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ORIGINAL RESEARCH

Levels and Factors of Nurses' Alarm Fatigue in Critical Care Settings in Saudi Arabia: A Multicenter Cross-Sectional Study

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Background: A continuous and high frequency of alarms from monitoring and treatment devices can lead to nurses' sensory exhaustion and alarm fatigue in critical care settings.

Aim: The purpose of this study was to evaluate the level of alarm fatigue and determine the relationship between nurses' socio-demographic and work-related factors and the level of alarm fatigue in critical care settings in Hail City, Saudi Arabia.

Methods: Between May and July 2023, 298 nurses who worked in the emergency, intensive care, and critical care units of all the public hospitals in Hail City participated in a cross-sectional survey. Sociodemographic and work-related sheet and the Nurses' Alarm Fatigue Questionnaire were used to collect data.

Results: The total mean score of alarm fatigue was 26.38±8.30 out of 44. The highest score was observed for the item "I pay more attention to the alarms in certain", while the lowest score were observed for the items "I turn off the alarms at the beginning of every shift" with mean scores of 2.51 and 1.61, respectively. Nurses who were males, older than 30 years and Saudi citizens had significantly higher mean scores of alarm fatigue than their counterparts. In addition, significantly higher mean scores of alarm fatigue were noticed for nurses experienced for 10 years or more and who had regular morning shifts. Multiple linear regression showed that male (p=0.014), age (p=0.012), and Saudi nationality (p <0.029) were the independent factors affecting the level of fatigue alarm among nurses.

Conclusion: Nurses working in critical care settings at hospitals in Hail city are exposed to average levels of alarm fatigue, which can be influenced by sex, age, nationality, and experience of nurses. Therefore, it is imperative to manage alarm fatigue in critical care units by considering work-related and personality-related factors to ensure patient safety.

Keywords: alarms, fatigue, nurses, intensive care units, emergency

Introduction

The advancement of technology has led health agencies and healthcare providers (HCPs) to use various devices and equipment, such as ventilators, monitors and infusion pumps, to provide the best medical care, particularly in critical and intensive care units (ICUs).[1] These devices and equipment enable continuous monitoring of stability and any changes in physical hemodynamic conditions related to disease and the administration of medications.[1–3] Warning systems are commonly included in monitoring and treatment devices used by healthcare institutions and help to make HCPs, especially nurses, aware of any abnormalities in either the patient's physiologic status or the devices.[2–4] However, these devices may produce large numbers of alarms that can lead to sensory exhaustion for the nurses during their work, interrupt them and affect their responses to alarms, a condition known as alarm fatigue.[5] Alarm fatigue occurs when medical professionals are overexposed

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to alerts, it can cause sensory overload and lead to missed and desensitized alarms.[6] It may negatively affect the nurses' quality of care as well as the patient safety.

In one hospital's emergency departments in Finland, a study revealed that various medical equipment generated 28,176 alarms in one month, or about 125 alarms per monitor each day.[7] In South Korea, approximately 2184 clinical alarms were detected in ICUs over two days, ie, 45.5 clinical alarms per hour, with 63.8% of these being false alarms.[8] As a result, the Emergency Care Research Institute (ECRI) identified clinical alarms and alarm overload as one of the main ten health medical technology concerns in 2020.[9] Nurses in ICUs and emergency departments are the main HCPs responsible for responding to and dealing with clinical alarms, but they may experience an excessive number of clinical alarms and repeated false alarms over a long period that can lead to an improper response.[10–12] According to the findings of one study, more than 85% of clinical alarms in different departments of a single hospital were false.[6] False alarms may result in undesired actions such as ignoring or reducing the frequency of alarms, deactivating or silencing vital alarms, establishing inappropriate alarm parameters and turning down the level of alarms, all of which may affect patients' health outcomes and threaten their lives.[10,13–15] Between January 2009 and June 2012, the Joint Commission on Accreditation of Healthcare Organizations received 98 alarm-related incidents; 80 of these incidents resulted in fatalities, 13 in constant function loss, and five in unexpectedly extended hospitalizations.[16] Consequently, the Joint Commission established the National Patient Safety Goals in 2014 to control and adjust the alarm safety standards.[16] The mean alarm score among Chinese critical care nurses was found to be 21.11 using the Alarm Fatigue Questionnaire (AFQ),[15] and the mean alarm score among Iranian nurses was found to be 19.08, indicating a moderate rank of alarm fatigue.[3]

