


Determinants of Medical Equipment Alarm Fatigue in Practicing Nurses: A Systematic Review

SAGE Open Nursing
Volume 9: 1–10
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DOI: 10.1177/23779608231207227
journals.sagepub.com/home/son



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Abstract

Objective: This study aimed to systematically evaluate the level of medical equipment alarm fatigue and its influencing factors among clinical nurses.

Methods: PubMed, Embase, CNKI, and Wanfang databases were systematically searched to identify articles on alarm fatigue of clinical nurses published before September 25, 2022. According to the evaluation criteria of prevalence studies recommended by JBI Evidence-Based Health Care Center, the quality of the literature meeting the inclusion criteria was evaluated, and Stata MPI7 software was used for meta-analysis.

Results: A total of 14 cross-sectional studies were included, with a total sample of 2,848 nurses. The results showed that the alarm fatigue score of clinical nurses was 21.76 (95% CI [20.27, 23.25]). Subgroup analysis showed that the nurses who worked night shift and had lower professional title had higher alarm fatigue.

Conclusion: The alarm fatigue of clinical nurses was at a moderate level. To reduce the alarm fatigue level of clinical nurses, nursing managers should strengthen the alarm safety awareness of nurses, rationally arrange nurse manpower, carry out training to actively improve the alarm management ability of nurses, and optimize the alarm level and frequency of alarm equipment.

Keywords

nurse, alarm fatigue, systematic review

Received 14 May 2023; Revised 18 August 2023; accepted 23 September 2023

Relevance to Clinical Practice

1. Influencing factors of nurse alarm fatigue include alarm-setting factors, device factors, and clinical nurse factors.
2. It is suggested that nursing leaders adopt the alarm management guidelines for clinical training, so as to improve the alarm management ability of nurses and reduce the alarm fatigue of nurses.
3. Intervene the influencing factors of alarm fatigue and pay attention to the lasting effect.
4. A comprehensive consideration of staff, device, and technology can improve the security of alarm management and reduce the gap between guidelines or standards and practice.

Introduction

Medical equipment alarm fatigue refers to a phenomenon where medical personnel who are exposed to alarms from multiple medical equipment for a long time become less sensitive to these alarms, resulting in the potential for them to

ignore critical equipment alarms. Alarm fatigue is often used to describe the impact of numerous alarms on nursing staff (Wilken et al., 2017). It refers to the desensitization and indifference of medical staff to numerous, repeated, or simultaneous alarm sounds, which is a major contributor to adverse alarm

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events, causing serious consequences for patients' safety (Bach et al., 2018). In addition, attending to many alarms can lead to exhaustion in nursing (Casey et al., 2018). Medical equipment plays an indispensable role in patient care, and medical staff can be exposed to equipment alarms up to 1000 times during a single shift (Ruskin & Hueske-Kraus, 2015). It has been reported that 72%–99% of clinical alarms may be false alarms (Bach et al., 2018; Srinivasa et al., 2017). Excessive false and unactionable alarms desensitize nurses, which may result in them missing critical alarms (Sowan et al., 2015). Most hospitals have reported adverse events in patients related to medical device alarms (Casey et al., 2018). It is therefore necessary to improve alarm management strategies and measurement methods of alarm fatigue level (Lewandowska et al., 2020). The study of Lewandowska emphasized the negative impact of alarm fatigue and pointed out the importance of improving alarm management systems to reduce this burden (Lewandowska et al., 2020). Bach pointed out that although there is limited high-quality research on the effect of alarm management procedures on alarm fatigue, current evidence supports that improved alarm management procedures have a positive effect on alarm fatigue in nurses (Bach et al., 2018).

The issue of alarm fatigue as a potential risk to patient safety has received significant attention. Alarm fatigue can lead to burnout, which seriously affects the safety of patients (Ding et al., 2023; Storm & Chen, 2021). Although in 2003, the Joint Commission on Accreditation of Healthcare Organization (JCAHO) sought to improve the efficacy of alerts in relation to national patient safety goals, adverse events to alarms continue to occur, which resulted in the deaths of 80 patients and the permanent loss of function in 13 patients (Leigher, 2020). In 2014, alarm fatigue was recognized as a threat to patient safety and was included in the national alarm management patient safety target as a problem requiring improvement (Ruskin & Hueske-Kraus, 2015; Sendelbach & Funk, 2013). The China Hospital Association released the Patient Safety Goal (2019 Edition), which for the first time listed "strengthening the safety and alarm management of medical equipment" as one of the major goals of patient safety. Alarm fatigue has been recognized as a significant patient safety issue by multiple institutions (Scott et al., 2019).

