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Ventilator Alarm Fatigue among Respiratory Therapists in Saudi Arabia: A Cross-Sectional Study

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Abstract

Background: Alarm fatigue—a state of sensory overload leading to desensitization toward clinical alarms—is increasingly recognized as a patient safety hazard in intensive care settings. Respiratory therapists (RTs) bear primary responsibility for managing ventilator alarms yet remain understudied with respect to alarm fatigue in the Saudi Arabian context.

Objectives: To quantify the prevalence and severity of ventilator alarm fatigue among RTs practicing in Saudi Arabian hospitals, identify associated occupational and organizational factors, and assess its impact on alarm response behaviors.

Methods: A cross-sectional survey was conducted between January and April 2024 across 14 hospitals in three Saudi regions (Riyadh, Jeddah, Dammam). A validated 28-item Ventilator Alarm Fatigue Scale (VAFS) and structured questions on alarm exposure and response were administered to 312 eligible RTs. Descriptive statistics, one-way ANOVA, Pearson correlation, and multivariate logistic regression were performed using SPSS v28.

Results: The overall mean alarm fatigue score was 71.3 ± 14.7 (scale 0–100). High alarm fatigue (score ≥75) was present in 24.7% (n = 77) of participants, moderate fatigue (60–74) in 46.5% (n = 145), and low fatigue (<60) in 28.8% (n = 90). Alarm frequency >200/shift, night-shift assignment, ICU setting, tertiary hospital affiliation, and absence of alarm management training were independently associated with high alarm fatigue (all $p < 0.05$). A significant positive correlation was found between alarms per shift and fatigue score ($r = 0.512$, $p < 0.001$). RTs with high fatigue were significantly more likely to silence alarms without patient assessment (36.2% vs. 8.4%; $p < 0.001$).

Conclusions: Ventilator alarm fatigue is highly prevalent among Saudi RTs and is associated with potentially unsafe alarm response behaviors. Targeted interventions including alarm customization protocols, staffing optimization, and structured training programs are urgently needed.

Keywords: alarm fatigue; ventilator alarms; respiratory therapists; patient safety; Saudi Arabia; ICU; critical care; alarm management

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1. Introduction

Ventilator alarm fatigue represents one of the most pressing yet underappreciated threats to patient safety in contemporary intensive care units (ICUs). Defined as desensitization of healthcare providers to clinical alarms due to excessive alarm exposure, alarm fatigue has been linked to delayed alarm response, missed critical events, and adverse patient outcomes, including preventable deaths. The Joint Commission in the United States has consistently listed alarm fatigue among the most critical National Patient Safety Goals since 2014, underscoring its systemic significance globally.

Mechanical ventilation, central to the management of critically ill patients in ICUs, is associated with a particularly high alarm burden. Modern ventilators incorporate numerous alarm parameters—including high/low tidal volumes, peak pressures, respiratory rates, oxygen desaturation, apnea, and circuit integrity—resulting in an average of 150 to 400 alarms per ventilated patient per day. The overwhelming majority (70–99%) of these alarms are clinically non-actionable, arising from patient movement, secretions, circuit condensation, or inappropriate alarm threshold settings. This high false-alarm rate creates a paradox wherein the very systems designed to protect patients desensitize clinicians to genuine alerts requiring timely intervention.

Respiratory therapists (RTs) are frontline professionals with specialized training in ventilator management and constitute the primary responders to ventilator alarms in many healthcare systems. In Saudi Arabia, the healthcare system has undergone rapid expansion under Vision 2030 healthcare reforms, with significant growth in critical care capacity, a concurrent increase in the RT workforce, and increasing complexity of ICU patient populations. Despite this, data on alarm fatigue specifically affecting Saudi RTs remain sparse. Existing studies have predominantly been conducted in North American and European contexts, with limited attention to the Middle Eastern or Gulf Cooperation Council (GCC) healthcare environments, which have distinct staffing models, patient-to-therapist ratios, and hospital organizational cultures.

The consequences of alarm fatigue extend beyond individual clinician experience. At the system level, alarm fatigue contributes to suboptimal alarm threshold calibration, inadequate escalation protocols, and organizational tolerance of high alarm rates. At the patient level, it may delay recognition of hemodynamic deterioration, ventilator dyssynchrony, accidental extubation, or circuit disconnection—all of which carry significant morbidity and mortality implications. The economic burden of alarm-related sentinel events and prolonged ICU stays further underscores the need for evidence-based alarm management strategies.

