

Subjective Mental Workload Profile and Human Error Probability in Nurses: A Cross-sectional Analytical Study

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Abstract

Aim: Medical errors cause serious and often preventable injuries to patients. This study aimed to identify and evaluate human errors to reduce their risk and its relationship with the subjective mental workload (SMWL) in nursing staff using the human error assessment and reduction technique (HEART). **Methods:** This cross-sectional analytical study was performed in one of the hospitals of Rafsanjan in Iran. First, task analysis was performed using the hierarchical task analysis method and nurses' tasks were determined. Next, the human error probability (HEP) during the work for all tasks was determined with the HEART method. Finally, the factors and conditions that were effective in causing the errors were determined. Employees' SMWL was also determined using the NASA-TLX index. **Results:** The mean \pm standard deviation (SD) HEP score for nurse's tasks was 1.79 ± 3.44 . Results indicated a significant direct correlation between SMWL and HEP scores ($r^2 = 0.893$, $P < 0.0001$). In addition, the mean rank of SMWL varied significantly across different human error groups based on the type of public duty ($P < 0.001$), indicating higher SMWL reported for tasks with elevated human error scores. **Conclusion:** The SMWL among the examined nurses was elevated, and it further increased during night shifts. In addition, there was a heightened HEP in certain nursing tasks. Given the increased SMWL and the potential for errors in complex tasks, it is crucial to prioritize that these responsibilities and implement control measures aimed at reducing the SMWL of the healthcare staff.

Keywords: Employee workload, human error assessment and reduction technique method, medical errors, mental health, nurses

INTRODUCTION

In daily work, individuals encounter various harmful factors, including chemicals, physical elements, and ergonomic/psychological stressors. Exposure to these can lead to complications and diseases such as depression, respiratory issues, musculoskeletal disorders, physiological disorders, and cancer.^[1-5] Ergonomics, coordinating physical and psychological aspects with the work environment, is vital for optimal performance. Balancing the physical, psychological, and work environment within the organization is key for employees to achieve desirable performance.^[6] A central focus in ergonomics is preventing human error, deemed the primary cause of unsafe behaviors and accidents.^[7,8]

Scientifically, the error is defined as a deviation from conditions reducing work accuracy, representing the gap between one's mental perception and the objective reality. This disparity leads

to errors in work and decision-making; hence, minimizing the gap reduces errors.^[8] Other studies reveal that human error contributes significantly to accidents, accounting for 90% of them.^[9] A critical focus is on medical errors, recognized globally for imposing substantial costs on societies. Occupations in healthcare, due to their sensitivity and importance, highlight the severity of even seemingly minor mistakes, potentially resulting in fatalities. Medical errors are broadly defined as deviations from physician instructions.^[8] Research on medical

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errors reveals their occurrence among physicians, nurses, and other health-care workers. It has been found that 70% of medical errors are preventable, 6% are probably preventable, and 24% are not preventable.^[10] According to the World Health Organization, physicians experience human errors in one out of 10 patients.^[11] Furthermore, studies have found that medical errors in Iranian hospitals vary from 0.06% to 42%, with certain cases surpassing the global average.^[12]

Key causes of human error in nurses include work complexity, environmental stress, fatigue, environmental conditions, experience, education, and personality.^[13] Additional factors contributing to medical errors in nurses encompass insufficient in-service training, burnout, stress, high subjective mental workload (SMWL), and poor communication among health-care professionals.^[14] SMWL significantly impacts employee behavior, performance, efficiency, and productivity in work environments.^[15] The combination of practical and mental work can result in poor mental processing and reduced mental work performance in nurses.^[16] Increased SMWL, along with extended working hours, are key factors leading to fatigue. Consequently, fatigue contributes to reduced efficiency, impaired thinking processes, heightened risk of human error, and the adoption of risky behaviors, such as taking shortcuts.^[17]

An overview of national and international texts on human errors reveals a limited focus on studying this issue in hospital settings, particularly among nursing jobs.^[18] Due to the lack of studies in this field, the present study was conducted with the aim of quantifying medical errors using the human error assessment and reduction technique (HEART) method, determining SMWL, and investigating the relationship between SMWL and human error probability (HEP) in nurses. We hypothesized that the SMWL of nurses is high and can lead to an increase in HEP in them.

MATERIALS AND METHODS

Study design

This cross-sectional analytical study was conducted in Iranian hospitals. In this study, we examined the relationship between SMWL and HEP in the form of an analytical approach.