So how to handle alarms correctly? Guidelines issued by the Emergency Care Research Institute (ECRI) refer to the concept of the life cycle of a clinical alarm, which refers to the process from the time an alarm is generated until the patient's condition is addressed and the alarm is eliminated. Clinical alarm life cycle includes four important parts: alarm generation, transmission, identification and response. ECRI believes that by mastering the life cycle of the alarm, the fault point can be identified in the alarm management and effective measures can be taken (ECRI, 2013). An implementation strategy to prevent nurse alarm fatigue incorporates guidelines from the American Association of Critical Care Nurses (AACN) for the management of ECG monitoring alarms, including daily electrode changes and appropriate skin preparation, eliminate inoperable

and duplicate alarms and adjust default threshold alarms, educate and instruct registered nurses and custodial technicians to customize alerts, and reduce the overuse of continuous cardiac monitoring by implementing guidelines (AACN, 2018; Sandau et al., 2017; Turmell et al., 2017). The Practice Guide for Clinical Alarm Management of Multiparameter Monitors in China (2020 edition) recommends the use of the Subjective fatigue symptom Scale revised by the Japan Occupational Health Association to evaluate the alarm fatigue degree of nurses and suggests that hospitals may consider the use of Internet of Things technology signal filtering technology and advanced alarm generation algorithm artificial intelligence system to optimize the hospital alarm management system. By improving the specificity of the alarm, false alarms can be reduced effectively, thereby further preventing alarm fatigue (Yue, 2021). Therefore, it is very important to make clear the influencing factors of alarm fatigue and develop improvement strategies. In this study, meta-analysis was used to systematically evaluate alarm fatigue and its influencing factors among clinical nurses, which would provide a basis for improvement strategies. PROSPERO registration number CRD42023410993 has been obtained for this study.

Methods

We used the PRISMA reporting guidelines to conduct this systematic review and meta-analysis (Page et al., 2021).

Literature and Strategy

We searched the English databases PubMed and EMBASE, the Chinese databases CNKI and Wanfang, and other relevant literatures on medical equipment alarm fatigue among clinical nurses and its influencing factors. Relevant articles published from the inception of the database to September 25, 2022, were retrieved. Regarding the search strategy, search terms were combined with subject words and free words, and truncated words were used to improve the recall ratio. The English search terms were "Clinical alarms" OR "Alarm fatigue" OR "Alarm

Table 1. Search Strategies—PubMed as an Example.

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((((("Clinical Alarms"[Mesh]) OR (Alarm fatigue [Title/
Abstract])) OR (Alarm fatigue*[Title/Abstract])) OR (Clinical
alarms*[Title/Abstract])) AND (((("Nurses"[Mesh]) OR
(Nurs*[Title/Abstract])) OR ("Nursing"[Mesh])) OR
("Primary Health Care"[Mesh]))

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#1 "Clinical alarms" [MeSH]
#2 "Alarm fatigue" [Title/Abstract]
#3 "Alarm fatigue*" [Title/Abstract]
#4 # 1 OR #2 OR #3
#5 "Nurse" [MeSH]
#6 "Nurs*" [Title/Abstract]
#7 "Health care" [Title/Abstract]
#8 # 5 OR #6 OR #7
#9 # 4 AND #8

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fatigue*"; "Nurse" OR "Nurs*" OR "Nursing" OR "care" OR "caring." Search strategies—PubMed as an example (Table 1):

Inclusion and Exclusion Criteria for Literature

Inclusion criteria: studies involving clinical nurses, observational study describing alarm fatigue levels and related factors in clinical nurses, study tools including at least a clinical alarm fatigue-related scale for measurement, having a clear analysis of results, and the article that is in Chinese or English.

Exclusion criteria: literature reporting incomplete data or where data cannot be extracted, reviews and other secondary studies, interventional research, qualitative research, and studies where full text or repeated publication is not available.

Study Selection and Data Extraction

Literature selection and quality evaluation were conducted independently by two evidence-based trained researchers in strict accordance with inclusion and exclusion criteria. In case of disagreement, the evaluator discussed or consulted a third person for arbitration. Literature data were extracted by two researchers independently, including basic information of the study, sample size, influencing factors involved, outcome measurement data, and key elements of bias risk assessment.

