ensuring a holistic approach to understanding and mitigating fatigue within healthcare settings (Steege, Pasupathy, & Drake, 2018). Addressing the issue of fatigue among healthcare workers in the Emergency Room (ER) is of utmost importance due to its direct implications for patient safety. Fatigue can impair decision-making, reduce reaction times, and compromise the quality of care provided, all of which are critical in the high-stakes, fast-paced environment of the ER. By focusing on this prevalent issue, this research aims to provide actionable insights that improve healthcare worker well-being and ensure safer, more effective patient care. This study, therefore, underscores the critical role of addressing fatigue as a fundamental component of enhancing patient safety in emergency healthcare settings.

The SEIPS 2.0 model organizes the work system by separating individuals and teams, differentiating between personal and organizational factors, and recognizing the impact of both internal and external environments. This approach highlights the significance of hierarchical relationships in healthcare, as noted by Werner et al. (2020), and underscores the interconnectedness of various levels within healthcare systems. Events or conditions at one level, such as a clinical unit or a patient's home, can be influenced by factors at both higher levels (e.g., the culture of the organization or community) and lower levels, e.g., the skills of individuals or teams (Braithwaite, Herkes, Ludlow, Testa, & Lamprell, 2017). Efforts in this direction have begun to explore the complex interplay of factors across different levels, highlighting the importance of considering cross-level and multi-level effects in healthcare human factors research (Wang, Liu, & Ye, 2023). SEIPS 2.0 represents a sophisticated human factors and ergonomics framework tailored to analyze and optimize healthcare systems and worker performance(Purchase, Bowie, Hibbert, Krishnan, & Carson-Stevens, 2023). Utilizing the SEIPS 2.0 model, this study provides a holistic and comprehensive analysis of the factors contributing to fatigue among healthcare professionals in the Emergency Room (ER). By examining a wide range of influences, from organizational structures to individual behaviors, the model helps researchers identify the root causes of fatigue, enabling the development of targeted interventions to improve worker well-being and patient care quality (Søvold, Naslund, Kousoulis, Saxena, Qoronfleh, Grobler, et al., 2021). Incorporating data collection through surveys and employing Structural Equation Modeling-Partial Least Squares (SEM-PLS) for data analysis, the study leverages empirical evidence to validate the SEIPS 2.0 framework. This approach allows for a detailed understanding of the interplay between various factors and their impact on fatigue levels. It prioritizes interventions and resource allocation to mitigate fatigue and optimize healthcare delivery in these crucial environments.

The primary objective of this research is to tackle the pressing issue of healthcare worker fatigue in high-stress environments, particularly in Emergency Rooms (ERs), where fatigue critically affects patient safety. ERs are characterized by intense demands, with time-sensitive and physically taxing tasks that increase the likelihood of fatigue among healthcare workers. This study focuses on a hospital ER, an ideal setting due to its high acute cases and intense operational demands. It targets healthcare professionals like doctors, nurses, and support staff who experience significant physical and mental workloads. A representative sample of these workers was selected to ensure the study accurately reflects their experiences. The research employs the System Engineering Initiative for Patient Safety (SEIPS 2.0) model, a comprehensive framework for understanding healthcare work systems and their impact on worker performance and safety outcomes. This model identifies fatigue-related factors such as workload, environmental conditions, tools and technologies, and organizational policies. By evaluating these components, SEIPS 2.0 facilitates actionable solutions to enhance resilience and optimize patient safety through systemic interventions. Beyond immediate improvements in ER settings, the findings have broader implications for healthcare management. Addressing fatigue can reduce burnout and turnover, providing strategic insights for sustainable work environments prioritizing healthcare worker well-being and patient care quality.

METHOD

This study involves 30 healthcare workers from a hospital's Emergency Room (ER) in Malang, representing the entire ER staff. The sample allows for a comprehensive assessment of fatigue factors in this high-intensity environment. Data were collected through direct observation, including heart rate measurements for Cardiovascular Load (CVL), Bourdon Wiersma test results for mental workload, and Likert-scale questionnaires based on the SEIPS model. Ethical clearance was obtained from the University of Muhammadiyah Malang (No. 1/P2M-HDL/FT-UMM/VII/2022).

