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Title

Noise Pollution in the Intensive Care Unit: A Mixed-Methods Exploration of Lebanese Nurses Perceptions

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Abstract

Background: Noise in intensive care units (ICUs) is a recognized environmental hazard, yet most evidence documents its prevalence and sources rather than how nurses experience, interpret, and absorb sustained exposure, particularly in low- and middle-income country (LMIC) settings, where systemic strain may reshape that experience.

Aim: To examine ICU nurses' perceptions of noise sources and their perceived effects on health, occupational functioning, and burnout, and to explore their lived experiences of noise exposure, coping strategies, and perceptions of organizational responses to noise.

Methods: A convergent mixed-methods design was used. A cross-sectional survey of 228 ICU nurses across Lebanon assessed perceived noise sources, burnout, and the perceived impact of noise across four domains (subjective perception, emotion, physiology, performance). Semi-structured interviews with 20 ICU nurses were thematically analyzed. Qualitative and quantitative components were integrated during interpretation to compare, contrast, and explain findings.

Results: Most noise sources were rated "moderate" by the majority of nurses, with monitor alarms, the most frequently cited high-level source (50%). Impact scores exceeded the domain midpoint for subjective perception (11.0 ± 3.4/20), emotion (13.8 ± 4.4/25), and physiology (14.2 ± 4.3/25), and fell below it for performance (10.6 ± 4.2/25); impact varied significantly by region across all domains ($p \leq 0.017$), highest in Bekaa and lowest in North Lebanon. Burnout was at the onset threshold (mean 3.5 ± 1.2/7). Perceived impact increased with longer hospital ($r = 0.17$, $p = 0.009$) and ICU experience ($r = 0.13$, $p = 0.046$), even as nurses reported the least effect on performance. Qualitative accounts helped explain this pattern: nurses described "getting used to" noise while continuing to report impaired concentration, repeated tasks, tinnitus, and headaches that persisted after their shifts, alongside informal, individually driven coping and inconsistent institutional responses.

Conclusion: Getting used to" ICU noise is compensatory endurance that preserves task performance while cognitive and emotional costs accumulate as early burnout. Because systems lean on individual adaptation, the burden is silently displaced onto staff, a dynamic intensified in an unstable LMIC context. These findings support the need for system-level mitigation rather than individual habituation.

Keywords: Intensive care units; Occupational noise; Nurses' wellbeing; Professional burnout; Mixed-methods study; Lebanon

Introduction

Intensive care units (ICUs) are among the noisiest environments in any hospital. Sound levels routinely exceed the World Health Organization's recommended threshold of 35 dBA, often reaching 60 dBA or higher during the day, driven by the continuous operation of ventilators, infusion pumps, and monitors, overlapping staff communication, patient and family activity, and structural sounds such as doors opening and closing (Kebapcı & Güner, 2021; Konkani & Oakley, 2012; Kooshanfar et al., 2022; Pal et al., 2022; Terzi et al., 2019). For the nurses who work within them, this exposure is not incidental but sustained, and it carries measurable costs. Prolonged exposure has been linked to headaches, stress, anxiety, irritability, insomnia, fatigue, and long-term hearing impairment, and it threatens patient safety by disrupting communication, eroding concentration, and increasing the likelihood of clinical error (Kooshanfar et al., 2022; Pal et al., 2022; Terzi et al., 2019). ICU noise is therefore best understood not as background discomfort but as a chronic occupational stressor with consequences for both staff wellbeing and care quality.

Despite this recognition, nurses actually experience with and management of sustained noise exposure remains poorly understood, in part because the quantitative and qualitative evidence have been developed in isolation from one another. Quantitative studies have largely measured sound levels across hospital units, identified peak periods, and assessed compliance with recommended thresholds, but they were not able to access how nurses interpret or cope with what they hear (Darbyshire & Young, 2013; Scquizzato et al., 2020). Qualitative studies, on the other hand, have explored healthcare professionals' perceptions of noise and its perceived impact on practice but could not situate that lived experience within objective exposure patterns (Kebapcı & Güner, 2021; Kooshanfar et al., 2022). Neither approach alone captures the full complexity of ICU noise as a perceived and managed phenomenon, and the interplay between nurses' characteristics, their working conditions, and the consequences they report remains underexplored (Kooshanfar et al., 2022; Shorten & Smith, 2017). Therefore, an integrated, mixed-methods perspective is needed to bridge measurable exposure and the subjective experience that shapes how nurses adapt to it.

This gap is most consequential in low- and middle-income countries (LMICs), where strained health systems may amplify the burden of environmental stressors, yet where evidence is scarcest. Lebanon offers a salient case. Since the onset of its multisectoral crisis in 2019, the health sector has faced collapsing salaries, large-scale nurse migration, staffing shortages, deteriorating nurse-to-patient ratios, and variable infrastructure and equipment maintenance, leaving ICU teams increasingly exposed to cumulative occupational stressors (Bourji et al., 2020; Dankar & Ammar, 2025; Soubra et al., 2018). Research on hospital noise in this setting is nonetheless minimal: prior Lebanese work has examined alarm fatigue among clinicians (Bourji et al., 2020) and a noise-reduction initiative in a pediatric unit (Soubra et al., 2018), but no study has examined ICU noise from the perspective of nurses themselves. More broadly, the few LMIC studies available have prioritized sound-level measurement over nurses' subjective experience, leaving the intersection of structural vulnerability and occupational noise largely unexamined (Kooshanfar et al., 2022). Lebanon thus represents both an understudied national context and a critically relevant case for understanding how systemic instability shapes nurses' exposure and responses to ICU noise.

The present study addresses these gaps using a convergent mixed-methods design, integrating quantitative and qualitative strands to examine how ICU nurses in Lebanese hospitals perceive, experience, and respond to occupational noise. Specifically, it aims to: (1) Quantify Lebanese nurses' perceptions of ICU noise sources and their perceived effects on health, occupational

functioning, and burnout; (2) Explore nurses' lived experiences of and coping strategies in response to ICU noise exposure; and (3) Examine nurses' perceptions of organizational responses to noise, including existing gaps and opportunities for improvement.

Methods

Study Design and Setting

A convergent mixed-methods design was used to integrate quantitative cross-sectional survey data with qualitative semi-structured interviews, with the two strands collected concurrently and brought together during interpretation. Figure 1 outlines this process, illustrating the quantitative and qualitative strands of data collection and analysis and the point at which findings were integrated.