In addition to the negative consequences of clinical alarms, alarm fatigue can put nurses under work-related stress, leading to negative emotional effects such as anxiety, tension, and sadness.[17] It can also negatively impact nurses' competence and focus when performing their duties.[15,18] In addition, not all generated alarms have clinical significance. For instance, a study revealed that the majority of alarms were not clinically relevant, did little to alleviate patients' conditions and could even make nurses become alarm-fatigued.[19] Nurses may come across around 1,000 alarms every shift, which may not require any technical or clinical reaction.[12] In this regard, 80–99% of alarms might not require action.[20] Therefore, investigating the origin, amount and nature of alarm fatigue among nurses is the first stage in a multifaceted strategy to enhance workflow, reduce patient risk, and boost safety in healthcare facilities.[12] Educational training courses on strategies to deal and manage alarm and alarm fatigue for nurses have been recommended to be included in nursing curricula.[3,4]

There are factors that may contribute to enhancing alarm fatigue among nurses and need to be investigated to provide future strategic plan to manage them. In a recent study that was conducted by Nyarko et al 2023,[13] factors such as years of experience in the critical care unit and having policies related to alarm management, type of intensive care units were associated with an increased risk of alarm fatigue. Another study has shown that appeared that nurses' alarm fatigue was negatively correlated with their participation in ward monitoring device training programs and positively correlated with working 12-hour shifts (as opposed to 8-hour and 24-hour shifts) and working in Intensive Cardiac Surveillance Units (as opposed to other ICUs).[5] In addition, sociodemographic and work- related characteristics such as gender, education level, job position, years of experience, and duty shift were considered as a risk factors.[21] However, determination the level of the alarm fatigue among nurses and the factors affecting its level could help in the increasing the health policy managers' awareness to manage this problem.

As far as we are aware, no research has been done in Saudi Arabia to look at alarm fatigue among nurses and factors that may affect its level. Thus, the objectives of this study were to assess the level of nurses' alarm fatigue and to determine the relationship between nurses' sociodemographic and work-related factors among Saudi Arabian nurses working in critical care settings in Hail City.

Methods

Study Design and Population

Between May and July 2023, 298 nurses who worked in the emergency, intensive care, and critical care units of all the public hospitals in Hail City participated in a cross-sectional survey. Saudi and non-Saudi nurses were included if they consented to participate voluntarily. Nurses who had less than one year of experience or refused to participate were excluded. Using the

OpenEpi web-based calculator, Version 3.01 (www.openepi.com), a sample size of 292 nurses was calculated according to the following parameters: a population size of 1200, a 95% confidence level, and 5% absolute precision. Nonetheless, the survey was sent to 400 nurses, and 298 of them completed it, representing a 75% response rate.

Study Instruments

Data were collected using the nurses' demographic and work-related sheet including age, sex, marital status, nationality, years of experience, level of training, department, job position, patient-to-nurse ratio, shift length, number of working hours per shift, and additional outside employment and the Nurses' Alarm Fatigue Questionnaire (AFQ) which was developed by Torabizadeh et al.[18] The 13 questions in the questionnaire were all evaluated on a 5-point Likert scale (0 = never; 1 = seldom; 2 = occasionally; 3 = generally; 4 = constantly), with the exception of items 1 and 9, which had the opposite value. Accordingly, the tool's total scores ranged from 0 to 44, with higher scores revealing a high level of alarm fatigue. Permission from the author to use the questionnaire was obtained. The design feasibility and item readability were evaluated in a pilot study with 30 nurses who were not involved in the final analysis of study data. The questionnaire was found to be understandable, and its internal consistency reliability was verified to be good using Cronbach's alpha coefficient ($\alpha = 0.847$).