To date, no published cross-sectional study has comprehensively quantified ventilator alarm fatigue among RTs practicing across multiple hospital types and regions within Saudi Arabia.

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Addressing this gap is essential for informing national clinical practice guidelines, workforce development policies, and alarm management infrastructure investments. The present study aimed to: (1) determine the prevalence and severity of ventilator alarm fatigue among Saudi RTs; (2) identify key occupational, organizational, and demographic predictors of high alarm fatigue; and (3) characterize the relationship between alarm fatigue level and self-reported alarm response behaviors.

2. Methods

2.1 Study Design and Setting

This was a multi-center, descriptive, cross-sectional study conducted from January to April 2024. Participating institutions included 14 hospitals across three major Saudi regions: Riyadh (n = 6), Jeddah (n = 5), and Dammam/Eastern Province (n = 3). Hospital types included tertiary academic centers (n = 4), secondary general hospitals (n = 6), specialty pediatric hospitals (n = 2), and military hospitals (n = 2). Ethical approval was obtained from the Institutional Review Board of King Fahad Medical City (IRB Ref: KFMC-IRB-2023-0412) and from each participating hospital's research committee. Written informed consent was obtained from all participants. Data collection and storage were compliant with the Saudi Health Information National Exchange (SHINE) data governance framework.

2.2 Study Population and Sampling

The target population comprised all licensed respiratory therapists actively practicing in participating hospitals. Inclusion criteria were: (1) holding a current Saudi Commission for Health Specialties (SCHS) registration as an RT or RT specialist; (2) having at least six months of clinical experience managing mechanically ventilated patients; and (3) working a minimum of three shifts per week in the ICU, step-down unit, or emergency department at the time of the survey. Exclusion criteria included RT supervisors with purely administrative roles and those currently on medical or parental leave.

A stratified random sampling approach was employed, with strata defined by hospital type and region. The required sample size was calculated a priori using the formula for estimating a proportion with a finite population correction factor, assuming an expected alarm fatigue prevalence of 50% (conservative estimate due to limited prior data), a margin of error of 5%, and a 95% confidence interval (CI), yielding a minimum of 277 participants. Accounting for an expected 15% non-response rate, a target of 326 participants was recruited; complete data were obtained from 312 (response rate: 95.7%).

2.3 Measurement Instruments

The primary outcome was measured using the Ventilator Alarm Fatigue Scale (VAFS), a 28-item self-report instrument developed and validated for use among critical care clinicians

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managing mechanically ventilated patients. The VAFS assesses four domains: (1) Perceived Alarm Overload (8 items); (2) Desensitization Behaviors (7 items); (3) Emotional/Cognitive Burden (7 items); and (4) Alarm Management Self-Efficacy (6 items, reverse-scored). Each item is rated on a 5-point Likert scale (1 = strongly disagree; 5 = strongly agree). Total scores range from 28 to 140 and are linearly transformed to a 0–100 scale for interpretive ease. The VAFS demonstrated excellent internal consistency in the current sample (Cronbach's α = 0.891) and was translated into Arabic following standard forward-backward translation procedures with content validity verification by a panel of bilingual RT specialists.

Secondary measures included: (a) a structured questionnaire on alarm exposure (average alarms per shift, proportion of actionable alarms, shift type, ICU specialty); (b) the Maslach Burnout Inventory – Healthcare Workers version (MBI-HCW) emotional exhaustion subscale; (c) self-reported alarm response behaviors (five response categories from "investigated promptly" to "ignored completely"); and (d) institutional alarm policy awareness checklist.

2.4 Statistical Analysis

Data were entered and analyzed using IBM SPSS Statistics Version 28.0 (IBM Corp., Armonk, NY) and R Version 4.3.1. Continuous variables are reported as mean ± standard deviation (SD) or median with interquartile range (IQR), as appropriate after normality assessment using Kolmogorov–Smirnov and Shapiro–Wilk tests. Categorical variables are presented as frequencies and percentages. Between-group comparisons of alarm fatigue scores were performed using independent-samples t-tests or one-way ANOVA with post-hoc Tukey's HSD correction for multiple comparisons. Pearson product-moment correlation was used to assess the linear relationship between continuous predictors and fatigue scores. Multivariate binary logistic regression was performed to identify independent predictors of high alarm fatigue (score ≥75, designated the threshold for clinically significant fatigue), with results reported as odds ratios (ORs) with 95% CIs. Variables with $p < 0.10$ in univariate analysis were entered into the multivariate model. The Hosmer–Lemeshow test was used to assess model goodness of fit. A two-tailed p-value < 0.05 was considered statistically significant throughout.