The research systematically assesses fatigue levels and associated risks using scoring metrics. Physical fatigue is evaluated with %CVL, while mental fatigue is measured using the Bourdon Wiersma test. These methods provide insights into fatigue severity and highlight safety risks, as reduced alertness and slower response times in ER settings can jeopardize patient care.

This assessment of physical fatigue is done by gathering heart rate data to compute the %CVL, which helps determine fatigue levels based on the %CVL equation (Lee, Moon, Choi, & Jang, 2020). Mental fatigue is evaluated using the Bourdon Wiersma test (I. K. Widana, Sumetri, Sutapa, & Suryasa, 2021), which measures the health worker's reaction time, precision, and consistency. Following the fatigue assessment, the research applies the SEIPS 2.0 framework to analyze the significance of various obstacles contributing to health workers' fatigue during service. This analysis involves distributing surveys that include Likert scale questions regarding their views on the obstacles associated with each SEIPS model subfactor identified within the ER, as detailed in the table (Werner et al., 2020). The questionnaire's fatigue indicators are correlated with the fatigue level evaluation metrics: heart rate (Y1), focus (Y2), response time (Y3), and steadiness (Y4). The SEIPS 2.0 model was applied in this study to analyze work system components influencing fatigue among healthcare

Table 1. Factors and Subfactors on Health Worker Fatigue Using the SEIPS 2.0 Model

SEIPS Factor 2.0	SEIPS 2.0 Subfactor	Subfactor Description
Work system (X1)	Patients (X1.1)	Non-communicative patients contribute to health workers' fatigue. Insufficient rest time also exacerbates their fatigue.
	Health workers (X1.2)	Insufficient rest time also exacerbates their fatigue.
	Nursing tasks for the patients (X1.3)	The responsibility of interacting and communicating with patients' families places additional stress on health workers, contributing to their exhaustion.
	Tools and Technology (X1.4)	Inefficient tools further strain health workers, leading to increased fatigue.
	Organization (X1.5)	Fixed working hours on weekends and a lack of rotating shifts wear down health workers.
	Internal Environment (X1.6)	Excessively warm room temperatures make conditions uncomfortable for health workers, adding to their fatigue
	External Environment (X1.7)	The extensive commute from their homes to their place of work further burdens health workers, affecting their overall fatigue levels.
Process(X2)	Physical Work Processes (X2.1)	Physical work processes influence health workers' fatigue levels.
	Cognitive Work Processes (X2.2)	The mental workload from work processes also plays a significant role in the fatigue experienced by health workers.
	Social/Behavioral Work Processes (X2.3)	Work processes involving social interactions among health workers impact their fatigue levels.

workers systematically. It facilitated identifying and assessing key factors contributing to physical and mental fatigue, including patient interactions, workload, and workplace environment. The model categorizes work system and process components into specific subfactors, providing a structured framework for pinpointing areas that require intervention to mitigate fatigue effectively.

The data are analyzed using SmartPLS software. First, a model illustrating the variables is constructed, as shown in Figure 1. SEM-PLS testing identifies the key factor contributing to fatigue. A T statistic above 1.96 or a p-value below 0.05 signifies a significant relationship between variables (Devyani & Meria, 2023). The strength of these relationships is measured through path coefficients ranging from -1 to 1; values near the extremes indicate stronger correlations, while those near zero imply weaker ones (Cesana, 2018). The factor with the highest path coefficient is targeted for improvement, aiming to streamline processes and achieve better outcomes. The collected data is analyzed to detail the results for each factor and subfactor within the SEIPS 2.0 model in a descriptive narrative format. The study concludes by addressing its objectives and providing recommendations, offering insights for the research site, and guiding future studies to enhance subsequent research efforts.