Data Collection and Ethical Approval

The University of Ha'il's Research Ethics Committee granted approval for this study (Ethical Approval No: H-2023-248). Before data collection, the nurses were approached and invited to participate in this study. The researchers gave the nurses the questionnaire and informed consent forms during their breaks and waited for them to finish the forms after outlining the goal of the study. A written informed consent was given to nurses and they were advised that their contributions are voluntary, and they might withdraw at any moment without reason. Only aggregated data were shared, and participants' code numbers were used throughout data collection and analysis to ensure their privacy and confidentiality.

Statistical Analysis

Data were analyzed using the IBM SPSS Statistics software, Version 27 (IBM Corp., Armonk, NY, USA). Categorical variables were measured as frequencies and percentages where continuous variables as mean and standard deviation (SD). To detect the normality of distribution, the Kolmogorov–Smirnov test was used where the results indicated the normal distribution of data (p-value was 0.056). Based on the independent variables, independent-samples *t*-test or one-way analysis of variance (ANOVA) was used to compare the mean scores of alarm fatigue. A p-value was considered statistically significant at level less than 0.05.

Results

The majority of nurses were males (57%), and more than half were aged 30 years or younger, with a mean age of 31.7±5.7 (range 20–57). In addition, the majority of nurses were Saudi (69.1%), married (54.7%), had a bachelor's degree (78.5%), were registered nurses and worked in ICUs (43.3%). Approximately one-third of hospitals had a nurse-to-patient ratio of 1:2 (31.9%), followed by those having a ratio of 1:5 or more (24.8%). More than half of nurses had irregular working schedules (58.4%), followed by regular morning shifts (38.6%) (Table 1). Out of 44, the average alarm fatigue score was 26.38±8.30. The highest score was observed for the item "I pay more attention to the alarms in certain shifts", followed by the items "I believe much of the noise in the ward is from the alarms of the monitoring equipment", "Alarm sounds make me nervous", and "Generally, I hear a certain amount of noise in the ward", with mean scores of 2.51, 2.27, 2.23 and 2.18, respectively. On the other hand, the lowest scores were observed for the items "I turn off the alarms at the beginning of every shift", "I react differently to the low-volume (yellow) and high-volume (red) alarms of the ventilator", and "When alarms go off repeatedly, I become indifferent to them", with mean scores of 1.61, 1.77 and 1.86, respectively (Figure 1).

(Table 2) shows that nurses who were males ($P = 0.010$), older than 30 years ($P = 0.030$) and Saudi citizens ($P = 0.009$) had significantly higher mean scores of alarm fatigue than their counterparts. In addition, significantly higher mean scores of alarm fatigue were observed for nurses with experience of 10 years or more ($P = 0.045$) and who had regular morning shifts

Table 1 Characteristics of Nurses Participated in the Study (N = 298)

Characteristic		n (%)
Sex	Male	170 (57.0)
	Female	128 (43.0)
Age (years)	≤30	154 (51.7)
	>30	144 (48.3)
	Mean ± SD	31.7±5.7
	Range	20–57
Nationality	Saudi	206 (69.1)
	Non-Saudi	92 (30.9)
Marital status	Single	127 (42.6)
	Married	163 (54.7)
	Divorced	8 (2.7)
Level of qualification	Diploma	24 (8.1)
	Bachelor	234 (78.5)
	Master's	40 (13.4)
Length of experience (years)	≤5	97 (32.6)
	6–9	99 (33.2)
	≥10	102 (34.2)
Department	ICU	129 (43.3)
	Critical care unit	60 (20.1)
	Emergency department	109 (36.6)
Job position	Assistant nurse	24 (8.1)
	Registered nurse	197 (66.1)
	Head nurse, supervisor	77 (25.8)
Nurse-to-patient ratio	1:1	22 (7.4)
	1:2	95 (31.9)
	1:3	61 (20.5)
	1:4	46 (15.4)
	1:5 or more	74 (24.8)
Working shift duration	Regular morning shift	115 (38.6)
	Regular night shift	21 (7.0)
	Irregular schedule	162 (54.4)

Abbreviations: SD, standard deviation; ICU, intensive care unit.