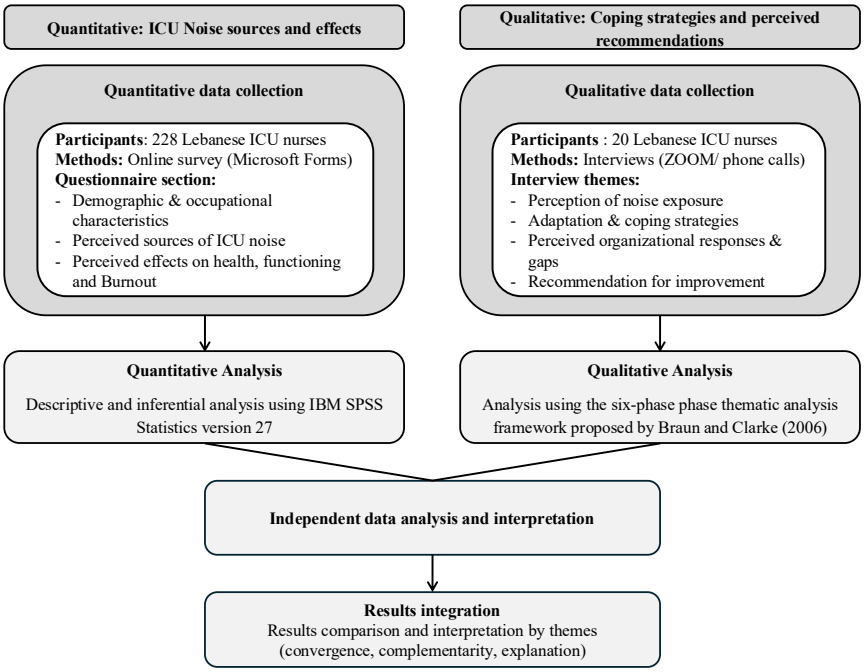

Figure 1: Process of the convergent parallel mixed-method study

The study was conducted in Lebanese hospitals between March and October 2025.

Population and Recruitment

The study population comprised registered nurses and assistant nurses working in intensive care units across Lebanon at the time of data collection. Eligible participants were of Lebanese nationality, currently employed in an ICU, able to provide informed consent, and willing to discuss their occupational experiences of noise exposure. Recruitment proceeded through an institutional channel: the Lebanese Order of Nurses distributed the survey link to nursing directors across hospitals nationwide, who in turn shared it with ICU nurses and assistant nurses in their facilities. Because this distribution occurred through an indirect chain — from the Order to nursing directors, who then forwarded the link through their own facility channels — the exact number of nurses

who received the invitation could not be determined. Participation was entirely voluntary, and nurses self-selected into the study by completing the online questionnaire.

Quantitative Component

Sampling

The required sample size was estimated at 175 participants, based on an effect size of 0.30, a significance level of $\alpha = 0.05$, and a power of 0.80. After data cleaning and exclusion of incomplete responses, 228 nurses were retained for analysis.

Data Collection

Quantitative data were collected through a self-administered online questionnaire (Microsoft Forms) available in Arabic, English, and French. Electronic informed consent was embedded on the first page, and participants were required to indicate agreement before proceeding. The questionnaire took, on average, 11 minutes to complete and was anonymous and voluntary. Quantitative data collection took place between March and June 2025.

Measures

The two outcome variables were the perceived impact of noise and burnout. The perceived impact of noise was assessed using a tool adapted from Kooshanfar et al. (2022), which the original authors validated through content validity assessment (content validity index = 0.94; content validity ratio = 0.92 across all four domains). The instrument captures four domains: subjective perception, emotion, physiology, and work performance, with each domain originally comprising five items. During data collection, one item from the subjective perception domain was inadvertently omitted from the Arabic version of the questionnaire due to a technical error, while it remained present in the English and French versions; this discrepancy was identified only after data collection had concluded, precluding correction at that stage. To assess its potential impact, a sensitivity comparison was conducted between participants who responded to the item and those who did not, revealing no significant differences in outcomes between the two groups. The subjective perception domain was therefore scored using the four items common to all three language versions, while the remaining domains retained five items each. All items were rated on a 5-point Likert scale ranging from never to always, and domain scores were computed by summing the constituent items, with higher scores indicating a greater perceived impact of noise (domain score ranges are reported in Table 3).

Burnout was measured using the 10-item Burnout Measure–Short Version (Malach-Pines, 2005), with each item rated on a never-to-always scale (range 1 – 7). A mean burnout score was calculated by averaging the 10 items, with higher scores reflecting greater burnout.

The independent variables comprised participants' socio-demographic and occupational characteristics, including age, gender, marital status, educational attainment, years of hospital and ICU experience, type of ICU, job position, and monthly overtime hours. The questionnaire also assessed nurses' perceptions of noise sources, comprising 11 internal and 9 external sources, each rated as low, moderate, or high.

Statistical Analysis

All analyses were conducted in IBM SPSS Statistics version 27. Categorical variables were summarized using frequencies and percentages, and continuous variables using means and standard deviations. Skewness and kurtosis values for key variables fell within ±1, indicating acceptable normality and justifying the use of parametric tests. Bivariate associations between the noise-impact domains and burnout and the independent variables were examined using independent-samples t-tests for dichotomous variables, one-way ANOVA for variables with more than two categories, and Pearson correlation coefficients for continuous variables. Variables reaching statistical significance in the bivariate analyses were entered into a multiple linear regression model to identify factors independently associated with the subjective perception domain. A p-value < 0.05 was considered statistically significant throughout.

Qualitative Component

Sampling

A purposive sampling strategy was used to ensure representation across characteristics that emerged as significantly associated with noise-related outcomes in the quantitative component, namely governorate, education level, and marital status, in addition to ICU type, which was retained given its conceptual relevance to noise exposure. Sampling criteria were informed jointly by the quantitative findings and conceptual relevance to noise exposure. Governorate was prioritized given its consistent and significant association across all four noise-effect domains and burnout in the survey data; ICU type was retained for its conceptual relevance to noise exposure; and ICU experience and education level were included given their significant bivariate associations with perceived noise impact. Marital status, although significantly associated with subjective perception scores in the quantitative component, was not used as a formal stratification criterion given the modest target sample size, stratification was limited to variables with the clearest structural or occupational relevance to noise exposure, and marital status was instead recorded as a background characteristic of the sample. The initial target of 32 participants was allocated proportionally across governorates (Beirut/Mount Lebanon, North, Beqaa, South), reflecting governorate's role as the strongest and most consistent correlate in the quantitative results; within each governorate, purposive selection further prioritized diversity in ICU type (adult vs. pediatric), years of ICU experience ($\leq$4 vs. >4 years; median = 4 years), and education level (university vs. technical). Although the target was 32 participants, data saturation was reached after 20 interviews, when no additional themes or codes emerged. This sample size aligns with qualitative research standards that prioritize thematic saturation and analytic depth over numerical representativeness (Creswell, 2013; Guest et al., 2006).

