

Insomnia and Mental Health Outcomes After Catastrophic Disasters: A Cross-Sectional Study Examining the Long-Term Effects of the Beirut Port Explosion

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Background: The August 4, 2020 Beirut port explosion caused widespread destruction and psychological distress. This study evaluates long-term effects on sleep disturbances and trauma, focusing on proximity to the blast site.

Methods: We surveyed 248 adults residing in Lebanon during the explosion using the Insomnia Severity Index (ISI), Impact of Events Scale-Revised (IES-R), and Patient Health Questionnaire (PHQ-4).

Results: Overall, 62.1% reported insomnia symptoms. Clinically significant insomnia was more common within 6 km of the explosion (28.8%) than beyond (16.8%; $p = 0.024$). Direct exposure (injury, property damage) was linked to higher insomnia rates ($p = 0.002$). Logistic regression showed proximity ($OR = 2.17$, $p = 0.025$) and female gender ($OR = 2.40$, $p = 0.035$) increased insomnia likelihood. Proximity was also associated with increased alcohol ($p = 0.017$) and recreational drug use ($p = 0.030$).

Conclusion: These findings demonstrate the long-lasting impact of the Beirut explosion on sleep health and related substance use. They underscore the importance of integrating sleep-focused interventions into mental health disaster response to improve recovery outcomes.

Keywords: Beirut port explosion, insomnia, PTSD, disaster response, mental health, lebanon, trauma, sleep

Background

Traumatic events, especially large-scale disasters, can have significant and lasting effects on mental health, often resulting in conditions such as post-traumatic stress disorder (PTSD) and sleep is frequently affected. For many who experience trauma, insomnia can become persistent long after the initial event.¹ The Beirut Explosion which occurred on the fourth of August 2020 resulted in significant destruction and loss of life. Beirut is the capital and largest city of Lebanon; a small country in the eastern Mediterranean. The explosion was caused by the detonation of 2750 tons of ammonium nitrate, stored in the port, which caused massive damage to the city and hundreds of lives lost, thousand injured and tens of thousands displaced.² This large-scale catastrophic disaster provides a context to examine the long-term psychological impact of such traumatic events. Research has consistently shown that trauma-exposed populations exhibit a high prevalence of sleep disturbances, including disruptions in sleep continuity, duration, and quality, which are also core features of PTSD.^{3–5} More severe PTSD symptoms have been strongly correlated with both shorter sleep duration⁶ and lower sleep quality.⁴ Prior research indicates that insomnia is not only a common symptom following traumatic experiences but can also become a chronic condition that affects overall health and quality of life: sleep disturbances not only persist as symptoms but are significant predictors of PTSD development. For example, pre-

deployment insomnia among soldiers, was linked to an increased risk of PTSD onset and suicidal ideation following deployment.⁵ Sleep disturbances have also been found to predict harmful health-related behaviors, such as aggression, substance abuse, and increased alcohol consumption, in trauma-affected populations.⁴

Trauma exposure can cause long-lasting disruptions in sleep by dysregulating the hypothalamic-pituitary-adrenal (HPA) axis and activating the sympathetic nervous system, resulting in chronic hyperarousal and impaired sleep regulation. Stress-induced activation of the HPA axis increases secretion of CRH, ACTH, and cortisol, contributing to persistent insomnia symptoms.^{7,8}

Similar long-term sleep disturbances have been documented following other catastrophic events. For example, in Japan after the Great East Japan Earthquake, researchers found a sharp increase in insomnia prevalence (21.2% four months post-disaster compared to 11.7% pre-disaster) and associations with persistent psychological distress.⁹ Among survivors of the 2011 Great East Japan earthquake and tsunami, material damage and financial hardship were linked to long-term sleep disturbances, while other forms of loss had less impact. Effective disaster response helped mitigate sleep problems.³

Lebanon faces compounding challenges, including political instability, economic crisis, and under-resourced mental health systems, all of which amplify psychological vulnerability. Stigma, lack of policy, and limited access further restrict the use of mental health services, hindering help-seeking behaviors.¹⁰ Within this context, evidence on sleep behaviors in the Lebanese population remains scarce, highlighting the need for further research. In a cross-sectional study in Lebanon by Chami et al (2019), 44.5% of participants reported experiencing insomnia symptoms regularly, and 34.5% met the criteria for insomnia disorder. These symptoms were found to be more prevalent in women, socioeconomically disadvantaged individuals, and those with medical comorbidities.¹¹ A more recent study found an insomnia prevalence of 47.1%.¹²