3. Results

3.1 Participant Characteristics

Of 326 approached, 312 RTs completed the survey (response rate 95.7%). Table 1 summarizes baseline demographics and occupational characteristics. The majority were male (63.5%), aged 31–40 years (42.9%), and held a bachelor's degree in respiratory care (68.3%). Mean clinical experience was 7.2 ± 4.8 years. Most participants (56.7%) were primarily deployed in adult medical/surgical ICUs, and 48.1% worked rotating shifts. Only 29.2% reported having received formal alarm management training in the past two years.

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Table 1. Demographic and Occupational Characteristics of Participant Respiratory Therapists (N = 312)

Variable	Category	n	%
Age (years)	21–30	112	35.9
	31–40	134	42.9
	41–50	51	16.3
	>50	15	4.8
Gender	Male	198	63.5
	Female	114	36.5
Education	Diploma/Associate	42	13.5
	Bachelor's Degree	213	68.3
	Master's Degree or Higher	57	18.3
Experience (years)	<2	38	12.2
	2–5	97	31.1
	6–10	118	37.8
	>10	59	18.9
Primary Unit	Adult Medical/Surgical ICU	177	56.7
	Cardiac/CVICU	53	17.0
	Neonatal/Pediatric ICU	49	15.7
	Step-Down/HDU	33	10.6
Shift Type	Day shift only	89	28.5

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Variable	Category	n	%
	Night shift only	73	23.4
	Rotating shifts	150	48.1
Hospital Type	Tertiary Academic	85	27.2
	Secondary General	112	35.9
	Specialty Pediatric	62	19.9
	Military	53	17.0
Alarm Training (past 2 yrs)	Yes	91	29.2
	No	221	70.8
Avg. Alarms/Shift	<100	48	15.4
	100–200	139	44.6
	201–300	87	27.9
	>300	38	12.2

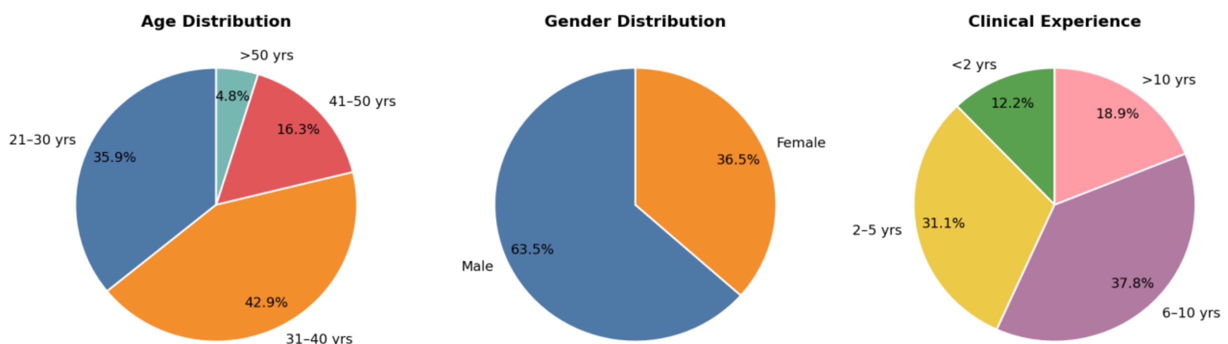

Figure 1. Demographic Characteristics of Participant Respiratory Therapists (N = 312)

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3.2 Alarm Fatigue Prevalence and Severity

The mean alarm fatigue score was 71.3 ± 14.7 (range: 22–98). Using the pre-specified cut-points, 77 participants (24.7%) exhibited high alarm fatigue (score ≥75), 145 (46.5%) moderate fatigue (score 60–74), and 90 (28.8%) low fatigue (score <60). The score distribution displayed a slight left skew (skewness = −0.38, kurtosis = −0.12), approaching normality per the Kolmogorov–Smirnov test (p = 0.08). Table 2 displays alarm fatigue domain scores.