Data Collection

Qualitative data was gathered through semi-structured interviews conducted by telephone or via Zoom, according to participants' preferences and availability. Participants were recruited through a voluntary opt-in mechanism embedded at the end of the survey, whereby respondents who agreed to be contacted provided their contact information; 20 nurses were subsequently interviewed. Interviews followed the survey phase and lasted approximately 15–20 minutes. Each interview was conducted by two trained members of the research team, one leading the discussion and the other taking detailed notes and supporting transcription. At the outset, the researcher outlined the study's objectives, described confidentiality procedures, and obtained verbal consent for participation and audio recording. Nineteen participants consented to recording; where recording was declined, the second researcher produced real-time verbatim notes to ensure complete data

capture. All recorded interviews were transcribed verbatim and subsequently deleted to protect participant privacy. The interview guide was developed to explore the following domains (Supplementary File 1): definitions and perceptions of ICU noise; sources, effects and types of noise; strategies used by ICU staff; current hospital-level noise prevention or reduction measures; and recommendations for improving the ICU acoustic environment. Each domain comprised broad, open-ended questions accompanied by optional probes to encourage elaboration.

Data Analysis

Interview transcripts were analyzed using the six-phase thematic analysis framework of Braun and Clarke (2006), selected for its flexibility and its capacity to capture both individual experiences and shared meanings within the dataset. Analysis began with repeated reading of all transcripts to achieve familiarization. Initial codes were generated manually using a primarily deductive approach informed by the interview guide, while remaining open to inductive insights emerging from participants' narratives. Related codes were grouped into broader conceptual categories and refined iteratively, yielding a final structure of five themes: perceptions of noise and adaptation; sources and nature of noise; impact of noise exposure; coping mechanisms and institutional measures; and recommendations for improvement. Representative quotations were selected for each theme to illustrate the findings and retain participants' voices.

Trustworthiness

To enhance dependability, one author conducted the initial coding and theme development, while co-authors independently reviewed and cross-checked the coding outputs; discrepancies were resolved through discussion until full agreement was reached. Although no formal audit trail was maintained, detailed analytic notes documenting coding decisions and theme refinement were kept throughout. The research team consisted of five members (four women and one man), all trained in public health with prior experience in qualitative research. Regular team meetings facilitated reflexive dialogue, allowing the researchers to examine their assumptions and analytical decisions and helping ensure that interpretations remained grounded in participants' accounts.

Ethical Considerations

Ethical approval was obtained from the Ethics Committee of the Saint-Joseph University of Beirut (Reference: CEHDF-2633). Participation in both components was entirely voluntary and confidential. All data, including survey responses, interview notes, audio recordings, and transcripts, were stored securely on the university Microsoft OneDrive in anonymized, password-protected folders accessible only to the research team. In line with the approved protocol, all collected materials will be permanently deleted following publication.

Results

Quantitative Results

Sample Characteristics

A total of 228 ICU nurses from hospitals across all regions of Lebanon responded to the survey (Table 1). Participants were predominantly female (77.6%), and just over half were single (56.6%), with 39.0% married. Their mean age was 31.9 ± 9.8 years, with a mean of 7.9 ± 8.0 years of hospital experience and 6.4 ± 7.3 years of ICU experience (n = 227). Around two fifths of the participants held a university bachelor's degree (43.9%). Participants were relatively evenly

distributed across governorates: Beirut–Mount Lebanon (31.1%), Bekaa (25.9%), South (22.4%), and North (20.6%). Regarding working conditions, nearly half reported no overtime (48.2%), while 16.2% worked more than 40 hours of overtime per month. Two-thirds were registered nurses (67.5%), and most worked in medical ICUs (60.5%).

Table 1: Demographic and occupational distribution of participants (n = 228)

Characteristic	n	%
Gender		
Female	177	77.6
Male	50	21.9
Prefer not to say	1	0.4
Marital Status		
Single	129	56.6
Married	89	39.0
Divorced	9	3.9
Widowed	1	0.4
Highest Education Level		
Technical Baccalaureate (BT)	14	6.1
Advanced Technician (TS)	26	11.4
Technical License (LT)	64	28.1
University bachelor's degree (BS)	100	43.9
Master's degree (MS) or more	24	10.5
Governorate		
Beirut – Mount Lebanon	71	31.1
Bekaa	59	25.9
South	51	22.4
North	47	20.6
Overtime hours/month		
No overtime	110	48.2
10 and less hours/month	26	11.4
Between 10 and 20 hours/month	26	11.4
Between 21 and 40 hours/month	29	12.7
41 and more hours/month	37	16.2
Type of ICU		
Medical ICU	138	60.5
NICU	64	28.1
Open heart/CCU	21	9.2
PICU	5	2.2
Job Position		
Nurse Aide	39	17.1
Registered Nurse	154	67.5
Head Nurse	35	15.4
	Mean ± SD[1]	**Min - Max[2]**
Age	31.9 ± 9.8	19 - 63
Hospital experience (in years)	7.9 ± 8.0	0 - 40
ICU experience (in years) (n = 227)	6.4 ± 7.3	0 - 40

Perceived Sources of Noise

[1] SD: Standard Deviation

[2] Minimum - Maximum

Across both internal and external sources, most noise was rated as moderate, with high ratings concentrated in a small number of sources, suggesting that no single source was perceived as a dominant problem by most nurses (Table 2). Inside the ward, monitor alarms/ventilators, ringing phones, and patients moaning and crying, were identified as high noise contributors by 50%, 35%, and 32% of participants, respectively. Outside the ward, participants reported the hospital renovation activities (22%) and conversation among visitors and family members (18%) as high sources of noise. In contrast, noise from televisions and radios was perceived as a minor source of noise both inside and outside the ICU ward, with only 3% of participants identifying them as high contributor to noise in either setting,