Setting

In this study, hospital nurses in Rafsanjan City, Iran, were invited to participate. The specialized hospital, with 400 active beds and around 1100 staff members, had the largest occupational population of 600 nurses. The samples for this study were specifically selected from among the nurses.

Participants

The participants were those nurses with at least one-year of work experience, people with normal general health and no mental problems during the study. The general health of nurses was measured using the general health questionnaire (GHQ), and those who scored higher than 23 were included in the study as normal healthy people. The GHQ, composed of 12- or 28-item, is a self-report instrument to measure for

symptoms of psychological well-being and stress.^[19] It has been translated and validated in at least two languages in addition to English, including Spanish and Persian. People who had mental problems during the study (due to the death of relatives, family problems, etc.) were excluded from the study. In a study conducted by Sarsangi *et al.*,^[20] the mean (standard deviation [SD]) SMWL in Iranian nurses was reported as 68.2 (16). Based on this, the sample size was calculated with a SD of 16 at a confidence level of 95% and accuracy of 3 score as Equation 1.

$$N = \frac{(Z_{1-\frac{\alpha}{2}})^2 \times \delta^2}{d^2} \rightarrow N = \frac{1.96^2 \times 16^2}{3^2} \approx 110 \quad (1)$$

Finally, considering the entry and exit criteria, 107 people were examined in this study. Participants were selected using a simple random sampling technique. For this purpose, first, the people who met the inclusion criteria were identified and a code was assigned to each of them. Then, the samples were selected by lottery.

Data collection

Demographic and occupational characteristics

To determine the demographic and occupational characteristics including gender, age, height, weight and work experience of employees, a researcher-made checklist was used and the desired variables were collected using this checklist through face-to-face interviews.

Task analysis

To determine the duties and subduties of nursing jobs and break the job, the hierarchical task analysis (HTA) method was used and the processes in this job were analyzed into related tasks and subtasks. This method was first proposed by Annett in 1971 and later developed by other researchers. In the HTA method, all job tasks are divided into a set of subtasks in a hierarchical process. The final goal is considered and to achieve it, the task is divided into smaller components.^[21,22]

Determining the human error probability

To evaluate the HEP in the nurses, the HEART technique was used. This method was introduced in 1985 by Williams in England.^[23] This method is designed as a relatively fast method for assessing human reliability. In this method, it is assumed that human reliability essentially depends on the nature of the task being performed. In HEART, 9 generic task types (GTT) are identified and assigned figures and ranges as human uncertainty. These mentioned groups come along with 38 EPCS. Finally, a set of error-reduction strategies to deal with the situations that create the most impact is presented. After identifying the EPCS, the analyst assigns a value of 0–1 to each, and then all the values are put into a formula and the HEP is determined.

In the present study, after determining the job duties by the method of HTA, GTT, and the general error probability (GEP)

for each type of task were determined. EPCS were then determined for each task. Then, for each EPC, its effect ratio was determined, which includes a numerical determination between 0 and 1. The calculations were then performed to determine the evaluated effect for each EPC, and finally, the HEP was determined using Equation 2.

$$\text{HEP} = \text{Evaluated Impact} \times \text{GEP} \quad (2)$$

Determining the subjective mental workload

The present study utilized the NASA-TLX method to gauge the mental workload among the employees under examination. Originally developed by NASA to assess SMWL, the NASA-TLX questionnaire evaluates the mental workload applied to individuals across various tasks.^[24] It serves as a multidimensional assessment tool, aiming to measure the volume and perceptual pressure associated with specific tasks, activities, systems, team efficiency, or other performance aspects. The method divides the total workload into six subscales: mental demand, physical demand, temporal demand, performance, effort, and frustration level. Through this assessment, individuals' overall susceptibility to high SMWL is evaluated. The score that can be achieved in this method is between 0 and 100. A lower score indicates a lower mental workload and vice versa.^[24] The final score of SMWL was classified into four groups (very high >75, high = 51–75, average = 25–50, and low <25). In the present study, nurses were first asked to report their overall SMWL separately for morning and night shifts separately. In the next step, after determining the duties of nurses and determining the type of task according to the HEART method, nurses were asked to report their SMWL separately when performing each task and to state that what SMWL they perceive, separately.

Data analysis

SPSS v. 18 (SPSS Inc. Chicago, Delaware, USA) software was used to analyze the data. Shapiro–Wilk test was used to evaluate the normality of the data. Wilcoxon nonparametric statistical test was used to compare the mean score of HEP between different tasks (GTT). The Kruskal–Wallis test was used to compare the rank of SMWL in different groups of human error based on the GEP. Pearson correlation test was used to investigate the relationship between SMWL and the HEP. A significance level of 95% ($\alpha = 0.05$) was used for the tests.