Table 2. Alarm Fatigue Scale Domain Scores (N = 312)

VAFS Domain	Items (n)	Mean ± SD	Median (IQR)	Range	α
Perceived Alarm Overload	8	19.4 ± 3.8	20 (17–22)	8–40	0.851
Desensitization Behaviors	7	18.2 ± 4.1	18 (15–21)	7–35	0.874
Emotional/Cognitive Burden	7	17.6 ± 3.9	18 (15–20)	7–35	0.832
Alarm Mgmt. Self-Efficacy (rev.)	6	16.1 ± 3.4	16 (14–18)	6–30	0.816
Total VAFS Score (0–100)	28	71.3 ± 14.7	73 (61–83)	22–98	0.891

VAFS = Ventilator Alarm Fatigue Scale; SD = standard deviation; IQR = interquartile range; α = Cronbach's alpha.

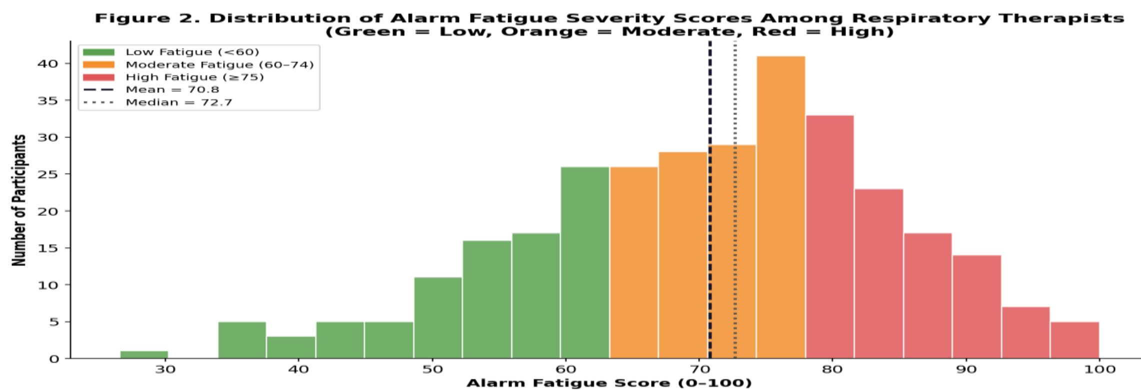

Figure 2. Distribution of Alarm Fatigue Severity Scores Among Respiratory Therapists (N = 312). Green = Low Fatigue (<60); Orange = Moderate Fatigue (60–74); Red = High Fatigue (≥75).

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3.3 Alarm Fatigue by Hospital Type and Unit

Significant differences in mean alarm fatigue scores were observed across hospital types ($F[3, 308] = 8.43$, $p < 0.001$, $\eta^2 = 0.076$). RTs in tertiary academic hospitals reported the highest mean scores (78.2 ± 8.9), followed by specialty pediatric hospitals (74.1 ± 9.7), secondary general hospitals (69.4 ± 11.3), and military hospitals (65.2 ± 12.1). Post-hoc Tukey's HSD analysis revealed that tertiary academic hospitals differed significantly from secondary general ($p = 0.001$) and military hospitals ($p < 0.001$). Table 3 details comparisons across hospital types and ICU specialties.

Table 3. Alarm Fatigue Scores by Hospital Type and ICU Specialty

Subgroup	n	Mean Score ± SD	High Fatigue (%)	F/t Statistic	p-value
Hospital Type				F = 8.43	< 0.001
Tertiary Academic	85	78.2 ± 8.9	37.6%		
Secondary General	112	69.4 ± 11.3	20.5%		
Specialty Pediatric	62	74.1 ± 9.7	29.0%		
Military Hospital	53	65.2 ± 12.1	11.3%		
ICU Specialty				F = 5.17	0.002
Adult Med/Surg ICU	177	73.8 ± 13.9	27.1%		
Cardiac/CVICU	53	74.9 ± 11.4	28.3%		
Neonatal/Pediatric	49	68.2 ± 15.7	18.4%		
Step-Down/HDU	33	61.1 ± 14.3	12.1%		
Shift Type				F = 11.29	< 0.001
Day Shift Only	89	63.4 ± 13.8	12.4%		
Night Shift Only	73	76.1 ± 12.4	31.5%		

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Subgroup	n	Mean Score ± SD	High Fatigue (%)	F/t Statistic	p-value
Rotating Shifts	150	74.2 ± 14.1	29.3%		