Table 2: Major noise sources inside and outside the ward according to nurses (n=228)

Noise source	**Low N (%)**	**Moderate N (%)**	**High N (%)**
Inside the ward			
Monitor alarms and ventilators	8 (3.5)	106 (46.5)	114 (50.0)
Phone ringing	28 (12.3)	120 (52.6)	80 (35.1)
Patient moaning and crying	39 (17.1)	116 (50.9)	73 (32.0)
Conversation between visitors/family members	44 (19.3)	114 (50.0)	70 (30.7)
Doors opening and closing	87 (38.2)	96 (42.1)	45 (19.7)
Oxygen or suction	49 (21.5)	139 (61.0)	40 (17.5)
Other medical equipment	45 (19.7)	149 (65.4)	34 (14.9)
Conversation between workers	71 (31.1)	125 (54.8)	32 (14.0)
Cleaning work	118 (51.8)	92 (40.4)	18 (7.9)
Opening of drawers of cloths chests	133 (58.3)	86 (37.7)	9 (3.9)
TV, Radio	166 (72.8)	54 (23.7)	8 (3.5)
Outside the ward			
Renovation work in the hospital	77 (33.8)	102 (44.7)	49 (21.5)
Conversation between visitors/family members	78 (34.2)	109 (47.8)	41 (18.0)
Rolling of trolley wheels	93 (40.8)	104 (45.6)	31 (13.6)
Doors opening and closing	107 (46.9)	91 (39.9)	30 (13.2)
Broadcast	105 (46.1)	101 (44.3)	22 (9.6)
Conversation between workers	105 (46.1)	103 (45.2)	20 (8.8)
Cleaning work	122 (53.5)	90 (39.5)	16 (7.0)
Registration	125 (54.8)	91 (39.9)	12 (5.3)
TV, Radio	160 (70.2)	61 (26.8)	7 (3.1)

Perceived Effects of Noise and Burnout

Table 3 presents the mean scores across the four noise-effect domains and the burnout measure. The mean score for the physiology domain was 14.2 ± 4.3 (range 5–25), the emotion domain was 13.8 ± 4.4 (range 5–25), the subjective perception domain was 11.0 ± 3.4 (range 4–20), and the performance domain was 10.6 ± 4.2 (range 5–25). Relative to their respective scale midpoints, the physiology and emotion domains fell at or near the midpoint, subjective perception slightly below, and performance was the lowest-scoring domain, suggesting that nurses perceived noise as affecting their physiological and emotional experience more than their task performance. The mean burnout score was 3.5 ± 1.2 (range 1–7), corresponding to the lower bound of the range indicating the presence of burnout symptoms as defined by the Burnout Measure–Short Version (Malach-Pines, 2005).

Table 3: Mean scores of nurses' perceived effect of ICU noise on health, occupational functioning, and burnout (n=228)

Outcome	Number of Items	Mean ± SD	Minimum	Maximum
Physiology	5	14.2 ± 4.3	5	25
Emotion	5	13.8 ± 4.4	5	25
Subjective perception	4	11.0 ± 3.4	4	20
Performance	5	10.6 ± 4.2	5	25
Burnout	10	3.5 ± 1.2	1	7

Factors Associated with Perceived Effects of Noise and Burnout

Bivariate analyses revealed several significant associations across the outcome domains (Table 4). Governorate was the most consistent correlate, showing a significant association with all five outcomes. Nurses working in the Bekaa region reported the highest scores across every domain—subjective perception (12.2 ± 3.4, p = 0.013), emotion (14.8 ± 4.6, p = 0.017), physiology (15.8 ± 4.6, p = 0.002), performance (11.8 ± 4.2, p = 0.002), and burnout (3.9 ± 1.0, p = 0.007)—while the lowest scores were consistently observed among nurses working in North Lebanon.

Educational level was associated with two domains: compared with nurses holding technical degrees, those with university degrees reported significantly higher emotion scores (14.4 ± 4.5 vs. 13.0 ± 4.1, p = 0.014) and higher burnout scores (3.7 ± 1.3 vs. 3.3 ± 1.0, p = 0.037).

The subjective perception domain scores were significantly higher among ever-married nurses than among single nurses (11.7 ± 3.3 vs. 10.5 ± 3.4, p = 0.009) and showed weak but significant positive correlations with both hospital experience (r = 0.17, p = 0.009) and ICU experience (r = 0.13, p = 0.046), indicating that longer professional experience was associated with greater perceived impact of noise. The multiple linear regression results indicate that after adjustment, governorate was the only independent predictor to retain significance: nurses in North Lebanon scored significantly lower than those in the Bekaa region (B = −1.79, 95% CI −3.09 to −0.49, p = 0.007) (Table 5).

Table 4: Association of the subjective perception domain with demographic and occupational factors (n = 228)