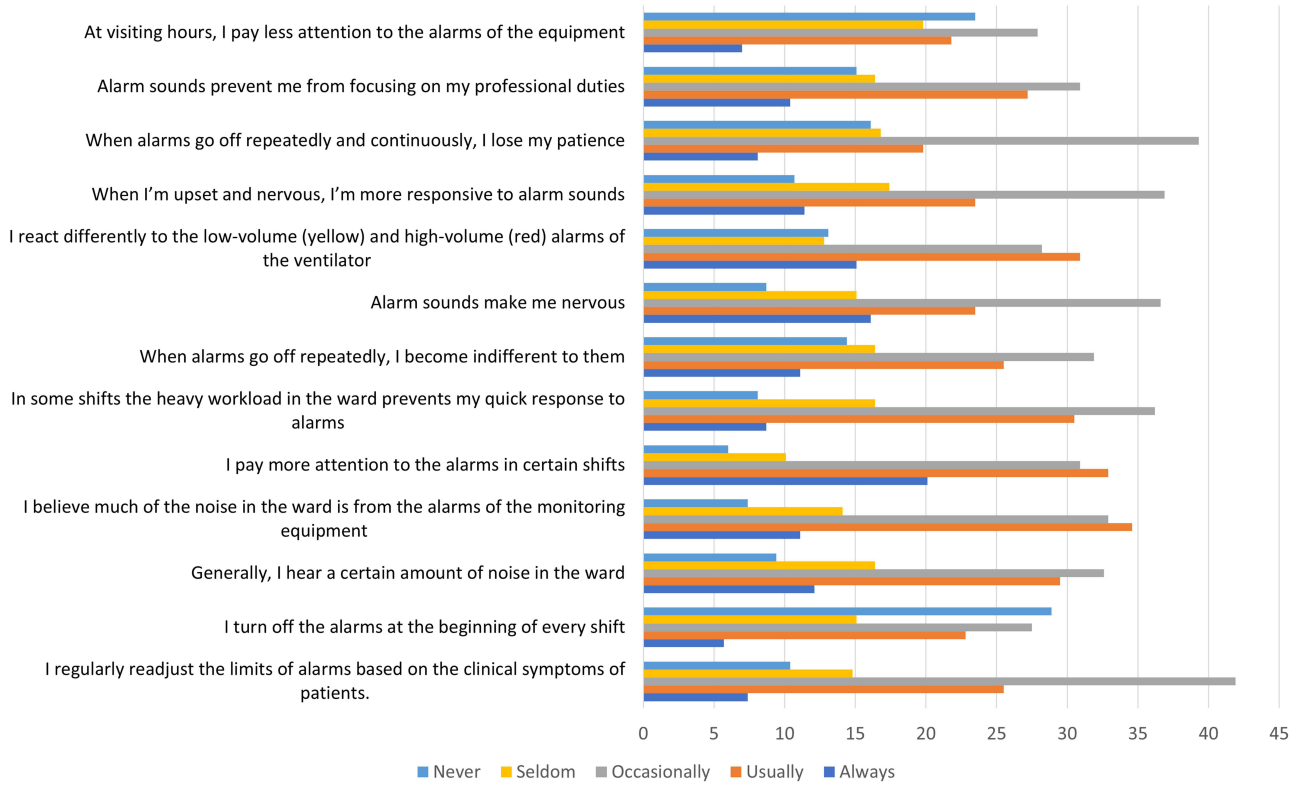

Figure 1 Nurses' responses to the items of Alarm Fatigue Questionnaire.

($P = 0.034$). However, no significant variations were detected between the mean scores of alarm fatigue according to marital status, level of qualification, department, job position, and nurse-to-patient ratio.

Multiple linear regression showed that male (p=0.014), age (p=0.012), and Saudi nationality (p <0.029) were the independent factors affecting the level of fatigue alarm among nurses (Table 3).