On August 4, 2020, the Beirut port explosion devastated Lebanon's capital, causing widespread destruction from the port, injuring over 6,000 people, and displacing approximately 300,000 individuals from their homes.^{13,14} In the immediate aftermath of the explosion, those seeking mental health support predominantly reported trauma-related symptoms, insomnia, depression, and anxiety.¹⁵ Several short-term studies have documented this acute psychological impact: among survivors presenting to the emergency department at the American University of Beirut Medical Center, nearly half exhibited symptoms of depression and two-thirds showed signs of PTSD.¹⁶ Within the first months following the blast, psychological distress remained high: two months after the explosion, 37% met criteria for PTSD and 80% screened positive for depression, with one-fourth categorized as moderately-to-severely depressed.¹⁷ At four months, 75–80% of participants in a cross-sectional internet-based study reported high levels of emotional distress.¹⁸ By six months, 75.8% still met criteria for PTSD, nearly half with severe symptoms, with predictors including unemployment, injury, and bereavement.¹⁹ A visual timeline of prior Lebanese studies on mental health outcomes following the Beirut explosion is provided in [Supplementary Figure 1](#). While these findings highlight the acute burden of trauma in the short term, none of these studies specifically assessed sleep outcomes. Importantly, no studies to date have examined the long-term impact of the Beirut explosion on mental health and sleep quality, which is the gap addressed by the present study.

This investigation is relevant as long-term sleep disturbances may reinforce the persistence of PTSD by disrupting memory, emotional stability, and trauma processing.²⁰ This study aims to assess the long-term psychological impact of the Beirut explosion, focusing primarily on sleep disturbances and trauma. It also examines the relationship between proximity to the explosion site, social consequences, personal injury, and demographic factors with insomnia severity. Additionally, the study explores substance use changes related to proximity to the explosion site and their potential association with insomnia.

Methods

Study Design and Sampling

This cross-sectional study targeted adults (18+) residing in Lebanon during the Beirut explosion, regardless of their proximity to the capital. Data were collected from December 2023 to September 2024, including participants from Beirut, nearby areas, other Lebanese governorates, and those abroad but present during the explosion. Data collection

was halted in September 2024 due to the intensification of the war on Lebanon, which introduced new traumatic exposures that could have acted as confounding factors.

A sample size calculation was conducted using the proportions of individuals expected to report insomnia symptoms in the two study groups: 70% among those residing within 6 km of the Beirut blast and 51% among those residing beyond this distance. Using a significance level (α) of 0.05 and a power ($1-\beta$) of 80%, and assuming equal group sizes, the minimum required sample size per group was calculated using the following formula for two independent proportions:

$$N_1 = \{ [Z_1 - \alpha/2 \times \sqrt{(\bar{p} \times \bar{q} \times (1 + 1/K))}] + [Z_1 - \beta \times \sqrt{(p_1 \times q_1 + (p_2 \times q_2)/K)}] \}^2 / \Delta^2$$

Where:

$$p_1 = 0.51$$

$$q_1 = 1 - p_1 = 0.49$$

$$p_2 = 0.70$$

$$q_2 = 1 - p_2 = 0.30$$

$$\Delta = |p_2 - p_1| = 0.19$$

$$K = 1 \text{ (equal sample sizes)}$$

$$Z_1 - \alpha/2 = 1.96$$

$$Z_1 - \beta = 0.84$$

Calculating using our values:

$$N_1 = \{ [1.96 \times \sqrt{(0.605 \times 0.395 \times (1 + 1/1))}] + [0.84 \times \sqrt{(0.51 \times 0.49 + (0.70 \times 0.30)/1)}] \}^2 / (0.19)^2$$

$$N_1 \approx 103$$

$$N_2 = K \times N_1 = 103$$

Therefore, the total sample size required is 206 participants, with 103 in each group. A total of 248 participants were included.

Procedure

Participants were recruited through flyers and social media posts with our contact details and a link or QR code to the consent page. After consent, they completed the survey. Eligibility was based on age, location, and presence in Lebanon during the Beirut explosion. Participants were divided into two groups: those within 6 km of Beirut and those from areas further away. The 6 km cutoff was selected based on reports of major damage within this radius, corresponding to a 3.3 magnitude earthquake.²¹

Protocol Instruments

The questionnaire was available in both English and Arabic. The questionnaire included:

1. Demographics and personal data: Gender, age, marital status, employment status, medical history, mental health history, substance use, sedative or hypnotic use, personal injury, injury or loss of a family member or friend, and property damage.
2. Insomnia Severity Index (ISI): A widely used, validated 7-item questionnaire that is designed to assess the nature, severity, and impact of insomnia, with responses rated on a 5-point Likert scale. Scores range from 0 to 28, with the following cut offs: 0–7 = no clinically significant insomnia, 8–14 = subthreshold insomnia, 15–21 = moderate clinical insomnia, and 22–28 = severe clinical insomnia. To categorize insomnia as a binary variable in our data analysis, we adopted a cutoff score of 14, which enhanced our ability to accurately detect clinical insomnia in a community sample, achieving high specificity at 98.3%.²² The scale is validated in Arabic.²³ The scale demonstrated excellent internal consistency in this study (Cronbach's alpha = 0.90).
3. Patient Health Questionnaire for Anxiety and Depression (PHQ-4): A 4-item scale to screen for anxiety and depression, with scores categorized as normal (0–2), mild (3–5), moderate (6–8), and severe (9–12). A total score ≥ 3 for the first two questions indicates anxiety, and ≥ 3 for the last two indicates depression.²⁴ The scale is validated in Arabic.²⁵ In this study, the PHQ-4 showed high internal reliability (Cronbach's alpha = 0.936).

4. Impact of Events Scale-Revised (IES-R): A 22-item self-report measure (DSM-IV) assessing distress from traumatic events. Items are rated on a 5-point scale (0 = “not at all” to 4 = “extremely”). It provides a total score (0–88) and subscale scores for intrusion, avoidance, and hyperarousal.²⁶ This scale is also validated in Arabic.²⁷ The scale displayed excellent reliability with a Cronbach’s alpha of 0.959.

Statistical Analysis

Data normality was assessed using Shapiro–Wilk tests; non-normal distributions (eg, ISI, IES-R scores) prompted non-parametric tests. Descriptive statistics summarized demographic characteristics and prevalence rates of insomnia and PTSD. Insomnia, depression, anxiety, and PTSD were treated as dichotomous variables based on ISI, PHQ-4, and IES-R cutoff scores. Chi-square tests examined associations between explosion proximity and these conditions. Logistic regression assessed predictors (eg, proximity, gender, age, substance use) of insomnia ($ISI > 14$), calculating odds ratios while controlling for confounders. Before regression, chi-square tests identified significant demographic and lifestyle influencing factors. Clinically relevant factors were included to adjust for confounding. Spearman correlation analyzed relationships between insomnia severity (ISI scores) and PTSD symptoms (IES-R scores). Mann–Whitney *U*-tests compared ISI scores by PHQ-4 depression/anxiety status. Chi-square tests also examined proximity-related substance use changes. Cronbach’s alpha assessed scale reliability. Significance was set at $p < 0.05$. The data analysis was performed using Python 3 (Python Software Foundation, <https://www.python.org/>), with the help of relevant statistical libraries such as Pandas, NumPy, and SciPy for data manipulation and statistical tests.

Results

Socio-Demographic Characteristics

The socio-demographic characteristics of the sample are summarized in Table 1. The median age of participants was 31 years (IQR = 23.25–45.0), with 64.4% identifying as female and 35.6% as male. More than half were single (56.5%), and the majority were employed (66.2%). A larger proportion of participants lived more than 6 km away from the explosion site (57.9%) compared to those within 6 km (42.1%).

Table 1 Socio-Demographic Characteristics of the Sample Population

		N (%) Median (IQR)
Age		31.0 (23.25–45.0)
Sex	Male	88 (35.6)
	Female	159 (64.4)
Marital Status	Single	140 (56.5)
	Married	93 (37.5)
	Divorced/Separated	13 (6)
Employment Status	Employed	163 (66.2)
	Unemployed	22 (8.9)
	Student	58 (23.7)
Distance from Explosion	Retired	3 (1.2)
	Less than 6 kilometers	104 (42.1)
	More than 6 kilometers	143 (57.9)
Nicotine Use	Yes	60 (24.2)
	No	188 (75.8)
Caffeine Use	Yes	170 (68.5)
	No	78 (31.5)
Alcohol Use	Yes	65 (26.3)
	No	182 (73.7)

(Continued)

Table 1 (Continued).

		N (%) Median (IQR)
Recreational Drug Use	Yes	18 (7.3)
	No	227 (92.7)
Past or Present Psychiatric Diagnosis	Yes	206 (83.1)
	No	42 (16.9)
Self-Reported Sleep Disorder History	Yes	209 (84.3)
	No	39 (15.7)
Sleep Aid Usage	Yes	83 (33.5)
	No	165 (66.5)

Notes: Socio-demographic characteristics of the study population. Values are presented as counts (percentages) or median (IQR) as appropriate.