Quality Assessment

The prevalence study quality assessment tool developed by the JBI Evidence-Based Health Care Centre in Australia (2016) was used. It consists of nine assessment items (Table 2), and the evaluator is required to make a judgment of "yes," "no," "unclear," and "not applicable" for each evaluation item and to decide on whether to include, exclude, or obtain further information after group discussion. Literature quality evaluation was divided into A, B, and C grades. If all the nine evaluation criteria were satisfied, it is Grade A, indicating a low risk of bias. If six to eight criteria are met, it is Grade B, indicating a moderate risk of bias. If three to five criteria are met, it is the Class C, indicating a high risk of bias.

Statistical Analysis

StataMP17 software was used for data analysis. First, clinical heterogeneity among the included studies was assessed. The fixed-effects model is used if there is no heterogeneity ($P > 0.1$, $I^2 < 50\%$), and the random-effects model is used if there is high heterogeneity ($P \leq 0.1$, $I^2 \geq 50\%$). Subgroup analysis was used to explore the sources of heterogeneity, such as educational background and professional title, which were basically the same classification criteria in the included literature. $P \leq 0.001$ was considered statistically significant. Continuous variable data were mean difference (MD) or standardized

Table 2. Quality Evaluation Results of the Included Literatures ($n = 14$).

Study	1	2	3	4	5	6	7	8	9	Level
Wang Jing	Y	Y	Y	Y	Y	Y	Y	Y	Y	A
Yin Xin	Y	Y	Y	Y	Y	Y	Y	Y	Y	A
Jiang Yifan	Y	Y	Y	Y	Y	Y	Y	Y	Y	A
Wang Donghua	Y	Y	Y	Y	Y	Y	Y	Y	Y	A
Liu Qiaohong	Y	Y	Y	Y	Y	Y	Y	Y	Y	A
Yang Jing	Y	Y	Y	Y	Y	Y	Y	Y	Y	A
Sun Jing	Y	Y	Y	Y	Y	Y	Y	N	Y	B
Wang Na	Y	Y	Y	Y	Y	Y	Y	Y	Y	A
Wang Qin	Y	Y	Y	Y	Y	Y	Y	Y	Y	A
Luo Lingling	Y	Y	Y	Y	Y	Y	Y	Y	Y	A
Yunxia Zhao	Y	Y	Y	Y	Y	Y	Y	N	Y	B
Neda Asadi	Y	Y	Y	Y	Y	Y	Y	Y	Y	A
Ok Min Ch	Y	Y	Y	Y	Y	Y	Y	Y	Y	A
Yu Jin Jeong	Y	Y	Y	Y	Y	Y	Y	Y	Y	A

Note. 1. Was the sample frame appropriate to address the target population? 2. Was the sampling technique appropriate to address the target population? 3. Was the sample size adequate? 4. Were the study subjects and the setting described in detail? 5. Was the data analysis conducted with sufficient coverage of the identified sample? 6. Was the identification of the condition or phenomenon accurate? 7. Were objective, standard criteria used for measurement of the condition or phenomenon? 8. Was the timeframe for the condition or phenomenon appropriate? 9. Was the response rate adequate, and if not, were the characteristics of nonrespondents described? "Y" indicates yes, "N" indicates no, "UN" indicates unclear, and "NA" indicates not applicable.

mean difference (SMD) due to different measurement tools. 95% CI was calculated in all effects analysis.

Results

Overview of the Included Studies

A total of 1,246 relevant literatures were retrieved, including 272 from PubMed, 839 from Embase, 68 from CNKI, and 67 from Wanfang. After screening (Figure 1), 14 cross-sectional studies were finally included, including 10 Chinese and 4 English literatures, with a total sample size of 2,848 nurses. See Table 4 for the basic characteristics of the included studies and Table 2 for the results of bias risk assessment.

Risk of Bias Assessment

In the 14 cross-sectional studies included in this study, the inclusion and exclusion criteria of the study population were clearly defined in the literature, which was consistent with the purpose of this study. All studies used standard measurement tools with good reliability and validity, reported outcome indicators, and used appropriate statistical methods. Generally, 12 papers included in the study were Grade A, and the rest were Grade B.