RESULTS

Demographic characteristics of employees are presented in Table 1. 67 (62.6%) of the employees were men and 40 (37.4%) were women.

The results of the HTA, GTT, GEP score, and HEP score are presented in Table 2. The results showed that a total of 26 main tasks for the nursing job can be determined. The results related to the type of task (GTT) showed that out of 26 determined tasks using the HTA, 10 tasks (38.5%) are type C. After that, the highest percentage of type E tasks was determined with

Table 1: Descriptive results of personal characteristics of the studied employees

Variables	Average \pm SD	Minimum	Maximum
Age (years)	38.35 \pm 6.61	24.00	54.00
Weight (kg)	75.36 \pm 13.22	46	110
Height (cm)	171.89 \pm 9.02	155	195
Work experience (years)	7.31 \pm 4.98	1	20
BMI	25.41 \pm 3.38	17.96	36.00

BMI: Body mass index, SD: Standard deviation

27% (7 tasks). Furthermore, 23% of the tasks (6 tasks) were type of D tasks. The lowest number of tasks was related to type G tasks with 11.5% (3 tasks).

The mean \pm SD of HEP score was determined to be 1.79 \pm 3.44. The highest HEP was related to the task of adjusting and using DC shock in emergency cases (HEP = 14.48). The lowest HEP was determined for the skincare task (HEP = 0.0014). Out of 38 EPCS presented in the HEART methodology, a total of 19 cases were involved in determining the HEP score in the existing tasks. Among these EPCS, the factor of “novice and inexperienced” had the highest frequency with 21 repetitions. “High stress” with 12 repetitions, “unreliable work tools,” “control system opacity,” and “lack of clarity and timely and direct confirmation of action” were jointly ranked next with 4 repetitions in the next EPCS.

The results related to the mean \pm SD of the HEP score as well as the comparison of the mean of these scores by GEP are presented in Table 3. The highest mean score of HEP was determined for type C tasks with a score of 4.34. The results of the nonparametric Kruskal–Wallis test showed that there was a statistically significant difference between the mean rank of HEP of different groups ($P < 0.001$).

Descriptive and comparative results of the SMWL are presented separately in the work shift and frequency distributions of employees at different levels of the SMWL are presented in Table 4 and Figure 1. The total means SMWL in morning and night workers was 72.45 and 76.07, respectively. The results of the paired *t*-test showed that there is a statistically significant difference between the indices of SMWL in the morning shift and night shift ($P < 0.001$). Furthermore, the analysis showed that there is a statistically significant direct relationship between SMWL and HEP ($r^2 = 0.893$, $P < 0.001$).

The comparative results of the average SMWL by the mean score of HEP according to the type of tasks are presented in Table 5. The results of the Kruskal–Wallis nonparametric test showed that the mean rank of SMWL in different groups of GTT is statistically different ($P < 0.001$). This means that the nurses reported a higher SMWL for tasks with a higher HEP score.

DISCUSSION

This study tries to examine the relationship between SMWL and the HEP in nurses. The results of this study showed that

Table 2: Descriptive results of determining the human error probability by human error assessment and reduction technique method

Tasks	GTT	Total impact assessed	GEP	HEP
DC shock in emergencies	C	90.5	0.16	14.48
CPR procedure	C	50.2	0.16	8.032
Perform intubation	C	33.94	0.16	5.43
Airway suction	C	36.63	0.16	5.86
Medications	D	3.64	0.09	0.32
Changing the position of the endotracheal tube	C	20.54	0.16	3.28
Prescribing intravenous drugs	D	3.75	0.09	0.33
Prescribing intramuscular drugs	D	3.75	0.09	0.33
Get ABG	C	1.5	0.16	0.24
Record vital signs	D	1.32	0.09	0.118
Blood transfusions and blood products	C	2.84	0.16	0.454
Establish a venous line	C	1.32	0.16	0.21
Heart monitoring	C	1.23	0.16	0.196
Meeting the patient's defecation needs	D	1.12	0.09	0.1
Gavage	C	34.56	0.16	5.52
Breathing exercises	D	3.6	0.09	0.324
Oxygen administration	E	3.6	0.02	0.072
Balancing the body's electrolyte	E	3.6	0.02	0.072
Electrocardiography	E	3.6	0.02	0.072
Record patient information	E	3.5	0.02	0.07
Monitor the patient's gradual movement	E	4.7	0.02	0.094
Prepare the room	E	13.32	0.02	0.266
Stomach catheterization	E	37.29	0.02	0.745
Check and monitor the level of consciousness	G	3.9	0.0004	0.00156
Skin care	G	3.5	0.0004	0.0014
Refer the patient to a nutritionist	G	8.05	0.0004	0.0032