	Subjective Perception		Emotion		Physiological		Performance		Burnout	
Variable	**Mean ± SD**	**p-value**	**Mean ± SD**	**p-value**	**Mean ± SD**	**p-value**	**Mean ± SD**	**p-value**	**Mean ± SD**	**p-value**
Gender		0.360*		0.080*		0.065*		0.945*		0.105*
Female	11.2 ± 3.5		14.0 ± 4.3		14.5 ± 4.1		10.6 ± 4.2		3.6 ± 1.2	
Male	10.7 ± 3.2		12.8 ± 4.7		13.2 ± 4.7		10.6 ± 4.5		3.3 ± 1.1	
Marital status		**0.009***		0.290*		0.503*		0.856*		0.218*
Single	10.5 ± 3.4		13.5 ± 4.6		14.0 ± 4.1		10.6 ± 4.2		3.4 ± 1.2	
Ever married	11.7 ± 3.3		14.1 ± 4.1		14.4 ± 4.5		10.7 ± 4.3		3.6 ± 1.1	
Governorate		**0.013^**		**0.017^**		**0.002^**		**0.002^**		**0.007^**
Bekaa	12.2 ± 3.4		14.8 ± 4.6		15.8 ± 4.6		11.8 ± 4.2		3.9 ± 1.0	
Beirut and Mount-Lebanon	10.8 ± 4.0		14.3 ± 4.5		13.6 ± 4.4		11.2 ± 4.6		3.6 ± 1.3	
South Lebanon	10.8 ± 3.0		12.9 ± 4.0		14.4 ± 3.7		9.6 ± 3.7		3.2 ± 1.2	
North Lebanon	10.2 ± 2.7		12.5 ± 3.9		12.9 ± 3.6		9.3 ± 3.7		3.2 ± 0.9	
Education level		0.612*		**0.014***		0.375*		0.058*		**0.037***
Technical degree	10.9 ± 3.1		13.0 ± 4.1		13.9 ± 4.1		10.0 ± 3.8		3.3 ± 1.0	
University degree	11.2 ± 3.7		14.4 ± 4.5		14.4 ± 4.4		11.1 ± 4.5		3.7 ± 1.3	
Overtime		0.888^		0.424*		0.797*		0.951*		0.864*
No overtime	11.1 ± 3.4		14.0 ± 4.2		14.3 ± 4.1		10.6 ± 4.2		3.5 ± 1.1	
Overtime	11.0 ± 3.5		13.5 ± 4.6		14.1 ± 4.5		10.6 ± 4.2		3.5 ± 1.2	
Type of ICU		0.825*		0.712*		0.339*		0.441*		0.711*
Pediatrics	11.1 ± 3.2		13.9 ± 4.1		14.6 ± 3.8		10.3 ± 3.9		3.6 ± 1.1	
Adults	11.0 ± 3.5		13.7 ± 4.5		14.0 ± 4.5		10.8 ± 4.4		3.5 ± 1.2	
Job position		0.547^		0.176^		0.577^		0.087^		0.281^
Aid nurse	10.6 ± 2.8		12.6 ± 4.5		14.0 ± 4.4		9.3 ± 3.4		3.3 ± 1.1	
Registered nurse	11.2 ± 3.6		14.0 ± 4.4		14.4 ± 4.4		10.8 ± 4.2		3.5 ± 1.2	
Head nurse	10.8 ± 3.1		14.1 ± 3.9		13.6 ± 3.6		11.2 ± 4.7		3.7 ± 1.1	
	Pearson's coefficient	**p-value**	**Pearson's coefficient**	**p-value**	**Pearson's coefficient**	**p-value**	**Pearson's coefficient**	**p-value**	**Pearson's coefficient**	**p-value**
Age	0.12	0.063	0.05	0.440	-0.06	0.391	0.06	0.358	0.03	0.643
Hospital experience	**0.17**	**0.009**	0.10	0.136	0.01	0.876	0.10	0.116	0.04	0.590
ICU experience	**0.13**	**0.046**	0.04	0.544	0.03	0.643	0.07	0.268	0.03	0.695

*: Independent t-test / ^: One-way ANOVA

Table 5: Multivariate linear regression analysis of factors associated with the subjective perception domain (n = 228)

	Unstandardized B	95% CI	P-value
Marital Status			
Ever married/ Single (reference)	0.74	-0.21; 1.70	0.125
Governorate Bekaa (reference)			
Beirut – Mont Lebanon	-1.17	-2.36; 0.03	0.057
North Lebanon	**-1.79**	**-3.09; -0.49**	**0.007**
South Lebanon	-0.81	-2.13; 0.52	0.232
Hospital experience	0.04	-0.05; 0.12	0.385
ICU experience	0.02	-0.07; 0.11	0.618

Qualitative Results

Participant Characteristics

Twenty ICU nurses were interviewed, comprising 18 women and 2 men. The sample included 18 registered nurses and 2 head nurses working across adult ICU, neonatal (NICU), pediatric (PICU), and coronary care (CCU) settings, with reported experience ranging from less than one year to 25 years. Thematic analysis generated five overarching themes, presented below with representative quotations.

1. Perception of Noise and Adaptation

Participants expressed varied perceptions of noise, with many describing it as an inherent and defining feature of ICU work rather than an occasional disturbance. The environment was frequently characterized as *"loud," "unpleasant,"* and marked by *"continuous noise"* that blurred the boundary between essential sounds and background clutter. Over time, however, many nurses—particularly those with more than four years of experience—reported developing a form of tolerance or desensitization, frequently summarized by the expression *"we got used to it."* This was interpreted as a professional coping mechanism that allowed staff to maintain functionality despite constant auditory stimulation. When probed further, however, participants acknowledged that this adjustment was more surface-level endurance than genuine resistance: feelings of annoyance, irritability, and mental fatigue persisted even among the most experienced respondents. Several reflected that familiarity created a false sense of normality, dulling sensitivity without reducing stress, and noted that cumulative exposure produced headaches, agitation, or difficulty concentrating that became accepted as part of the work environment rather than recognized as signs of strain. As one participant explained, *"You get used to the noise, but it doesn't mean it stops bothering you"* (P1).

2. Sources and Nature of Noise

Participants described the ICU as a dense and dynamic auditory environment shaped by multiple, interacting sources. Internal noise was the most dominant category, encompassing the constant operation of medical equipment—ventilators, monitors, alarms, suction machines, and infusion pumps—alongside staff interactions and patient-related sounds such as crying, coughing, and groaning. These sounds, though familiar, were perceived as cumulative and overwhelming when occurring simultaneously, and staff conversations during emergencies or teaching moments were also identified as major contributors. External noise, though less frequent, added a further layer of disturbance; several participants referred to traffic, car horns, nearby construction, and, in some cases, gunfire and explosions during periods of political unrest, describing these intrusions as

unpredictable and particularly distressing because they penetrated an otherwise controlled clinical space. A recurrent distinction emerged between *functional* and *non-functional* noise. Functional noise, such as alarms and monitor beeps, was regarded as essential for patient safety—*"If we don't hear them, there is a risk to the patient's life"* (P8)—whereas non-functional noise, including loud conversations and overlapping signals, was viewed as avoidable and indicative of poor environmental control. Participants described these overlapping sounds as *"mixed tones"* that merged human voices with electronic signals, creating confusion and cognitive strain. This layering frequently led to sensory overload, and many nurses noted that, over time, they had learned to "tune out" certain alarms or voices to focus on essential tasks—an adaptive strategy that nonetheless carried potential safety risks.