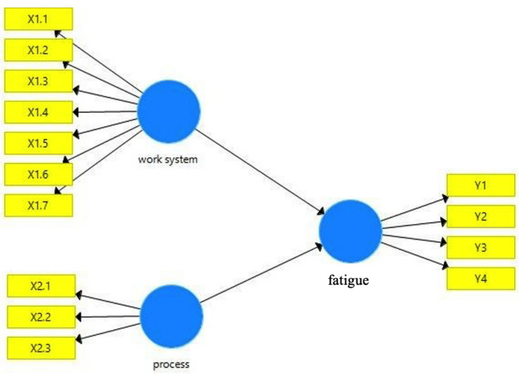

Figure 1. Conceptual framework

RESULT AND DISCUSSION

Measurement of Cardiovascular Load (%CVL)

The assessment of physical workload using the Cardiovascular Load (CVL) method involves collecting essential data, including each healthcare worker's work pulse, resting pulse, age, and gender. Work pulse measurements are taken at 1:00 PM (morning shift), 4:00 PM (afternoon shift), and 10:00 PM (night shift), while resting pulse data is recorded at 6:30 AM (post-night shift), 7:30 AM (morning shift), and 2:30 PM (afternoon shift). Analysis of %CVL from 30 healthcare workers in the emergency room indicates that 80% require improved workload management, while 20% fall into the "Short Time Work" category, with all %CVL values exceeding 30%. The respondent with the lowest %CVL recorded 37.19%, indicating the least cardiovascular strain, while the highest %CVL reflects the most significant cardiovascular burden. The average %CVL tends to increase with age, and female healthcare workers show a higher average %CVL than their male counterparts. These findings highlight the need for targeted interventions to improve workforce efficiency and reduce physical strain on healthcare workers.

Age influences work fatigue through its effects on physical resilience and work capacity (Fisher, Chaffee, Tetrick, Davalos, & Potter, 2017). Younger individuals generally have more incredible stamina for demanding tasks, while older individuals experience reduced capacity, leading to quicker fatigue onset (Caldwell, Caldwell, Thompson, & Lieberman, 2019). Female health workers tend to report more fatigue than males, attributed to differences in body size, muscle mass, and hormonal factors (Hunter, 2016). For example, a 42-year-old female respondent may experience higher cardiovascular strain due to age-related decline and gender-specific physiological factors despite performing similar tasks (Van Dyck, 2021).

Bourdon Wiersma Test

The Bourdon Wiersma test evaluates mental workload in tasks requiring precision, quick reactions, consistency, and handling monotony (I. Widana, Sumetri, & Sutapa, 2020). Health workers identify and mark sets of four dots from dot groups across 30 rows, assessing reaction time, accuracy, and constancy (Steinborn, Langner, Flehmig, & Huestegge, 2018). Reaction time and constancy are measured by row processing time, while accuracy is based on missed or incorrect markings. Results show an average reaction time of 17.45 seconds, accuracy at 24.7, and constancy at 27 seconds, all scoring in the "Doubtful" or "Less" categories, indicating fatigue and the need for improvements.

The study reveals significant trends in healthcare workers' cognitive and physical performance with age. Reaction times tend to lengthen, errors increase, and work consistency decreases among aging health workers, with female workers showing longer reaction times than males. Peak physical performance, which is typically achieved in the mid-20s, declines with age, reducing physical and mental capabilities. This decline impacts life activities and bodily functions, with men generally exhibiting higher productivity levels than women, partly due to differences in physical (Mayer & Rathmann, 2018). Women, with about two-thirds the muscular strength of men, may show greater carefulness in some scenarios (Roberts, Gebhardt, Gaskill, Roy, & Sharp, 2016). However, biological cycles can still heighten fatigue levels and affect their psychological and physical state (Gallagher & Schall, 2020).

Metrics like Reaction Time, Errors, and Consistency further highlight cognitive differences. Reaction times varied from 11.27 to 22 seconds, errors ranged from 10 to 38, and consistency scores spanned from 6.95 to 76.71, reflecting diverse cognitive adaptability and attention levels (Karvelis, Paulus, & Diaconescu, 2023). Such variability underscores the complex nature of cognition and its impact on work performance in high-stress environments like the Emergency Room (ER).