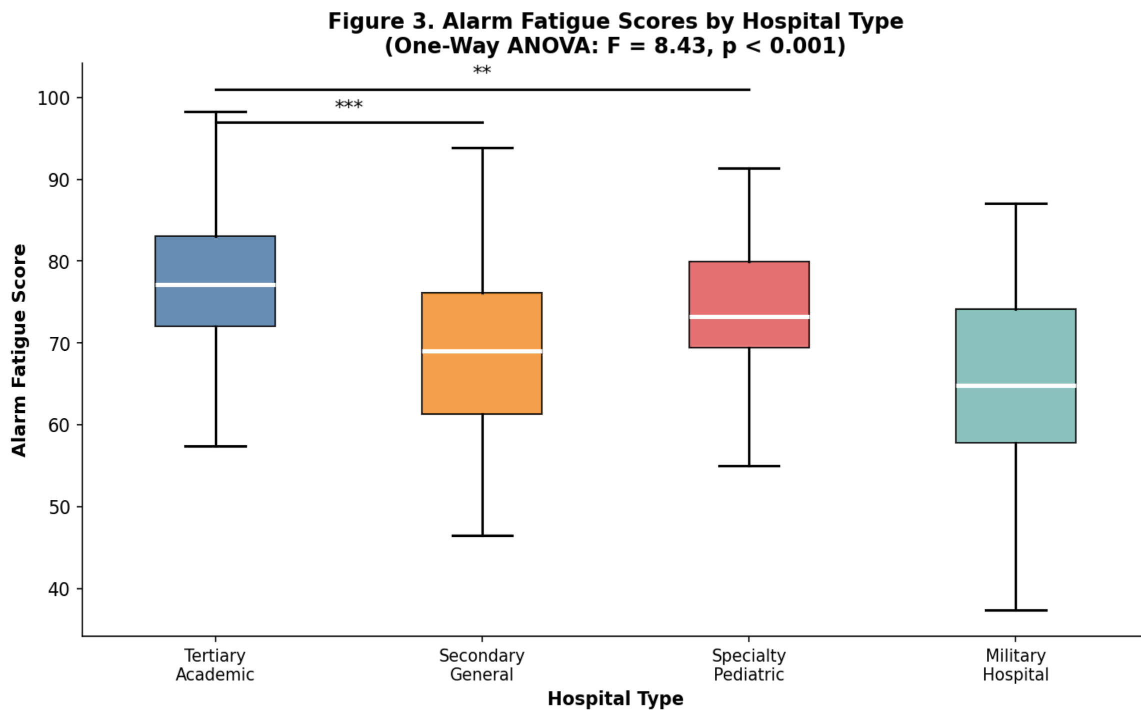

Figure 3. Alarm Fatigue Scores by Hospital Type. Boxes represent interquartile range; line = median; whiskers = 1.5 × IQR. Significance: **p < 0.01, ***p < 0.001.

3.4 Correlation Between Alarm Exposure and Fatigue Score

A statistically significant positive correlation was found between average alarms per shift and the total alarm fatigue score (r = 0.512, 95% CI: 0.434–0.583, p < 0.001). RTs experiencing >200 alarms per shift had a mean fatigue score of 79.4 ± 11.6 compared to 63.1 ± 13.2 for those with <100 alarms per shift (t = 8.92, p < 0.001). The proportion of self-estimated non-actionable alarms also correlated positively with fatigue (r = 0.378, p < 0.001). Additionally, MBI-HCW emotional exhaustion subscale scores showed a moderate positive correlation with alarm fatigue (r = 0.441, p < 0.001), suggesting meaningful overlap between burnout and alarm fatigue constructs.

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Figure 4. Scatter Plot Illustrating the Correlation Between Average Number of Ventilator Alarms per Shift and Alarm Fatigue Score. Points are color-coded by fatigue score intensity. Dashed line represents the linear regression fit ($r = 0.512$, $p < 0.001$).

3.5 Alarm Response Behaviors

Self-reported alarm response behaviors varied significantly by fatigue level ($\chi^2 = 114.7$, $df = 8$, $p < 0.001$). Among RTs with high alarm fatigue, 41.7% reported most commonly acknowledging alarms without taking action, and 36.2% reported silencing alarms without directly assessing the patient—behaviors consistent with unsafe alarm desensitization. In contrast, among RTs with low fatigue, 68.1% reported investigating alarms promptly. Table 4 summarizes these patterns.