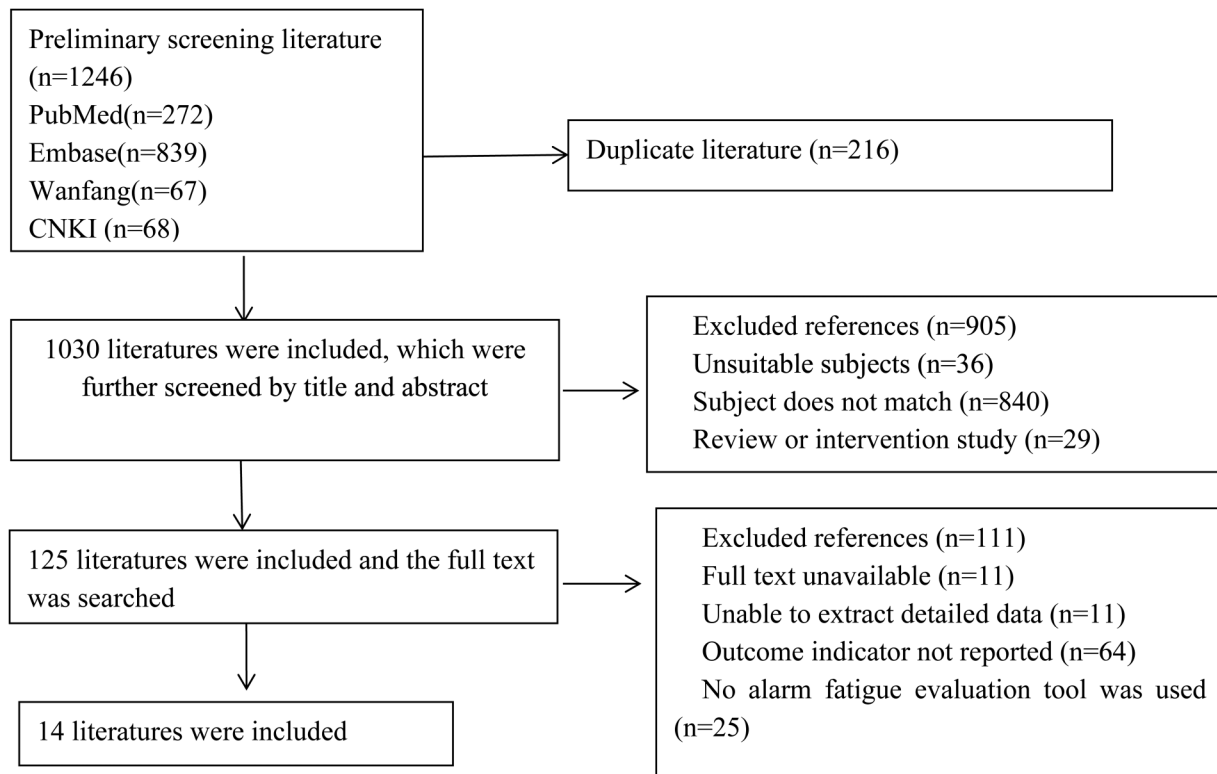


Figure 1. Literature screening flow chart.

Meta-Analysis Results of Alarm Fatigue of Clinical Nurses

Primary Outcomes. Alarm fatigue levels in clinical nurses were reported in the 14 included studies. All studies used the clinical alarm fatigue scale as the evaluation tool, with one study using the Japanese version of the scale. All 14 papers were included in the meta-analysis, which may have certain limitations. The results of random-effects model meta-analysis showed that the alarm fatigue score of clinical nurses was 21.76 (95% CI [20.27, 23.25]), as shown in Figure 2.

Meta-Analysis of Influencing Factors of Alarm Fatigue in Clinical Nurses. Meta-analysis was performed on three or more studies with the same assessment tools and influencing factors. The results showed that night shift and having a professional title had significant heterogeneity among the included literatures ($p \leq .001$), and random-effects model was used. Meta-analysis results showed that night shift and different professional titles were the main influencing factors of alarm fatigue among clinical nurses, as shown in Table 3.