3. Impact of Noise Exposure

Noise was perceived to affect the physical, mental, and professional functioning of staff, with consequences for patient care. Participants reported physical symptoms experienced during working hours and attributed to prolonged noise exposure, including headaches, tinnitus, fatigue, and disturbed sleep; for some, these symptoms persisted beyond the workplace, extending into time off shift. As one nurse observed, *"Even when I go home, the noise is always there"* (P8). The mental and emotional consequences were equally salient, with nurses describing recurrent anxiety, irritability, and emotional exhaustion, and several linking noise intensities to heightened stress and burnout during prolonged or high-intensity shifts. Beyond emotional strain, participants highlighted noise's detrimental effect on performance and concentration, explaining that constant interruptions and alarms impaired focus, disrupted communication and workflow, and often forced them to repeat or reorganize tasks. One participant reflected, *"it affects me physically. I don't concentrate. I don't give the patient his right. When there is too much noise, I don't know how to balance myself anymore"* (P13). Participants also expressed concern about effects on patients, particularly in NICUs, where excessive stimulation was seen as potentially harmful to infants' hearing and development, and in adult ICUs, where restless or distressed patients found it difficult to rest and became more agitated in noisy surroundings.

4. Coping Mechanisms and Institutional Measures

Nurses employed a range of strategies to manage continuous noise. At the individual level, many relied on short breaks, deep breathing, brief withdrawal, and task-focused attention to regain composure, while some listened to soft music during breaks or relocated temporarily to quieter spaces such as offices or staff lounges. Preventive and reactive measures were also adopted informally: nurses lowered alarm volumes, closed doors, and reminded colleagues to communicate more quietly, and in NICUs they often refilled syringes or checked infusion pumps in advance to pre-empt alarms. At the institutional level, engagement varies by facility. Some introduced controlled visiting hours, restricted night-time access, scheduled regular equipment maintenance, or upgraded to quieter devices, while others reported few such measures. Several participants described inconsistent enforcement of noise-control policies across departments and limited psychological support for staff affected by chronic exposure, with one noting, *"Training [about noise reduction] has been done several times—we're seeing results, not very strong, but better than before"* (P5).

5. Recommendations for Improvement

Participants offered recommendations spanning environmental, organizational, and cultural change. Many emphasized environmental modifications such as installing noise isolators and acoustic barriers, ensuring spatial separation between noisy areas and ICU wards, introducing low-decibel equipment, and maintaining devices to prevent excessive alarms. Organizational strategies were also stressed, including structured awareness sessions, continuous staff training, and enforcement of quiet hours during night shifts, *"Everyone talks about hand washing and safety, but no one talks about noise"* (P2). Several nurses underscored the need for supportive workplace cultures that acknowledge the psychological toll of persistent noise, suggesting relaxation rooms, mental health support, and open discussion of stress management: *"I think there should be psychological support for nurses to help them understand how this background noise affects them and how to manage it—we're already under a lot of stress, and the noise adds on top"* (P10). Finally, some proposed holistic enhancements to foster a calmer atmosphere, including soothing background music, natural elements such as plants and greenery, and sound-absorbing architectural design: *"A view onto a garden with trees would reduce stress and help psychologically; it has a positive impact on work"* (P5).

Discussion

This study pursued two complementary sets of objectives. The quantitative component was designed to identify and quantify the sources of noise perceived by ICU nurses, to examine the perceived effects of this noise across health and occupational functioning, and to assess nurses' burnout levels in relation to their noise exposure. The qualitative component, in turn, explored nurses lived experiences and perceptions of noise exposure, investigated the adaptation and coping strategies they employed in response to it, and examined their perceptions of organizational responses, including existing gaps and opportunities for improvement. Each component addressed its respective objectives separately; integrating the findings produced three meta-inferences: conclusions that neither component could have generated alone, but that emerged only when quantitative patterns and qualitative accounts were read against each other, consistent with the rationale for mixed-methods integration described by Shorten and Smith (2017). First, ICU noise is a chronic, layered, and context-shaped feature of nursing work. Second, nurses' adaptation to this environment reflects endurance rather than resilience. Third, the resulting burden is managed individually rather than institutionally. These inferences are cumulative: the nature of the exposure shapes how nurses adapt, and the form that adaptation takes shapes how the burden is ultimately distributed. Each is discussed below, drawing together convergent evidence and situating it within the broader literature.

ICU Noise as a Chronic, Layered Feature of Work

Across both components, noise emerged as a salient and persistent feature of ICU work rather than an occasional disruption. Quantitatively, elevated mean scores on the physiology, emotion, and subjective perception domains indicated a substantial perceived impact. Performance scores, by contrast, fell below the domain midpoint, and nurses continued to function despite the noise, a divergence that foreshadows the second meta-inference: burden and continued functioning are not mutually exclusive. Qualitatively, nurses described noise as continuous, intrusive, and embedded in daily practice, closely echoing the characterization of ICU noise as a disruptive, ever-present "factory" environment reported by healthcare providers in Kebapcı and Güner's (2021) qualitative study. The two components converged not only on the presence of noise but on its chronicity. Quantitatively, this is reflected in elevated physiology and emotion domain scores, which were

derived from items assessing how often symptoms occur rather than whether they occurred at all — indicating frequent, not occasional, impact. Qualitatively, nurses reported that physical symptoms such as headaches, fatigue, tinnitus, and disturbed sleep, experienced during shifts, frequently persisted beyond working hours. This suggests incomplete recovery between shifts and supports an interpretation of noise as a chronic rather than an acute exposure. The pattern is consistent with environmental and occupational health research demonstrating that prolonged noise exposure produces non-auditory effects that persist over time (Babisch, 2002; Basner et al., 2014), and with ICU-specific studies documenting similar somatic complaints among nurses exposed to continuous high noise levels (Darbyshire & Young, 2013; Kooshanfar et al., 2022; Terzi et al., 2019).

The qualitative component clarified why this exposure is so burdensome by revealing its layered and cumulative structure. Internal noise generated by monitors, ventilators, infusion pumps, and communication — consistent with monitor alarms and ventilators being rated the leading internal noise source in the survey (50% of nurses rated it "high") formed a constant auditory backdrop. This burden was intensified by overlap and simultaneity: multiple alarms, equipment sounds, and voices occurred concurrently, raising cognitive load and limiting nurses' capacity to attend selectively to meaningful signals. External noise, corroborated by survey findings identifying hospital renovation work and visitor conversations as the leading external contributors, added a further, less controllable layer, ranging from renovation work and visitors' conversations to traffic, construction, and episodes of political unrest, which were experienced as unpredictable intrusions into an otherwise controlled clinical space. A particularly important qualitative insight, not captured by the quantitative measures, was the distinction between functional and non-functional noise: clinical alarms were recognized as essential for patient safety, whereas avoidable, overlapping sounds were experienced as disruptive. This distinction helps explain why noise remained burdensome even when its sources were clinically justified, since nurses had to continuously filter meaningful alarms from background clutter, an effortful process corroborated by objective acoustic analyses showing that ICU soundscapes are dominated by overlapping, continuous noise exceeding recommended thresholds (Darbyshire & Young, 2013; Park et al., 2014; Scquizzato et al., 2020).