Table 2 Comparison of Alarm Fatigue Scores According to Sociodemographic and Work-Related Characteristics of Nurses at Critical Care Settings

Variables	Group	N	Mean ± SD	Test value	*P*-value
Sex					
	Male	170	27.29±8.63	t (2.558)	**0.010***
	Female	128	24.82±7.68		
Age (years)					
	≤30	154	25.22±7.69	t (−2.177)	**0.030***
	>30	144	27.31±8.82		
Nationality					
	Saudi	206	27.06±8.58	t (2.613)	**0.009***
	Non-Saudi	92	24.36±7.38		

(*Continued*)

Table 2 (Continued).

Variables	Group	N	Mean ± SD	Test value	*P*-value
Marital status					
	Single	127	25.74±8.12	F (0.946)	0.389
	Married	163	26.45±8.44		
	Divorced/Widowed	8	29.62±8.60		
Level of qualification					
	Diploma	24	27.12±11.76	F (0.571)	0.565
	Bachelor's	234	25.96±7.86		
	Master's	40	27.27±8.55		
Length of experience (years)					
	≤5	97	25.42±8.10	F (3.128)	**0.045***
	6–9	99	25.32±6.67		
	≥10	102	27.89±9.66		
Department					
	ICU	101	25.60±8.06	F (0.683)	0.506
	Critical care unit	31	26.50±8.73		
	Emergency department	82	26.83±8.40		
Job position					
	Assistant nurse	24	27.29±10.80	F (1.716)	0.182
	Registered nurse	197	25.59±8.08		
	Head nurse, supervisor	77	27.53±7.94		
Nurse-to-patient ratio					
	1:1	22	26.54±11.41	F (0.249)	0.910
	1:2	95	25.53±9.33		
	1:3	61	26.68±7.25		
	1:4	46	26.47±7.62		
	1:5 or more	74	26.51±7.12		
Working shift duration					
	Regular morning shift	115	27.66±8.44	F (3.428)	**0.034***
	Regular night shift	21	27.23±7.62		
	Irregular schedule	162	25.09±8.17		

Note: Star sign (*) and bold text indicate significant results.
Abbreviations: SD, standard deviation; ICU, intensive care unit.

Table 3 Sociodemographic and Health-Related Factors Affecting Nurses' Alarm Fatigue Level

Factor		B	S.E.	t	95% CI for β	P value
Sex						
	Male	Reference				
	Female	−2.582	1.043	−2.475	−4.635	0.014*
Age		0.332	132	2.516	0.072	0.012*
Nationality						
	Saudi	Reference				
	Non-Saudi	−2.477	1.126	−2.199	−4.693	0.029*
Length of experience (years)		0.212	132	−1.599	−0.472	0.111
Working shift duration						
	Regular morning shift	Reference				
	Regular night shift	−0.969	1.778	−0.545	−4.469	0.586
	Irregular schedule	−0.408	991	−0.412	−2.358	0.680

Note: Star sign (*) and bold text indicate significant results.
Abbreviations: B, coefficient of predictor variables; CI, confidence interval; S.E, standard error.

Discussion

This study revealed an average of nurses' alarm fatigue in critical care settings in public hospitals of Hail city, where alarm fatigue has increasingly become a phenomenon in which HCPs become desensitized to the constant barrage of alarms, leading to decreased responsiveness and potentially dangerous situations. Consequently, nurses may subdue or ignore alarms excessively.[11] For instance, an above-average level of alarm fatigue was reported among ICU nurses in Lebanon.[21] According to Lewandowska et al [17] nurses are particularly subjected to alarm fatigue because they consume most of their working time with care and monitor of patients. Generally, a nurse responds to an average number of alarms between 150 and 400 while on duty.[17] This constant onslaught of alarms can be overwhelming and cause physical exhaustion, a rise in workload, and a decline in concentration.