Influencing Factors of Alarm Fatigue Among Clinical Nurses

Factors Related to Clinical Nurses. Five studies showed that nurses with low education had higher alarm fatigue (Asadi

et al., 2022; Wang, 2017; Wang, 2018b; Wang, 2018c; Zhao et al., 2021). The alarm fatigue score of nurses with bachelor's degree or above was lower than that of nurses with junior college degree. The group with higher education level has a better ability to accept new knowledge and new skills. However, in Asadi's study, nurses with doctoral degrees had a higher degree of alarm fatigue, which may be related to the fact that doctors devote more energy to scientific research and participate less in clinical work, making them more prone to alarm fatigue when faced with more clinical alarms. Six studies have shown that night shift is an influencing factor of alarm fatigue (Jiang, 2022; Liu, 2022; Wang, 2017; Wang, 2018a; Wang, 2018c; Yang, 2021). Most studies indicated that the alarm fatigue score of shift nurses was higher than that of nonshift nurses, and shift nurses responsible for patient observation and nursing plan implementation had longer alarm exposure time and a higher frequency. However, Yang Jing concluded that the alarm fatigue of nurses in dayshift was significantly higher than that of nightshift nurses (Yang, 2021). This could be due to the longer working hours in day shift and shorter working hours in night shift of nurses included in the study (Table 4).

Seven studies have shown that working years is an influencing factor of nurse alarm fatigue (Liu, 2022; Luo, 2022; Sun, 2018; Wang, 2018b; Wang, 2018c; Yin, 2018; Zhao

Table 3. Subgroup-Analysis of Influencing Factors of Nurses' Alarm Fatigue.

Subgroup analysis	Inclusion study	Number	Heterogeneity test		Effect model	Alarm fatigue score Combined effect value (95% CI)	
			I ² (95%)	p			
Night shift	Yes	3 (Wang, 2017; Wang, 2018c; Yang, 2021)	356	95.7	p ≤ .001	Random	21.07 (18.78, 23.37)
	No	3 (Wang, 2017; Wang, 2018c; Yang, 2021)	49	90.1	p ≤ .001	Random	19.89 (16.26, 23.51)
Professional title	Nurse	3 (Wang, 2018a; Wang, 2018c; Yin, 2018)	405	93.2	p ≤ .001	Random	19.50 (16.56, 22.44)
	Nurse practitioner	3 (Wang, 2018a; Wang, 2018c; Yin, 2018)	511	98.0	p ≤ .001	Random	20.02 (16.89, 23.16)
	Supervisor nurse	3 (Wang, 2018a; Wang, 2018c; Yin, 2018)	139	95.2	p ≤ .001	Random	18.40 (14.61, 22.18)
	Deputy chief nurse and above	3 (Wang, 2018a; Wang, 2018c; Yin, 2018)	16	74.9	p ≤ .001	Random	15.43 (11.52, 19.35)

et al., 2021). Low working years is an independent risk factor for alarm fatigue of nurses. Nurses lack clinical alarm management experience and usually do not have the ability to deal with the alarms of monitoring instruments quickly and accurately. Excessive psychological pressure makes them more prone to alarm fatigue. However, Wang et al. pointed out in their study that nurses with longer working years tend to have higher alarm fatigue due to their long-term exposure to frequent medical alarms (Wang, 2018b). As a result, they choose to delay or refuse to deal with alarms of routine medical equipment that do not endanger patients' lives.

Five studies have shown that having a professional title is an influencing factor of nurse alarm fatigue (Liu, 2022; Wang, 2018a; Wang, 2018c; Yin, 2018; Zhao et al., 2021). Two studies showed that alarm fatigue was higher among female nurses, which may be related to the differences in psychology between men and women (Asadi et al., 2022; Wang, 2018c). Men are known to have stronger endurance and willpower and are less affected by external interference. Three studies showed that insufficient training was associated with higher alarm fatigue (Asadi et al., 2022; Wang, 2017; Wang, 2018c). Nurses who rarely attended training each year had higher alarm fatigue scores than those who attended training occasionally and often. Nurses with insufficient alarm knowledge cannot recognize or fully understand all alarms and are prone to alarm fatigue.

Alarm-Setting Factors. Five studies showed that alarm parameter setting frequency is related to alarm fatigue (Liu, 2022; Wang, 2017; Wang, 2018a; Wang, 2018b; Zhao et al., 2021). The study showed that nurses who "always set alarm parameters" had lower alarm fatigue than other nurses. Nurses routinely set alarm parameters according to the patient's condition and age at the end of the shift and can timely modify inappropriate alarm parameters to reduce invalid alarm.

Device Factors. Six studies showed that a high false alarm rate easily leads to higher alarm fatigue (Cho et al., 2016; Jeong & Kim, 2023; Wang, 2017; Wang, 2018b; Yang, 2021; Yin, 2018). The highest score in the study survey was "frequent false alarms led to a decrease in my attention and response speed to the alarm prompts of the monitor." Approximately 91% of nurses felt the noise of the alarm interfered with their work, resulting in alarm fatigue.