Regional and Contextual Variation in Noise Exposure

The context-dependence of this exposure was most evident in the regional variation observed quantitatively. Governorate was the single most consistent correlate of the outcome domains, reaching significance across all five. Nurses in the Bekaa region reported the highest scores, and those in North Lebanon the lowest; this difference remained robust in multivariate analysis, where North Lebanon scored significantly lower than Bekaa even after adjustment for other significant variables. By contrast, factors such as overtime hours, gender, and age showed no significant association with perceived noise impact. Notably, ICU type (pediatric versus adult) was also unassociated with any outcome domain in this sample, which contrasts with the implicit rationale behind unit-specific noise-reduction efforts such as Soubra et al.'s (2018) pediatric-unit intervention. In the present sample, regional and structural context, rather than unit type, appears to be the more consequential axis of variation. Qualitative accounts offered plausible mechanisms for the regional disparities, pointing to differences in infrastructure quality, surrounding environmental noise, and broader contextual instability consistent with the staffing and resource pressures documented among Lebanese ICU teams more broadly (Dankar & Ammar, 2025). Rather than acting as an independent driver of outcomes, region appeared — based on the

qualitative accounts above — to track underlying differences in infrastructure quality and environmental exposure, suggesting that geography functions as a proxy for these contextual conditions rather than a determinant in its own right. This is particularly salient in a low- and middle-income country (LMIC) operating under systemic strain, and it extends literature drawn predominantly from high-income settings (Darbyshire & Young, 2013; Park et al., 2014; Scquizzato et al., 2020) by demonstrating that context shapes not only the level of exposure but the way its impact is perceived.

Adaptation as Endurance Rather Than Resilience

The second meta-inference concerns how nurses respond to this environment, and here both components converged on a counterintuitive pattern: nurses adapt to noise behaviorally without experiencing a corresponding reduction in its burden. Quantitatively, greater cumulative exposure, indexed by longer hospital and ICU experience, was associated with higher, not lower, subjective perception of noise impact. Because this association is drawn from cross-sectional data, it cannot establish that exposure itself drives this pattern over time; it is equally consistent with alternative explanations that cross-sectional data cannot rule out — for instance, that nurses who are more sensitive to noise may be more likely to remain in ICU roles, or that unmeasured factors shape both experience and perception. The qualitative accounts, however, lend the association a plausible interpretive frame: senior nurses described a process of habituation captured by the phrase "we got used to it," yet, when probed, acknowledged that annoyance, irritability, and mental fatigue persisted. Read together, these findings suggest that adaptation operates primarily at the level of task execution. Nurses modify their attention, routines, and focus to preserve continuity of care, while the cognitive and emotional effects of exposure remain. Habituation, in other words, reflects behavioral adjustment rather than genuine relief, a pattern also reported among the healthcare providers interviewed by Kebapcı and Güner (2021), who similarly described normalizing noise while continuing to identify it as a source of strain.

Distinguishing this functional adaptation from authentic resilience is central to the study's contribution. Resilience would imply a reduced burden over time; instead, the burden persisted across domains (table 3). Physiological symptoms, emotional strain, and early burnout symptoms, reflected in a mean burnout score corresponding to the lower bound of the range indicating onset of burnout (Malach-Pines, 2005), coexisted with continued functioning. Performance was maintained, but qualitative accounts revealed that this required deliberate compensatory effort, including heightened vigilance, task repetition, and intensified focus. This interpretation is supported by cognitive research showing that environmental noise taxes attention and working memory even when observable task performance is preserved (Basner et al., 2014), and by burnout models that frame burnout as the cumulative product of prolonged exposure to interacting stressors rather than a single trigger (Maslach & Leiter, 2016). The pattern also echoes early ICU research demonstrating that nurses report becoming accustomed to high noise levels while continuing to experience elevated stress and burnout (Topf & Dillon, 1988), as well as subsequent work confirming that exposure remains associated with fatigue and emotional exhaustion despite apparent habituation (Kooshanfar et al., 2022; Pal et al., 2022; Terzi et al., 2019). Broader environmental health research similarly indicates that behavioral adaptation to chronic noise can sustain task performance without corresponding physiological or psychological recovery (Babisch, 2002).

A key risk of this dynamic is that endurance may be misread as tolerance. This concern is grounded directly in the qualitative findings (Theme 1: Perceptions of Noise and Adaptation): nurses who described "getting used to" noise nonetheless acknowledged that annoyance and fatigue persisted, as captured in one nurse's reflection that "you get used to the noise, but it doesn't mean it stops bothering you" (P1). Several participants also described deliberately "tuning out" certain alarms or voices to manage sensory overload — a strategy offering short-term relief while entailing desensitization to potentially meaningful signals (Cvach, 2012; Sendelbach & Funk, 2013). If this endurance is read as successful adaptation rather than as a coping response that leaves underlying strain intact, it risks understating the ongoing costs of sustained exposure, a pattern consistent with the alarm-fatigue literature (Bourji et al., 2020; Cvach, 2012; Lewandowska et al., 2020; Sendelbach & Funk, 2013)."

A Burden Individualized Rather Than Institutionally Managed

The third meta-inference follows directly from the second. Because adaptation reflects endurance rather than resilience, the persistent burden of noise must be absorbed somewhere, and the integrated findings indicate that it is absorbed by individual nurses rather than managed by institutions. Qualitative accounts showed that responses to noise were driven predominantly by individual and frontline coping. The quantitative finding that burden persisted despite continued functioning is consistent with a system that relies on staff to absorb exposure rather than reduce it. Across both components, structural and organizational solutions were largely absent, a pattern that stands in some contrast to Soubra et al.'s (2018) description of a successfully implemented, multidisciplinary noise-reduction initiative in a Lebanese pediatric unit; the present findings suggest that such structured, institution-led efforts remain the exception rather than the norm across Lebanese ICUs more broadly.