The finding that critical care nurses (CCNs) had the highest score for the item "*Alarms enhance the attention during the work*" in the present study could be attributed to the nature of their work and the prevalence of alarm fatigue in ICUs. Alarm fatigue is a significant issue for nurses, particularly in ICUs, where they are subjected to a lot of warnings from different equipment and monitoring devices.[3,22] Studies have shown that CCNs experience a moderate-to-high level of alarm fatigue, with scores ranging from 29.1 out of 40 to 69.4 out of 100.[8,23] This could be attributed to the complex and critical nature of their work, which requires constant monitoring of patients and their equipment. Moreover, monitoring equipment's alarms is a major source of noise in the hospital, as evidenced by the finding that CCNs had the second highest score. The loud noises of alarms can be obtrusive, stressful, and upsetting, making it challenging for nurses to perform their duties properly. Excessive noise levels in ICUs can negatively impact patients' health as well as nurses' physical and mental well-being.[24] Therefore, addressing noise-induced stress in CCNs is essential for improving nurses' working conditions and the caliber of patient care provided.[25] Healthcare facilities should assess their alarm rules and processes to find solutions to lessen the number of alarms. For instance, some alarms can be combined or completely deactivated.

In the present study, CCNs had the lowest scores for the item "*The alarm is adjusted to silent at the beginning of work*", which may imply that nurses providing critical care are aware of the dangers of alarm fatigue and are taking precautions to reduce them. Therefore, adjusting alarm settings can help to reduce the frequency of false alarms.[2] CCNs can lessen alarm fatigue and raise patient safety by prioritizing alarms, adjusting alarm parameters, and working together. Moreover, they should prioritize alarms so they can distinguish between those that need immediate attention and those that can be

delayed.[26] ICU nurses may set or handle alarms improperly if they are unable to control and respond to them effectively.[27] In perspective, it is crucial to develop alarm management standards to assist CCNs in coping with alarm fatigue.

The present study revealed that CCNs scored the lowest on the item "*Reaction to low low-volume (yellow) and high-volume may be different in ventilator*'s alarms". As a result, reaction to numerous alarms can affect their ability to provide safe and effective treatment to their patients, considering that nurses who provide critical care attempt not to ignore alarms. In this context, they are merely attempting to deal with the numerous alarms they are exposed to. Earlier studies have shown that alarm fatigue may result from receiving too many alarms and erroneous or ineffective alarms, contributing to burnout.[11,28] Healthcare facilities can help to reduce alarm fatigue by implementing alarm management techniques, including lowering the number of alarms, prioritizing alarms, and using softer alarms. On the other hand, the lowest score for the item "*Alarms that occur frequently cause less interesting for them*" implies that nurses are cognizant of the risks associated with alarm fatigue and are making an effort to successfully manage it. The high level of alarm fatigue in the present study suggests that additional efforts are needed to enhance alarm management in critical care settings. Other studies have also shown that when alarms go off repeatedly and constantly, nurses become irritable and impatient,[4,22] highlighting the importance of addressing alarm fatigue and enhancing alarm management in hospital settings.

The higher scores of male compared to female nurses on alarm fatigue in the present study can be partly explained by the fact that male nurses are more likely to work in ICUs, where alarm fatigue is more common. In contrast, female nurses in Ireland were found to be more likely to experience alarm fatigue.[3] However, the observational design of such studies makes it difficult to prove whether working in a critical care unit results in alarm fatigue. On the other hand, the significantly higher score for alarm fatigue among nurses older than 30 years in the present study may have resulted from their longer work experience, making them more desensitized to alarms. However, there is no concrete evidence from the literature that CCNs older than 30 years performed adversely in terms of alarm fatigue. Alarm fatigue, however, is a prevalent problem in healthcare, especially in ICUs. When HCPs are repeatedly exposed to many alarms, alarm fatigue can occur and lead to an increase in the number of missed alerts and a desensitization to medical alarm.[29]

In the present study, Saudi CCNs were found to have a significantly higher level of alarm fatigue compared to non-Saudis, suggesting that Saudi CCNs may be more likely to work in hospitals with less advanced alarm management systems. We did not find specific data comparing alarm fatigue between Saudi CCNs and those from foreign nationality. However, on study in Saudi Arabia reported that CCNs experienced moderate alarm fatigue and moderate-to-high burnout.[15] Another study showed that working in ICUs is associated with high levels of stress, which can lead to decreased productivity and poor healthcare quality if not well handled.[30] Although these studies did not show the association between nationality and alarm fatigue, their findings indicate that Saudi Arabian CCNs may be overly stressed and exhausted, which may play a role in alarm fatigue.