CPR: Cardiopulmonary resuscitation, GTT: Generic task type, GEP: General error probability, HEP: Human error probability, ABG: Arterial blood gas, DC: Direct current

Table 3: Comparative results of the average score of human error probability by type of general error probability

Task type	Average total impact	GEP score	HEART score (mean±SD)	P
Task type C	27.326	0.16	4.34±4.57	<0.001
Task type D	2.86	0.09	0.253±0.112	
Task type E	9.94	0.02	0.198±0.251	
Task type G	5.15	0.0004	0.00206±0.001	

HEART: Human error assessment and reduction technique, GEP: General error probability, SD: Standard deviation

several conditions cause human error in nurses, some of which can have a very high HEP in the employees. As a result, attention should be paid to these conditions and take necessary action to prevent the potentialities and thus prevent accidents and medical errors.

The findings of the current study revealed that tasks involving the DC shock in emergency, CPR procedure, intubation, airway suction, endotracheal tube replacement, and gavage demonstrated the highest HEP score. Various studies consistently highlight that procedures such as CPR, endotracheal intubation, medication, and airway suction carry high-risk levels due to their invasive nature and often

require time-sensitive execution. In a study by Beiruti *et al.*,^[25] evaluating the applicability of the HEART method in a medical setting, all tasks except gavage were assigned the highest HEP scores. Similarly, in a study by Mohammadfam *et al.*,^[26] three critical hospital processes – CPR, medication, and endotracheal intubation – were identified as the top three high-risk processes.

The findings of the current study revealed that tasks categorized as type C demonstrated the highest mean HEP scores, followed by type D, E, and G tasks. The elevated HEP scores for type C tasks can be justified by the complexity of these tasks, requiring a high level of knowledge and skills within the HEART method. Studies have consistently shown that tasks combining practical and mental work may lead to compromised mental processing, reduced mental performance, and an increased likelihood of human error.^[27] In a study by Beiruti *et al.*,^[28] tasks from groups C and D were found to have the highest HEP scores, with tasks from groups E and G following closely behind, aligning with the results obtained in our study.

In the current study, the overall mean of SMWL during morning and night shifts was 72.45 and 76.07, respectively. In general, employees reported higher mean indices and final SMWL scores during the night shift compared to the morning shift, and this difference was statistically significant. Previous

Table 4: Comparative results of subjective mental workload of employees by work shift

Variable	Shift work	Average	SD	Minimum	Maximum	P
Mental demand	Morning shift	76.81	17.17	22.00	100.00	<0.001
	Night shift	83.36	16.61	15.00	100.00	
Physical demand	Morning shift	37.46	20.12	10.00	77.00	<0.001
	Night shift	43.01	17.92	15.00	80.00	
Temporal demand	Morning shift	68.05	11.80	45.00	90.00	<0.001
	Night shift	72.70	13.74	35.00	96.00	
Performance	Morning shift	72.28	18.82	30.00	98.00	<0.001
	Night shift	66.35	18.05	26.00	90.00	
Effort	Morning shift	64.15	17.96	20.00	96.00	<0.001
	Night shift	70.43	15.78	34.00	100.00	
Frustration level	Morning shift	54.74	18.96	10.00	90.00	<0.001
	Night shift	59.81	17.31	20.00	90.00	
SMWL	Morning shift	72.45	13.09	35.00	96.87	<0.001
	Night shift	76.07	12.91	38.33	96.45	

SMWL: Subjective mental workload, SD: Standard deviation

Table 5: Comparison of subjective mental workload in 4 types of generic task type

Task type	Low average HEP	Average SMWL	Average rating	P
Task type C	4.34	58.43	21.40	<0.001
Task type D	0.253	35.86	13.00	
Task type E	0.198	27.70	7.57	
Task type G	0.00206	14.11	2.00	

SMWL: Subjective mental workload, HEP: Human error probability

research has indicated a notable association between fatigue and SMWL, particularly among shift workers who experience disruptions in their sleep cycles and insufficient rest, leading to cumulative fatigue that impacts SMWL.^[29] These findings align with a study by Hoonakker *et al.*,^[30] which reported a significant correlation between shift work and SMWL in shift workers. Sarsangi *et al.*,^[20] also observed a significant difference in average SMWL between various work shifts, consistent with the results of the present study.