At the individual level, nurses reported short breaks, deep breathing, temporary withdrawal to quieter spaces, and task-focused attention as means of managing noise-related strain. These strategies offered momentary relief, but they were essentially reactive and placed the responsibility for managing environmental stress on the individual, consistent with the broader literature on self-regulatory coping under chronic occupational stress, which similarly does not address the underlying exposure (Babisch, 2002; Maslach & Leiter, 2016). Beyond individual strategies, nurses described unit-level practices such as adjusting alarm volumes, anticipating equipment alerts, closing doors, and reminding colleagues to communicate more quietly. This reflected genuine frontline awareness, but they were situational and inconsistently applied rather than embedded in formal protocols, paralleling the alarm-management workarounds documented elsewhere, including by Bourji et al. (2020) in the Lebanese context, which sustain performance while increasing cognitive load and the risk of error (Cvach, 2012; Sendelbach & Funk, 2013). As with individual coping, these unit-level responses managed symptoms rather than addressing structural causes.

At the organizational level, the findings revealed notable gaps in institutional responsibility. Nurses described inconsistent enforcement of noise-related policies and limited access to psychological or occupational health support. Where interventions existed, they were often fragmented or insufficiently prioritized. Even in instances where participants described attempting a structured initiative resembling the one reported by Soubra et al. (2018), its effects were characterized as modest. Training and awareness initiatives were similarly uneven, frequently short-term or isolated, and unlikely to produce sustained change without accompanying structural modification

(Basner et al., 2014; Cvach, 2012). This organizational blind spot tends to normalize noise exposure and reinforce the expectation that staff will adapt independently, consistent with models of burnout that locate its drivers in organizational conditions rather than individual weakness (Maslach & Leiter, 2016). This connects directly to the second meta-inference: when endurance is misread as tolerance, institutions are effectively absolved of responsibility, and cumulative exposure is perpetuated while its health and performance costs remain hidden.

Participants' own recommendations consistently shifted the locus of responsibility away from individual endurance and toward environmental and organizational change, including acoustic redesign of ICU spaces, investment in quieter equipment, enforcement of quiet hours, and the provision of psychological support and restorative spaces. These align with broader calls in healthcare design and occupational health for system-level interventions that address environmental stressors at their source rather than relying on behavioral adaptation alone (Basner et al., 2014; Darbyshire & Young, 2013), and with Soubra et al.'s (2018) demonstration that structured, multidisciplinary noise-reduction efforts can be implemented successfully within a Lebanese hospital setting. This meta-inference is especially consequential in an LMIC context, where resource constraints make individualized coping the default response. Reliance on adaptation is not a neutral status quo but an implicit choice that offloads a system-level problem onto individual nurses, sustaining their exposure while leaving its underlying causes unaddressed.

Taken together, these three meta-inferences extend prior work in a specific way. Where earlier studies documented habituation and its coexistence with strain largely in isolation from one another (Kebapcı & Güner, 2021; Kooshanfar et al., 2022; Topf & Dillon, 1988), and where Lebanese research to date has addressed either alarm fatigue (Bourji et al., 2020) or a single successful unit-level intervention (Soubra et al., 2018) without connecting these to nurses' broader lived experience, the present study integrates these threads. It links habituation, burnout, and institutional gaps to explicit regional and organizational context within an LMIC health system under systemic strain, showing that where and how nurses work shapes not only their exposure to noise but the interpretive and institutional frameworks through which that exposure is, or is not, addressed.

Study Strengths and Limitations

This study offers several notable strengths. It provides novel national-level evidence from an LMIC context that remains underrepresented in the ICU-noise literature, drawing on participants across multiple governorates within a health system marked by resource constraints and broader environmental instability. Its convergent mixed-methods design allowed quantitative patterns to be interpreted alongside qualitative explanations, producing an integrated account rather than two parallel sets of findings. In particular, the qualitative findings highlighted mechanisms that survey data alone would have missed, including the distinction between functional and non-functional noise, the layered and overlapping structure of the ICU soundscape, and the reinterpretation of habituation as endurance rather than resilience. Taken together, these findings translate into concrete recommendations across levels: individual-level psychological support and restorative spaces; unit-level measures such as alarm-volume calibration and enforced quiet hours; and organizational investment in acoustic redesign and quieter equipment — several of which were directly proposed by participants themselves (see Qualitative Results, Recommendations).

Several limitations should also be noted. Noise exposure was assessed through self-report rather than objective acoustic monitoring, which may introduce reporting bias and precludes direct

linkage between perceived impact and measured sound levels. The cross-sectional design of the quantitative component limits causal inference: the data cannot establish whether noise exposure drives burnout and reduced performance, whether nurses experiencing greater burnout perceive noise as more burdensome, or whether both are shaped by other, unmeasured workplace factors. Additionally, due to a survey-administration error, the subjective-perception domain was completed using four of its five intended items for a subset of participants; scores for this domain are therefore not directly comparable to the source instrument's full domain and should be interpreted accordingly, although sensitivity analysis found no meaningful difference in outcomes between respondents who did and did not receive the omitted item. Finally, while the qualitative findings achieved thematic saturation, they support analytical rather than statistical generalization, with relevance best understood as extending to comparable ICU contexts rather than representing all settings uniformly.

Conclusion

ICU noise in Lebanon is a chronic, structurally patterned occupational stressor, and nurses' adaptation to it should not be mistaken for resilience. Continued functioning reflects compensatory effort sustained amid ongoing cognitive, emotional, and physiological strain, with the costs displaced onto staff and, potentially, patients. This dynamic is sharpened in a resource-constrained LMIC setting, where environmental stressors are readily normalized and individual endurance substituted for structural solutions. By foregrounding nurses' perspectives and integrating them with measured exposure, this study reveals the hidden costs of "getting used to" noise, early burnout, attentional fatigue, and perceived risks to patient safety, and supports a decisive shift away from reliance on individual adaptation toward system-level mitigation: environmental and acoustic design, alarm management, and protected staff wellbeing. These directions offer a foundation for future research, policy, and practice in critical care.

Declarations

Data availability. The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate. This study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from the Ethics Committee of Saint-Joseph University of Beirut (Reference: CEHDF-2633). Written informed consent to participate was obtained from all participants prior to their involvement in the study. Participants were informed of the purpose, procedures, potential risks and benefits of the study, and of their right to withdraw at any time without penalty. Confidentiality and privacy of participants' data were maintained throughout the research process. Competing interests. The authors declare no financial or non-financial competing interests.

Consent for publication. Not applicable. The manuscript does not contain any individual person's data, images, or identifiable information; all interview quotations are anonymized.

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