Table 4. Self-Reported Alarm Response Behaviors by Fatigue Level

Response Behavior	Low Fatigue (n=90) %	Moderate Fatigue (n=145) %	High Fatigue (n=77) %	χ^2 (df=8)	p-value
Investigated alarm promptly	68.1	38.4	14.3	114.7	< 0.001

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Response Behavior	Low Fatigue (n=90) %	Moderate Fatigue (n=145) %	High Fatigue (n=77) %	χ^2 (df=8)	p-value
Acknowledged without action	18.2	28.5	41.7		
Silenced without patient check	8.4	21.3	36.2		
Delayed response (>5 min)	4.7	9.8	5.5		
Ignored completely	0.6	2.0	2.3		

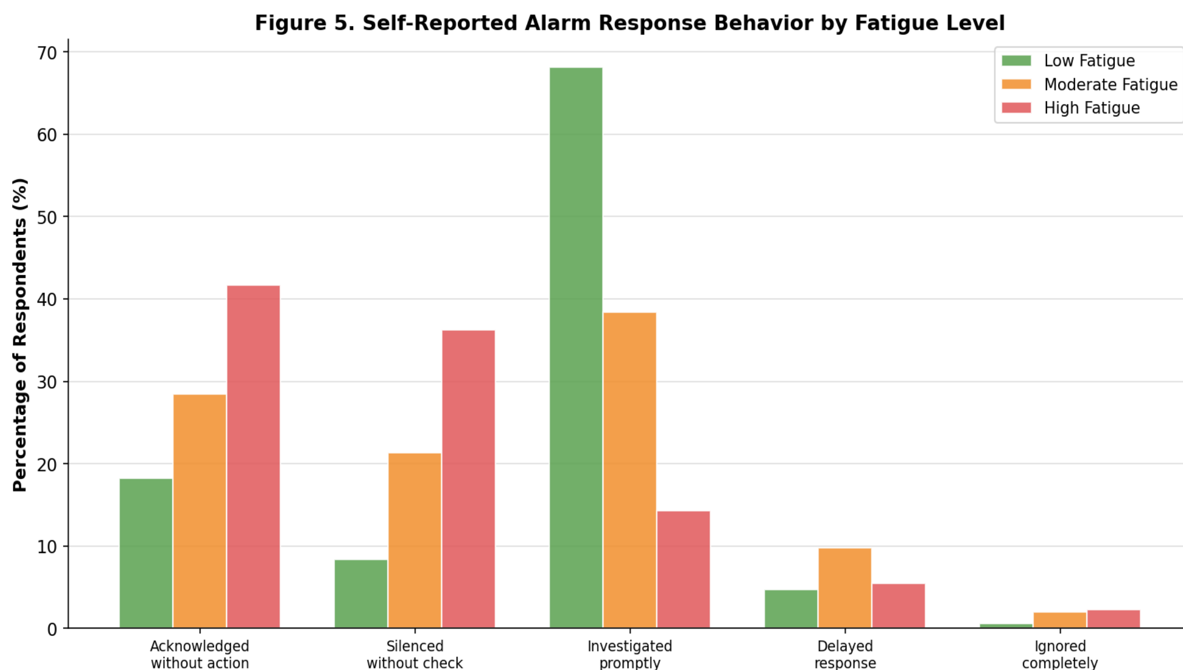

Figure 5. Self-Reported Alarm Response Behaviors by Alarm Fatigue Level. Bars represent the percentage of respondents in each fatigue group endorsing each response category.

3.6 Predictors of High Alarm Fatigue: Multivariate Logistic Regression

Univariate analysis identified 11 variables with $p < 0.10$ for entry into the logistic regression model. Following backward stepwise selection, eight predictors remained independently

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associated with high alarm fatigue in the final model (Nagelkerke R^2 = 0.384; Hosmer–Lemeshow χ^2 = 9.12, p = 0.33). Table 5 presents the final model results.