Discussion

Summary and Interpretation of Findings

Clinical Nurse Factors. Nurses' lack of awareness of alarm management and alarm fatigue lead to patient safety problems (Petersen & Costanzo, 2017). At present, the use of medical equipment in hospitals is increasing exponentially, and alarm is inevitable. Therefore, it is crucial to provide effective and continuous education and training on clinical alarm management for nurses and to improve their awareness of alarm fatigue (Nyarko et al., 2022). However, alarm management is complicated, with a variety of alarm settings, alarm signal priorities, and alarm upgrade algorithms. Nurses are the main users of medical alarms, and they work in a complex environment with many alarms. The adverse events related to alarms are common. As the main operators of these systems, clinical nurses need to receive adequate training to properly set and respond to device alarms (Johnson et al., 2017; Yue et al., 2017). Sowan's survey results showed that 50% of nurses clearly expressed the need for more training in cardiac monitoring instruments to properly manage alarms (Sowan et al., 2016). Bi's training of monitoring and alarm management based on the theory of planned behavior effectively reduces the alarm fatigue of nurses in the intensive care unit (Bi et al., 2020). Nyarko pointed out that educational intervention is conducive to reducing the total number of alarms and false reports and

Table 4. Basic information of the 14 included literatures.

Author	year	country	Study population	Sample size	Research type	Sampling method	Research tool	Alarm fatigue score	Influencing factor
Wang Jing	2017	China	ICU	118	Descriptive study	Convenience sampling	Alarm fatigue questionnaire	19.88 ± 3.72	Different educational background, departments, scheduling, alarm parameter setting frequency, high false alarm rate and inadequate system training
Yin Xin	2018	China	ICU nurses	622	Descriptive study	Convenience sampling	Alarm fatigue questionnaire	19.50 ± 6.40	Years of work, professional title
Jiang Yifan	2022	China	Anesthesiology nurse	241	Descriptive study	Convenience sampling	Alarm fatigue questionnaire	20.19 ± 7.33	Major, night duty
Wang Donghua	2018	China	ICU nurses	326	Descriptive study	Convenience sampling	Alarm fatigue questionnaire	17.04 ± 5.97	Nursing work environment; job title, night shift situation, frequency of setting alarm parameters, health status, attitude toward nursing work
Liu Qiaohong	2022	China	ICU nurses	225	Descriptive study	Cluster sampling method	Alarm fatigue questionnaire	22.32 ± 2.83	Age, working years, working with illness, job title, shift, no habit of setting medical equipment alarm, medical equipment management factors
Yang Jing	2021	China	ICU nurses	164	Descriptive study	Convenience sampling	Alarm fatigue questionnaire	20.25 ± 6.09	Scheduling and false alarm rate
Sun Jing	2018	China	Emergency department nurse	351	Descriptive study	Convenience sampling	Alarm fatigue questionnaire	21.05 ± 10.00	Working years
Wang Na	2018	China	ICU nurses	123	Descriptive study	Convenience sampling	Alarm fatigue questionnaire	18.88 ± 3.68	Educational background, professional title, department, working years, night shift, management factors of medical equipment alarm, and obstacles perceived by nurses
Wang Qin	2018	China	Hemodialysis room nurse	80	Descriptive study	Convenience sampling	Alarm fatigue questionnaire	25.01 ± 2.38	Gender, education, working years, annual number of training, setting parameter frequency
Luo Lingling	2022	China	ICU nurses	160	Descriptive study	Convenience sampling	Alarm fatigue questionnaire	23.82 ± 6.75	Working life, manpower, material resources, the basis of high-quality nursing services
Yunxia Zhao	2021	China	ICU nurses	215	Descriptive study	Convenience sampling	Alarm fatigue questionnaire	24.63 ± 8.99	Job title, working years, educational background
Neda Asadi	2022	Iran	ICU nurses	140	Descriptive study	Convenience sampling	Alarm fatigue questionnaire	19.08 ± 6.26	Training, education, gender
Ok Min Cho	2016	Korea	ICU nurses	35	Descriptive study	Observation method	Alarm fatigue questionnaire	24.3 ± 4.0	High false alarm rate
Yu Jin Jeong	2021	Korea	ICU nurses	48	Descriptive study	Convenience sampling	Alarm fatigue questionnaire	28.97 ± 4.01	High false alarm rate