Using %CVL (Cardiovascular Load) and the Bourdon Wiersma test, the study confirmed that all respondents experience physical and mental fatigue. These findings underscore the impact of ER demands on health workers' well-being and highlight the urgent need for interventions to reduce fatigue, ensuring better performance and health outcomes.

Partial Least Square Analysis – Structural Equation Modeling (PLS-SEM)

Following the establishment of fatigue among health workers serving in ER through %CVL calculations and the Bourdon Wiersma test, the study progressed to employing the SEIPS 2.0 model with the SEM-PLS (Partial Least Squares Structural Equation Modeling) method to identify the factors contributing to health workers' fatigue.

Table 2 presents the outer loading values for each indicator associated with Fatigue, Process, and Work System constructs. These values demonstrate convergent validity, as all indicators exceed the threshold of 0.7, confirming that the indicators strongly represent their respective constructs. This step validates that each indicator reliably measures the intended variable, a crucial initial step in SEM-PLS analysis to ensure that the measurement model is robust. All variables X and Y demonstrate strong convergent validity as their values exceed 0.7(Abma, Rovers, & van der Wees, 2016). The results indicate that the outer loading for each variable surpasses the 0.7 threshold, confirming their robust convergent validity.

Table 2. Sample Outer Loading Results

	Fatigue	Process	Work System
X1.1			0.737
X1.2			0.715
X1.3			0.842
X1.4			0.894
X1.5			0.901
X1.6			0.862
X1.7			0.882
X2.1		0.919	
X2.2		0.891	
X2.3		0.973	
Y1	0.839		
Y2	0.81		
Y3	0.898		
Y4	0.78		

Table 3. Results of Average Variance Extracted

	Average Variance Extracted
Fatigue	0.694
Process	0.861
Work system	0.7

Table 3 shows the Average Variance Extracted (AVE) values for each construct, with all values exceeding the threshold of 0.5. This result supports convergent validity across the constructs, indicating that each construct explains a substantial portion of the variance in its indicators. An AVE above 0.5 further assures that the indicators within each construct accurately capture the variance, minimizing measurement error. The threshold for declaring reliability through Average Variance Extracted (AVE) is a minimum of 0.50 (Cheung, Cooper-Thomas, Lau, & Wang, 2024)ote>. An AVE value under 0.50 suggests that the indicators predominantly reflect measurement error. According to the data in Table 3, all variables have an AVE value greater than 0.5, indicating a strong convergent validity across the research variables.

Table 4. Cross Loading

	Work System	Process	Fatigue
X1.1	0.737	0.223	0.290
X1.2	0.715	0.247	0.281
X1.3	0.842	0.405	0.329
X1.4	0.894	0.441	0.576
X1.5	0.901	0.531	0.469

X1.6	0.862	0.411	0.448
X1.7	0.882	0.529	0.369
X2.1	0.391	0.919	0.118
X2.2	0.363	0.891	0.197
X2.3	0.525	0.973	0.461
Y1	0.318	0.299	0.839
Y2	0.467	0.195	0.810
Y3	0.482	0.311	0.898
Y4	0.355	0.408	0.780

Table 4 details the cross-loading values for each indicator across the Work System, Process, and Fatigue constructs. The table supports discriminant validity by showing that each indicator correlates more highly with its respective construct than others. This finding confirms that each construct is distinct, providing evidence that the model variables are adequately differentiated, a key requirement for accurate structural modeling.

Table 5. Fornell Larcker Results

	Fatigue	Process	Work System
Fatigue	0.833		
Process	0.362	0.928	
Work system	0.495	0.491	0.836

Table 5 provides the Fornell-Larcker criterion results, with diagonal values representing each construct's square root of the AVE. According to the criterion, these diagonal values should exceed the inter-construct correlations to achieve discriminant validity. This table confirms that all constructs in the model meet the discriminant validity criteria, indicating that each construct is unique and does not overly share variance with other constructs.

The Cronbach's Alpha analysis results demonstrate the reliability of the constructs used in this study. The fatigue construct has a Cronbach's Alpha value of 0.852, indicating strong internal consistency. Similarly, the process and work system constructs are reliable, with Cronbach's Alpha values of 0.932 and 0.928, respectively. These results confirm the robustness of the measurement instruments used for assessing the constructs in the study.