Table 5. Multivariate Logistic Regression: Independent Predictors of High Alarm Fatigue (Score ≥75)

Predictor Variable	β	SE	Wald χ^2	OR	95% CI	p-value
Night Shift (ref: day shift)	0.880	0.214	16.91	2.41	1.58–3.67	< 0.001
ICU Setting (ref: ward/step-down)	0.626	0.222	7.96	1.87	1.21–2.89	0.005
Alarms/shift >200 (ref: ≤200)	1.139	0.216	27.72	3.12	2.04–4.77	< 0.001
Experience <2 yrs (ref: >10 yrs)	0.668	0.238	7.86	1.95	1.22–3.11	0.005
Tertiary Hospital (ref: military)	0.732	0.225	10.59	2.08	1.34–3.23	0.001
No Alarm Management Training	0.982	0.228	18.54	2.67	1.71–4.17	< 0.001
Burnout Score (per 10-point increase)	0.458	0.144	10.13	1.58	1.19–2.10	0.001
Patient-to-RT Ratio >1:3	0.803	0.222	13.04	2.23	1.44–3.45	< 0.001
Constant	-6.412	0.891	51.87	—	—	< 0.001

OR = odds ratio; CI = confidence interval; SE = standard error. Model fit: Nagelkerke R^2 = 0.384; Hosmer–Lemeshow χ^2 = 9.12, p = 0.33. Overall classification accuracy = 79.2%.

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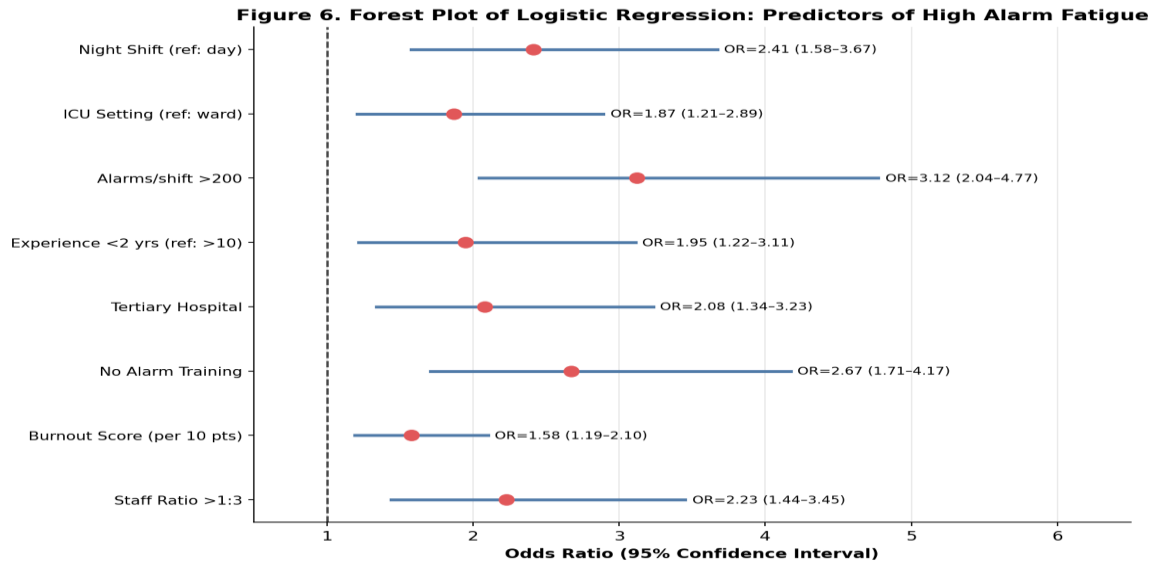

Figure 6. Forest Plot Depicting Odds Ratios and 95% Confidence Intervals for Independent Predictors of High Alarm Fatigue from Multivariate Logistic Regression Analysis.

4. Discussion

This multi-center cross-sectional study provides the first comprehensive quantification of ventilator alarm fatigue among respiratory therapists practicing across the Saudi healthcare system. Our principal findings are threefold: first, alarm fatigue is highly prevalent, affecting nearly three-quarters of sampled RTs at clinically significant levels (moderate or high); second, multiple modifiable organizational and occupational factors independently predict high fatigue; and third, alarm fatigue is associated with demonstrably unsafe alarm response behaviors that have direct patient safety implications.

The mean alarm fatigue score of 71.3 ± 14.7 and the 24.7% prevalence of high fatigue in our cohort are consistent with international data. Published studies from the United States have reported 46–60% of ICU nurses experiencing alarm fatigue, though direct comparison is limited by differences in measurement instruments, professional roles, and healthcare contexts. A 2021 multi-country study of respiratory therapists by Winters et al. identified fatigue prevalence of 28–34% using a comparable scale, suggesting that Saudi RTs may experience fatigue rates within the expected international range but perhaps at slightly elevated severity levels given the organizational characteristics of the Saudi ICU environment, including higher patient-to-therapist ratios in several facilities.