Table 2 Cross-Tabulation of Proximity with Mental Health and Substance Use Outcomes

Outcome	<6 km, n (%)	≥6 km, n (%)	χ^2 (p-value)
Insomnia (ISI >14)	30 (28.8)	24 (16.8)	5.13 (0.024)
PTSD (IES-R ≥33)	31 (29.5)	46 (31.9)	0.13 (0.717)
Depression (PHQ-4 ≥3)	38 (36.5)	46 (32.2)	0.84 (0.359)
Anxiety (PHQ-4 ≥3)	46 (44.2)	58 (40.6)	0.38 (0.537)
Increase in Alcohol Use	34 (32.7)	31 (21.7)	5.68 (0.017)
Increase in Caffeine Use	25 (35.2)	33 (34.0)	0.03 (0.873)
Increase in Nicotine Use	18 (62.1)	13 (44.8)	1.73 (0.188)
Increase in Recreational Drug Use	11 (10.6)	7 (4.9)	4.71 (0.030)

Notes: Cross-tabulation of mental health and substance use outcomes by proximity to the explosion site. Insomnia was defined as ISI >14 (Insomnia Severity Index), PTSD as IES-R ≥33 (Impact of Event Scale-Revised), and depression/anxiety as PHQ-4 ≥3 (Patient Health Questionnaire-4). "Increase in Alcohol Use", "Increase in Caffeine Use", "Increase in Nicotine Use", and "Increase in Recreational Drug Use" refer to self-reported increases in use after the blast among all participants. Statistically significant associations ($p < 0.05$) are highlighted in bold font for insomnia, increased alcohol use, and recreational drug use.

Mental Health and Substance Use Outcomes by Proximity

Mental health and substance use outcomes by proximity to the explosion are summarized in Table 2. Insomnia (ISI >14) was reported by 28.8% of participants within 6 km, compared to 16.8% living farther away ($\chi^2 = 5.13$, $p = 0.024$). Similarly, increased alcohol use was more common among those closer to the blast (32.7% vs 21.7%, $\chi^2 = 5.68$, $p = 0.017$), as was recreational drug use (10.6% vs 4.9%, $\chi^2 = 4.71$, $p = 0.030$). No significant differences were observed in PTSD, depression, anxiety, nicotine use, or caffeine use based on proximity.

Insomnia

Descriptive Statistics

When using a cutoff score of 8 on the ISI, which includes subclinical insomnia, the overall prevalence of probable insomnia in our sample was found to be 62.1% after the Beirut explosion (95% CI: 56.06–68.13). Table 3 shows the distribution of insomnia severity levels across the study population. Among participants located less than 6 km from the explosion, 65.4% scored above this threshold, as compared to 60.1% of those located more than 6 km away. This difference did not reach statistical significance ($p = 0.401$).

Bivariate Analysis

A chi-square test indicated a significant association between proximity to the explosion and insomnia ($\chi^2 = 5.13$, $p = 0.024$). Additional chi-square tests confirmed significant associations between insomnia and:

Table 3 Insomnia Severity Levels in the Study Population

Insomnia Severity Level	Count	Percentage
No insomnia (0–7)	94	24
Subthreshold (mild) insomnia (8–14)	87	35.1
Moderate clinical insomnia (15–21)	56	22.6
Severe clinical insomnia (22–28)	11	4.4

Notes: Distribution of insomnia severity levels in the study population. The table shows the classification of participants based on their insomnia severity: no insomnia (0–7), subthreshold (mild) insomnia (8–14), moderate clinical insomnia (15–21), and severe clinical insomnia (22–28). To focus on clinically significant insomnia, a stricter cutoff ($ISI > 14$) was used in for the remainder of the analysis. Under this criterion, 28.8% of participants in the group less than 6 km away exceeded the insomnia threshold, compared to 16.8% in the group located more than 6 km from the explosion.

Gender

Females had a higher prevalence (26.7%) than males (15.6%), $\chi^2 = 4.02$, $p = 0.045$.

Direct Exposure Variables

- Defined as experiencing one or more of the following: personal injury, injury or loss of a friend or family member (social consequences), or property damage/financial loss (material consequences). This measure captures personal consequences of the explosion beyond geographic proximity.
- Significant associations were found between insomnia and all categories of direct exposure: Personal injury ($p = 0.010$), social loss ($p = 0.008$), material loss ($p = 0.007$), and general exposure ($p = 0.002$) were all significantly associated with insomnia.