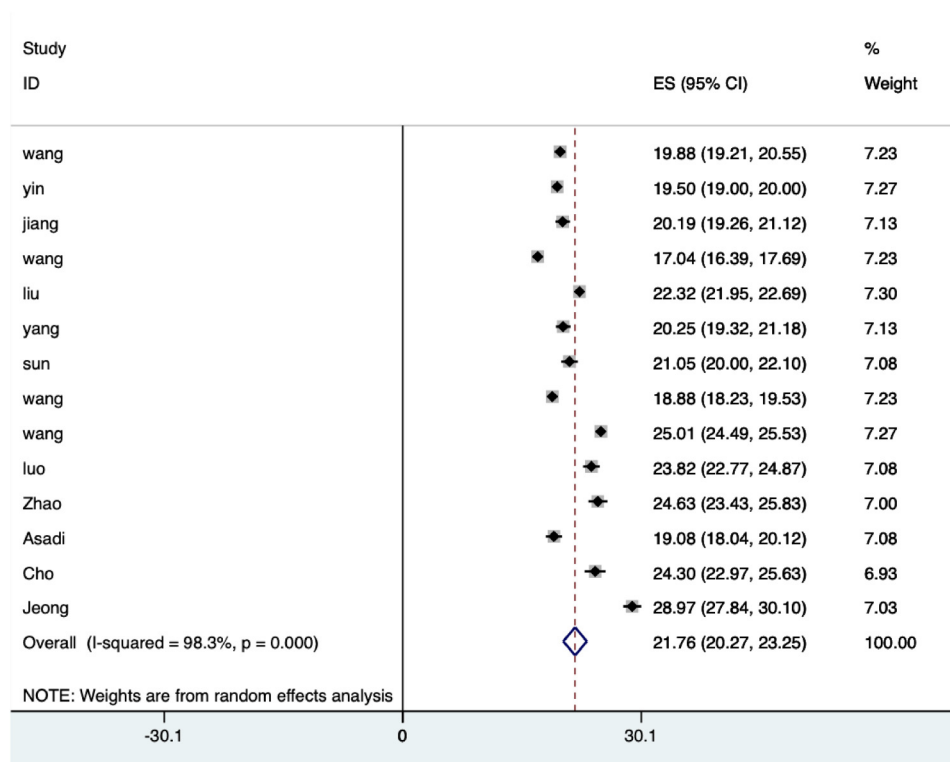


Figure 2. Forest plot of alarm fatigue score.

can effectively control the alarm fatigue of nurses (Nyarko et al., 2022). Therefore, it is necessary to carry out training for different nurse groups to reduce alarm fatigue.

Device Factors. Numerous false alarms and alarm-generating devices can easily lead to alarm fatigue, and most alarms lack clinical relevance (Simpson & Lyndon, 2019). Medical equipment sends alarm signals that do not need priority treatment for low-priority events (Johnson et al., 2017), and frequent monitor alarms often distract nurses' attention. False alarms due to faulty ECG leads, oximeter probes, or motion interference probes can also seriously cause alarm fatigue. In Alsaad's study, a total of 8,336 alarms were recorded during 4 weeks of monitoring instrument data collection, of which only 333 (4%) were actually actionable alarms (Alsaad, 2017). Kern-Goldberger pointed out that excessive monitoring can increase the risk of alarm fatigue, which could have a negative impact on nursing effect and lead to clinical nurses not being able to observe abnormal vital signs in time (Kern-Goldberger et al., 2022). Simpson pointed out that monitoring-only patients who need to be monitored and physiological indicators determined according to patients' conditions can reduce alarm burden and thus improve alarm fatigue (Simpson & Lyndon, 2019). Various problems in the design and practical use of patient monitoring systems can also lead to alarm fatigue (Kobayashi et al., 2017). Multidisciplinary teams should

facilitate informatics research to alleviate alarm fatigue. Alarm fatigue due to low-priority alerts can be reduced by extending alert delays, changing to visual alerts, or even considering eliminating alerts altogether (Cvach et al., 2013). A study describing the effect of implementing a nurse-driven, evidence-based, patient-customized monitoring package CEASE showed that reducing the number of monitoring alarms improved nurses' perception of alarm fatigue (Lewis & Oster, 2019). The specific meaning of this monitoring package CEASE is Communication, Electrodes (daily change), Appropriateness (assessment), and Setup alarm, an acronym for setting alarm parameters (patient customization), and education (Ongoing).