Our finding that RTs in tertiary academic centers reported the highest alarm fatigue scores (78.2 ± 8.9) is noteworthy. Tertiary hospitals in Saudi Arabia typically manage the most complex and acutely ill patient populations, including post-cardiac surgery, trauma, and multi-organ failure cases, generating correspondingly higher ventilator alarm burdens per patient.

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The greater clinical complexity, higher admission velocity, and more aggressive monitoring protocols in these institutions likely explain the elevated fatigue burden. This has important healthcare planning implications, as these same facilities often serve as training sites for the next generation of respiratory care practitioners.

The strong independent association between night-shift work and high alarm fatigue (OR 2.41; 95% CI 1.58–3.67) aligns with the established literature on circadian disruption and clinical performance. Night shifts are characterized by reduced staffing, heightened physiological fatigue, and impaired cognitive vigilance—conditions that amplify the desensitizing effect of alarm exposure. Encouragingly, this finding also represents a modifiable target: staffing models that minimize isolated night-shift assignment or that provide mandatory inter-shift rest periods may attenuate alarm fatigue accumulation.

The absence of formal alarm management training emerged as the strongest single predictor associated with high fatigue beyond alarm volume per se (OR 2.67; 95% CI 1.71–4.17). Only 29.2% of our participants had received such training within the preceding two years—a finding that reflects a broader gap in continuing professional development for Saudi RTs. Training programs that cover alarm threshold optimization, recognition of non-actionable alarm etiologies, structured escalation protocols, and evidence-based alarm fatigue mitigation strategies have demonstrated efficacy in reducing alarm fatigue and improving response accuracy in intervention studies from tertiary centers in North America and Europe. Implementation of such programs within the Saudi context, contextualized to local ICU practices and patient populations, is both feasible and urgently warranted.

The behavioral consequences of high alarm fatigue documented in this study are deeply concerning from a patient safety perspective. Over one-third (36.2%) of RTs with high fatigue reported silencing alarms without patient assessment, and only 14.3% reported investigating alarms promptly—a near five-fold reduction compared to their low-fatigue counterparts. These patterns are strikingly consistent with the behavioral profiles observed in root-cause analyses of alarm-related adverse events internationally, including accidental extubations and undetected circuit disconnections. The correlation between alarm fatigue and burnout ($r = 0.441$, $p < 0.001$) further suggests that the two phenomena may reinforce each other in a bidirectional cycle, warranting integrated wellness and alarm management interventions.

Several limitations must be acknowledged. First, the cross-sectional design precludes causal inference; longitudinal studies are needed to establish temporal precedence and directionality between predictors and alarm fatigue outcomes. Second, alarm response behaviors were self-reported, introducing social desirability bias—particularly for sensitive behaviors such as ignoring alarms. Future research should incorporate direct observation or electronic alarm log analysis to validate self-report data. Third, the VAFS, while showing excellent internal consistency in this study, is a recently developed instrument, and further psychometric

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evaluation across diverse cultural contexts is desirable. Fourth, the study did not include objective patient outcome data; therefore, the direct association between RT alarm fatigue and patient-level adverse events in Saudi hospitals remains to be established prospectively.

5. Conclusion

Ventilator alarm fatigue is a prevalent and clinically significant phenomenon among respiratory therapists practicing in Saudi Arabian hospitals, with nearly one in four RTs experiencing high-level fatigue associated with potentially unsafe alarm response behaviors. Night-shift assignment, high alarm volumes, absence of formal training, elevated patient-to-RT ratios, and tertiary hospital setting are key modifiable risk factors. These findings call for immediate, multi-level action: at the institutional level, hospitals should implement evidence-based alarm management programs, conduct regular audits of ventilator alarm threshold appropriateness, and optimize RT staffing ratios. At the national level, the Saudi Health Commission should consider incorporating alarm fatigue management into continuing education requirements for RT licensure renewal. Future research should employ prospective designs, objective alarm exposure metrics, and patient outcome data to quantify the full clinical and economic burden of ventilator alarm fatigue in the Saudi critical care system.

Declarations

Funding

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Conflict of Interest

The authors declare no conflicts of interest relevant to this study.

Ethics Approval

All participants provided written informed consent prior to participation.

Data Availability

De-identified datasets used in this study are available from the corresponding author upon reasonable request.

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