The composite reliability analysis reveals the reliability levels of the constructs used in the study. The fatigue construct achieves a composite reliability value of 0.862, indicating high reliability. The process construct shows an unusually high composite reliability value of 1.515, which may suggest potential measurement issues requiring further investigation. Meanwhile, the work system construct demonstrates excellent reliability with a composite reliability value of 0.961. These results highlight the robustness of the work system and fatigue measurements while suggesting a need for closer scrutiny of the process construct's measurement validity.

The Fatigue construct has an R^2 value of 0.264, indicating that the Work System and Process variables explain 26.4% of its variance. This result suggests a weak influence, as R^2 values above 0.75 indicate a strong effect, 0.5–0.74 a moderate impact, and 0.25–0.49 a weak effect (Purwanto & Sudargini, 2021). The Path Coefficient values range from -1 to 1, with higher values indicating stronger correlations. For the Work System, the Path Coefficient is 0.418, showing a moderate positive correlation, while the Process has a weaker positive correlation at 0.157 (Piumatti, Magistro, Zecca, & Esliger, 2018). These findings, derived from the SmartPLS Bootstrapping Report, provide insights into the relationships between the variables and their contributions to fatigue.

The analysis results indicate that the work system significantly affects fatigue, supported by a T statistic of 2.339 and a P-value of 0.020. This finding demonstrates that the work system plays a meaningful role in influencing fatigue levels among healthcare workers. Conversely, the process variable does not significantly affect fatigue, with a T statistic of 0.728 and a P-value of 0.467. These findings suggest that while the work system substantially contributes to fatigue, the process does not have a notable impact, highlighting the need to improve work system elements to address fatigue effectively.

The SEM-PLS structural model highlights the Work System's positive path coefficient (0.418) with Fatigue, emphasizing its critical role. The bootstrapping results validate this, with a P-value of 0.008 and a T-statistic of 2.339. An R^2 value of 0.264 indicates that 26.4% of the variance in Fatigue is explained by the Work System and Process variables, underscoring the importance of targeted interventions, particularly in the Work System subfactors defined by the SEIPS 2.0 model. (Bethel, Rainbow, & Johnson, 2022).

This study explored the relationship between work system variables and fatigue levels among healthcare workers using the SEIPS 2.0 model, which is well-suited for examining complex, multifaceted interactions in healthcare settings. Based on the results of calculations using the SEM PLS model, these seven sub-factors significantly influence health worker fatigue.

Patient

When examining the patient factor in healthcare delivery, it is essential to consider the unique challenges and dynamics that patients contribute to the healthcare system. A patient is broadly defined as an individual seeking health consultation to receive necessary services, directly or indirectly, in a hospital setting. This definition includes a diverse individual group with varying needs, expectations, and personal circumstances that influence their care journey.

A significant challenge within the patient factor is the variability in health literacy, which impacts patients' understanding of their conditions and ability to interpret symptoms, follow treatment plans, and participate actively in care (Nutbeam & Lloyd, 2021). Emotional and psychological states, which are shaped by health conditions, can further influence patient interactions with healthcare providers and their treatment experiences (Franklin, Lewis, Willis, Bourke-Taylor, & Smith, 2018).

Socioeconomic factors also significantly affect access to healthcare services. Economic limitations, lack of insurance, and geographic barriers can delay care, leading to health disparities (Xesfingi & Vozikis, 2016). Additionally, cultural and language differences may impede communication, reducing care effectiveness and patient satisfaction (Al Shamsi, Almutairi, Al Mashrafi, & Al Kalbani, 2020). In this case, a patient-centered approach is essential to address these challenges. Healthcare systems must enhance communication, adapt care to individual patient contexts, and improve accessibility to promote equitable and effective healthcare experiences (Kwame & Petrucka, 2021)

Health Workers

The challenges faced by health workers are both external and internal, stemming from the inherent demands of their profession. A significant internal challenge is the expectation for health workers to consistently perform at their peak, adversely affecting their rest and sleep hours (Mélan & Cascino, 2022). The Vital Patient Treatment unit, a critical hospital operation, further reduces health workers' rest time due to its intense demands. The high workload in emergency environments also heightens stress levels, increasing the risk of burnout syndrome (Gualano et al., 2021).