Alarm-Setting Factors. Alarm fatigue can lead to delayed or nonresponse to alarms related to patient safety, resulting in low job satisfaction and adverse nursing safety events, among which the reasons for alarm fatigue include the increase in alarm-related workload (Shanmugham et al., 2018). Frequent false alarms lead to reduced attention to or response to alarms, which is the primary obstacle to effective alarm management (Casey et al., 2018). Approximately 90% of nurses felt that inoperable alarms were frequent, disrupting patient care, and that trust in alarms was reduced, prompting nurses to sometimes disable the alarms. In Chromik's study, for both patients and healthcare workers, excessive alarms can cause stress, lead to distractions at work, and disrupt

circadian rhythms (Chromik et al., 2022). Shanmugham showed that modifying alarm threshold based on patients' conditions had a positive impact on the accurate handling of alarms and nurses' overall satisfaction (Shanmugham et al., 2018). However, clinical data are needed to guide practical decisions, such as when the setting of low oxygen saturation alarm limits and alarm delays can ensure patient safety and minimize alarm fatigue (Johnson et al., 2017). Alarm fatigue is a multidisciplinary problem requiring a multidisciplinary approach, and the solutions involve various aspects, such as reducing false alarms, setting alarm priorities, and alarm presentation content (Chromik et al., 2022). Scott et al. pointed out in their study on the correlation between alarm fatigue and alarm fatigue generated by mechanical ventilation equipment that patients may be desensitized to alarm sound due to alarm fatigue and ignore alarms that alert about patient injury (Scott et al., 2019). However, in Micah Seifert's quality improvement project on alarm management, through the management of problematic physiological alarms, the alarm fatigue of nurses did not decrease despite the reduction in alarm frequency (Seifert et al., 2021).

Limitations of the Study

Due to language limitations, only Chinese and English articles were included in this study, and all of them were cross-sectional studies, which poses an inevitable risk of bias. The influencing factors involved in this study were many but inconsistent, and the common influencing factors included in the study were few; therefore, it was not possible to conduct a meta-analysis on the influencing factors of a single study. In addition, a convenience sampling method was used in most of the included studies, which may have sampling errors. This conclusion needs to be verified using multicenter and large-sample studies.

Conclusion

To sum up, this study systematically evaluated the influencing factors of alarm fatigue in clinical nurses and found that there was a moderate level of alarm fatigue among clinical nurses. The results also showed that night shift, different professional titles, high false alarm rate, and excessive monitoring alarm were risk factors for alarm fatigue in clinical nurses. To reduce nurse alarm fatigue, managers need to develop reasonable intervention strategies to improve the alarm frequency and alarm level of various equipment and rationally organize nurse work shift.

An important part of the alarm management strategy is to educate nurses about alarm and pay attention to the assessment of alarm fatigue. Therefore, the next step will be to investigate the knowledge, attitude, and behavior of nurses about alarm fatigue from commonly used monitoring devices, in order to provide a basis for targeted intervention strategies.

How does this paper contribute to the wider global clinical community?

- Alarm fatigue can lead to serious adverse nursing events and harm patient safety. The research on the influencing factors of alarm fatigue can provide the basis for further intervention.
- Current studies on alarm fatigue focus on nurses in intensive care unit, but alarm fatigue does not only occur in this group. We systematically reviewed the status quo and influencing factors of alarm fatigue in nurse groups, including anesthesia nurses and emergency nurses.
- More high-quality studies are needed to confirm whether avoiding these influencing factors can reduce alarm fatigue in nurses.

Acknowledgments

First of all, I would like to express my gratitude to all those who helped me during the writing of this thesis. I gratefully acknowledge the help of my supervisor, who has offered me valuable suggestions in the academic studies. Second, I am also deeply indebted to all the authors in this study; with their help and teamwork, we finished this paper perfectly. Last, I should finally like to express my gratitude to my beloved family who have always been helping me and supporting without a word of plaint.

Author contributions

C.S.: conceptualization, methodology, data curation, writing—original draft, writing—review and editing, and project administration. Z.H.: conceptualization, methodology, resources, writing—review, and editing. W.S.: methodology, and data curation. J.R.: methodology and data curation. Z.H.: writing—reviewing and supervision. Z.H.: writing—reviewing and supervision. Z.H.: writing—reviewing. W.J.: writing—review and proof checking.


Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by the Medical Education Research project of Henan Province (Wjlx2020385).

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