In the present study, the significantly higher scores of fatigue alarms among nurses experienced for 10 years or more could be attributed to the fact that more experienced nurses have been exposed to more alarms throughout their careers, making them less sensitive to them. On the other hand, the higher scores among nurses with regular morning shifts could be attributed to their work overload because such shifts are frequently the busiest of the day in critical care units. According to Lewandowska et al [5] and Nyarko et al [11] more experienced nurses who work regular morning hours are more vulnerable to alarm fatigue, resulting in missed alarms and medical errors that cause patient deaths, increased clinical stress and burnout. In this case, managers can intervene by establishing a culture of safety in which nurses feel free to express their alarm fatigue concerns.

The lack of significant differences in the mean scores of alarm fatigue according to marital status, level of qualification, department, job position, and nurse-to-patient ratio could be explained by the fact that alarm fatigue is a complicated issue with many underlying causes. Personality-related factors, including nursing personality qualities and demographic factors, may influence alarm fatigue.[5,11] For instance, being single, holding a high-level post, working long hours, having a high professional title, and having a high degree of education were found to be adversely associated with alarm fatigue.[31] To ensure patient safety and avoid nurse burnout, it is imperative to manage alarm fatigue in critical care units by considering both work-related and personality-related factors.

Limitations

Although this study addressed an important issue related to patients' safety in ICUs and emergency departments, it has some limitations. It was a cross-sectional and used self-administered questionnaire, which may not accurately reflect the

levels and factors affecting the level of alarm fatigue among nurses. Other qualitative and longitudinal studies are recommended to provide a detailed description of this issue. Another limitation is that this study was conducted in Hail public hospitals only, that may restrict how far the findings can be generalized.

Implications

The results of this study can be used to develop and implement nurse education programs on alarm fatigue for nurses in critical care settings. These programs can assist nurses in understanding the reasons for alarm fatigue, its risks, how to avoid it, and efficient alarm management techniques. The findings of this study emphasize the need for developing and evaluating strategies for lowering alarm fatigue among CCNs. These strategies may include making adjustments to alarm management policies and systems. The Saudi Arabian Ministry of Health, for instance, should establish national regulations for critical care alarm handling. Policymakers should prioritize the development and implementation of hospital-level policies and procedures for alarm management. These policies and processes should be based on best practices and tailored to Saudi Arabia's particular requirements.

Conclusion

Critical care nurses, in Hail City, Saudi Arabia experienced a level of alarm fatigue but they reported implementing strategies to manage alarms. While they were attentive to alarms it was uncommon for them to completely turn off alarms at the start of their shifts. Various demographic and work-related factors had an impact on alarm fatigue levels. For example, male nurses, those above the age of 30 Saudi citizens, nurses with over 10 years of experience and those working regular morning shifts exhibited levels of alarm fatigue. These findings suggest that targeted interventions may be beneficial for these groups. Further research is necessary to understand the reasons behind these differences and develop interventions to address alarm fatigue among care nurses in Saudi Arabia. These interventions could include training programs tailored to demographics optimizing alarm systems based on preferences and adjusting scheduling practices to alleviate fatigue. By addressing these factors critical care nurse can create a more efficient work environment while improving patient outcomes.

Informed Consent Statement

Informed written consent was obtained from all participants who were involved in the study.

Institutional Review Board Statement

All procedures were carried out in accordance with the relevant standards and laws, including the Helsinki Declaration. The University of Ha'il's Research Ethics Committee granted approval for this study (Ethical Approval No: H-2023-248). Before data collection, a written informed consent was given to nurses and they were advised that their contributions are voluntary, and they might withdraw at any moment without reason. Only aggregated data were shared, and participants' code numbers were used throughout data collection and analysis to ensure their privacy and confidentiality.

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Disclosure

The authors declare no conflicts of interest in this work.

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