Health workers in ER teams also face daily ethical dilemmas while striving to provide professional care, highlighting their roles' psychological and emotional demands (Wolf et al., 2016). The commitment to high service standards often requires shift work, contributing to sleep disorders. Insufficient sleep and poor sleep quality impair health workers' performance, jeopardizing patient safety and well-being (Magnavita & Garbarino, 2017).

A study by James, Honn, Gaddameedhi, and Van Dongen (2017) revealed that night shifts and job stress are linked to sleep deprivation, reduced physical activity, and increased cardiometabolic risks among healthcare workers. Sleep issues remain a critical societal concern, disproportionately affecting the healthcare sector.

Nursing Tasks for the Patients

The challenges associated with nursing tasks encompass a diverse range of nurses' duties, each varying in difficulty, complexity, and uncertainty (Sekse, Hunskår, & Ellingsen, 2018). This study will explore nurses' specific responsibilities for critically ill patients within the critical care system. It will also examine task assignment and delegation processes to provide a comprehensive understanding of nursing care delivery models.

Based on this foundation, the investigation will highlight the multifaceted nature of nursing responsibilities, focusing on the technical, medical, organizational, and interpersonal aspects that shape effective care delivery. The study aims to unravel the intricate framework within which nursing care operates by analyzing who performs specific tasks and who holds responsibility for delegation.

This holistic approach is essential for identifying strategies to enhance patient care and optimize nurses' roles within the healthcare system (Himmelfarb, Commodore-Mensah, & Hill, 2016). Understanding the dynamics of task execution and delegation improves care outcomes and strengthens nursing's integral contribution to the healthcare ecosystem.

Tools & Technology

Tools and technologies are essential for improving patient care, with usability, accessibility, and functionality being key evaluation factors (Aceto, Persico, & Pescapé, 2018). Despite their importance, healthcare workers often face challenges in practical application, encountering tools that malfunction or fail to perform as required, which can hinder medical procedures (Bowsher et al., 2021). In emergencies, public and private healthcare facilities must provide life-saving services that prevent disabilities. These services rely on medical and non-medical equipment that must meet high quality, safety, and security standards. Additionally, all equipment must comply with legal requirements, including proper distribution permits, to ensure effective and safe patient care (Baker & Xiang, 2023).

Organization

Organizations function as structures coordinating time, space, resources, and activities, operating independently of the individuals who establish them. Key organizational factors include task assignments, patient load complexity, and methods for allocating care responsibilities (Yinusa & Faezipour, 2023). Other critical elements are work schedules, availability of resources like personal protective equipment and ventilators, management practices, incentives, and policies for patient care (Buheji & Buhaid, 2020). One significant issue is the policy governing work shifts. Healthcare workers often experience fatigue due to heavy workloads, disrupted sleep, and irregular circadian rhythms caused by shift work (Caldwell et al., 2019). Shifts typically include night shifts (21:30–07:00), day shifts (14:30–21:00), and morning shifts (07:30–14:00). However, shift allocation often ignores best practices, with some workers scheduled for more than five consecutive days, including weekends, without rotation. This poor distribution contributes to widespread fatigue, especially among night-shift workers.

Internal Environmental

The internal workplace environment, including layout, noise, temperature, and lighting, greatly influences patient experiences and healthcare workers' satisfaction (Eijkelenboom & Bluyssen, 2022). Physical conditions such as temperature, noise, lighting, and air quality are vital for optimizing performance (Appel-Meulenbroek, Le Blanc, & de Kort, 2019). Excessive heat can cause fatigue and impair focus, affecting procedural efficiency. Adequate lighting boosts morale, reduces errors, and minimizes eye strain (Caldwell et al., 2019). Noise, often disruptive, should not exceed 85 dB. The optimal temperature range of 18–28°C supports worker well-being, ensuring a productive and safe environment that enhances patient care quality (Al Horr et al., 2016).