The study revealed a significant positive correlation between SMWL and HEP among employees. In addition, there was a statistically significant difference in the average SMWL rank across various groups based on the GTT. Employees reported higher SMWL for tasks associated with elevated human error scores. Existing research highlights that SMWL influences employee behavior, performance, and efficiency, especially in occupations combining SMWL with practical work, leading to diminished mental processing and performance. Heavy SMWL and extended working hours contribute to fatigue, reduced efficiency, memory impairment, compromised thinking processes, fostering irritability, sensitivity, decreased learning, and an elevated risk of human errors and risky behaviors.^[27,31,32] Studies by Rahimian and Ghodrati,^[33] as well as Nikpima and Gholamnejad,^[34] underscore the impact of high SMWL on nursing errors and medication errors, respectively. Mazur *et al.*'s^[35] study further supports the association between

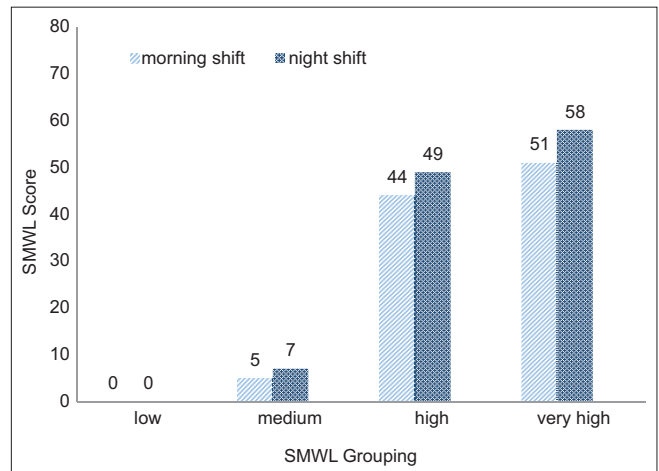


Figure 1: Frequency distribution of employees at different levels of subjective mental workload

increased SMWL and heightened human error occurrence, emphasizing its importance in radiation therapy. In conclusion, high SMWL in nursing employees may elevate the risk of errors, necessitating measures to mitigate SMWL and enhance overall safety for both individuals and patients.

The study identifies a concern with the HEP exceeding expected levels for six tasks, indicating potential overfitting in the HEP calculations. While the HEART method has been successful in estimating error probabilities, its accuracy for tasks with higher error potential may be limited due to overfitting. Recommendations include adjusting error-causing condition coefficients for hospital contexts. This concern aligns with observations and discussions raised in a parallel study within the health-care system.^[28] Limitations of the study include difficulties accessing hospital documents and time constraints affecting staff cooperation. The present study was analytical. A low sample size can lead to an increase in error in analytical studies. The small sample size in this study is one of the limitations of the study. Considering that this study

was conducted in one of Iran's hospitals, the generalization of its results to other nurses in Iran should be done with caution. To mitigate human errors in nursing, specialized instructions, targeted training, increased staffing, reduced overtime, and systematic work scheduling are suggested to enhance reliability and reduce HEP.

CONCLUSION

The SMWL among the examined nurses was elevated, and it further increased during night shifts. In addition, there was a heightened likelihood of human error in certain nursing tasks. Given the increased SMWL and the potential for errors in complex tasks such as DC shock in emergencies, CPR procedures, intubation, and airway suction, it is crucial to prioritize these responsibilities and implement control measures aimed at reducing the mental workload of the healthcare staff. To mitigate the critical consequences of human errors in nurses, it is essential to develop specialized instructions for various tasks, provide targeted training, reduce work time, and retrain scientific and practical skills.

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Ethical considerations code

This study was part of a thesis approved by the Ethics Committee of the Yazd University of Medical Sciences (IR.SSU.SPH.REC.1397.34). All participants were over 18 years of age, and the informed consent form for participating in the research was read and signed.

Conflicts of interest

There are no conflicts of interest.

Authors' contributions

Hadi Mirzabeigi: Analyzed and interpreted the data; wrote the paper and performed the experiments. Mahdi Jalali: Conceived and designed the experiments, edited the paper. Vida Sadat Anoosheh: Analyzed and interpreted the data, and edited the paper. Masoud Rostami: Translated the article into English, and edited the paper.

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