External Environmental

External factors such as societal trends, economic conditions, and policy changes significantly influence the work system (Esmailzadeh, Noori, Nouralizadeh, & Bogers, 2020). Organizations must consider these factors, including demographic shifts, public health priorities, funding fluctuations, and regulatory standards, to adapt their workforce strategies effectively (Figueroa, Harrison, Chauhan, & Meyer, 2019). The interplay between external and internal dynamics requires healthcare leaders to implement flexible, adaptive strategies to maintain high-quality care and support employee well-being (Onwujekwe et al., 2019).

Using the SEIPS 2.0 model, this study identifies work system components that significantly contribute to fatigue among healthcare workers in ERs. Improvements to the work system can enhance care quality, reduce burnout, and improve hospital efficiency. Physical fatigue, measured by Cardiovascular Load (%CVL), shows high exhaustion levels among staff, while mental fatigue, assessed via the Bourdon Wiersma test, reveals cognitive strain affecting concentration and decision-making. These findings underscore the need for targeted interventions to manage physical and mental fatigue, benefiting healthcare workers and organizational outcomes.

Implications for Practice

The findings of this study, mainly through ER visits and the application of the SEIPS 2.0 model, emphasize the importance of understanding interactions beyond traditional system boundaries. The SEIPS 2.0 concept of configuration is a critical tool for identifying key work system elements that facilitate care transitions, stressing the need for research tools to capture these dynamic interplays. Establishing trust and a non-punitive environment is essential in improving healthcare quality and safety (El-Sayed, Asal, Abdelaliem, Alsenany, & Elsayed, 2024). Encouraging open dialogue and reporting without fear of blame fosters a safety culture (Dekker, 2016), enabling healthcare staff to collaboratively identify and address systemic issues.

Shifting from individual blame to a systemic approach significantly enhances error prevention and promotes continuous learning (Spurgeon, Sujan, Cross, & Flanagan, 2019). This shift calls for healthcare organizations to implement frameworks that view healthcare as a complex system involving diverse contributors, including patients. Leadership must champion a culture of safety, trust, and open communication to address systemic issues effectively (Tan, Pang, Siau, Foo, & Fong, 2019). Applying the SEIPS 2.0 model to manage healthcare worker fatigue supports healthier and more productive work environments, improving worker performance and patient care quality. These strategies are crucial for sustainable hospital operations and fostering resilience across healthcare systems.

CONCLUSION

This study aimed to assess the physical and mental fatigue experienced by healthcare workers in the Emergency Room (ER) and to identify key factors contributing to this fatigue through the SEIPS 2.0 model and SEM-PLS analysis. The findings reveal that all ER health workers experience substantial physical and mental fatigue. Physical fatigue, as measured by the Cardiovascular Load (CVL) calculation, showed a %CVL above 30%, indicating widespread physical exhaustion among workers. Mental fatigue was assessed via the Bourdon Wiersma test, with results indicating areas needing improvement in reaction times, accuracy, and consistency—underscoring the need for targeted interventions.

Using the SEIPS 2.0 model and SEM-PLS method, this study identified the work system—encompassing patient interactions, health worker roles, nursing tasks, tools and technology, organizational structures, and environmental factors—as a significant contributor to healthcare worker fatigue. The model yielded a path coefficient of 0.418, with statistical significance supported by a P-value of 0.008 and a T-statistic of 2.339, highlighting the relevance of these factors in predicting fatigue levels.

Based on these insights, this study recommends several targeted interventions to mitigate fatigue and promote a sustainable work environment. Recommendations include enhanced communication training to improve patient and family interactions, strict adherence to work hours to ensure adequate rest, regular preventive maintenance of equipment, implementation of standard operating procedures (SOPs) for tool use to provide only trained personnel operate equipment, minimizing schedule deviations from regular shifts, and optimizing the physical environment through controlled room occupancy, temperature adjustments, and managed lighting to reduce heat exposure. These strategies are intended to foster a work environment that supports the well-being and efficiency of health workers, ultimately enhancing patient care and safety.

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