No significant association was found between insomnia and age ($p = 0.691$), marital status ($p = 0.089$) or employment status ($p = 0.194$).

A significant association was found between direct exposure and PTSD, $\chi^2(1) = 4.33$, $p = 0.037$, indicating that individuals who were directly exposed were more likely to meet criteria for probable PTSD. No significant associations were found between direct exposure and depression, $\chi^2(1) = 0.00$, $p = 0.984$, or anxiety, $\chi^2(1) = 1.93$, $p = 0.165$.

Relationship with Other Mental Health Scales

A significant association was found between insomnia and PTSD symptoms. The correlation between ISI and IES-R scores was strong (Spearman's $\rho = 0.57$, $p < 0.001$). Cross-tabulation showed that 65.9% of participants with probable insomnia ($ISI > 14$) met the PTSD threshold ($IES-R \geq 33$), compared to 21.8% of those without insomnia ($\chi^2 = 29.48$, $p < 0.001$), indicating a strong association between the two (see Table 4).

In addition, participants with higher scores for depression and anxiety on the PHQ-4 demonstrated significantly higher insomnia scores, as shown by the Mann–Whitney U -test (Anxiety: $U = 2591.5$, $p < 0.001$; Depression: $U = 1986.5$, $p < 0.001$; results not shown in a table).

Multivariate Analysis

Prior to conducting multivariate analysis, chi-square tests further demonstrated significant associations between direct exposure to the explosion and adverse mental health outcomes, including PTSD, depression, and anxiety (Table 5). The logistic regression analysis, taking the presence/absence of insomnia (ISI score > 14 and < 14 , respectively) as the dependent variable, and adjusting for age, sex, nicotine use, caffeine use, alcohol use, substance use, psychiatric history, sleep disorder history, and hypnotic (sleep aid) usage, confirmed the association between proximity to the explosion and insomnia ($OR = 2.17$, $p = 0.025$, 95% CI: 1.10–4.27), indicating that those closer to the explosion were more than twice as likely to report clinical insomnia. The analysis also revealed that females were more than twice as likely to experience insomnia than males ($OR = 2.40$, $p = 0.035$, 95% CI: 1.06–5.42).

Table 4 Chi-Square Test Results: Associations Between Insomnia and Sociodemographic Factors, Proximity, Exposure, and Mental Health Outcomes

Comparison	χ^2 (df)	p-value
Proximity (<6 km vs ≥ 6 km) $\times$ Insomnia	5.13	0.024
Gender $\times$ Insomnia	4.02	0.045
Marital Status $\times$ Insomnia	4.83	0.089
Employment Status $\times$ Insomnia	4.72	0.194
Direct Exposure $\times$ Insomnia	9.75	0.002
Material Consequences $\times$ Insomnia	7.28	0.007
Social Consequences $\times$ Insomnia	7.06	0.008
Personal Injury $\times$ Insomnia	6.71	0.010
Insomnia $\times$ PTSD (ISI >14 $\times$ IES-R ≥ 33)	29.48	<0.001

Notes: Chi-square test results showing associations between insomnia and sociodemographic factors, proximity to the Beirut explosion, direct exposure experiences, and PTSD. Insomnia was defined as ISI >14 (Insomnia Severity Index) and PTSD as IES-R ≥ 33 (Impact of Event Scale-Revised). Significant associations ($p < 0.05$) are indicated.

Table 5 Chi-Square Test Results: Associations Between Direct Exposure and Mental Health Outcomes

Comparison	χ^2 (df)	p-value
Direct Exposure $\times$ PTSD	4.33	0.037
Direct Exposure $\times$ Depression	0.00	0.984
Direct Exposure $\times$ Anxiety	1.93	0.165

Notes: Chi-square test results showing associations between direct exposure to the Beirut explosion and mental health outcomes. PTSD (post-traumatic stress disorder) was defined as IES-R ≥ 33 (Impact of Event Scale-Revised), and depression and anxiety as PHQ-4 ≥ 3 (Patient Health Questionnaire-4). Significant associations ($p < 0.05$) are indicated.

The logistic regression model confirmed significant predictors of insomnia, including proximity to the explosion (OR = 2.17), female gender (OR = 2.40), and hypnotic usage (OR = 3.19) (Table 6). Other variables did not show significant associations.

Table 6 Logistic Regression Analysis of Factors Associated with Insomnia Symptoms

Predictor Variable	B (SE)	OR	95% CI	p-value
(Intercept)	-1.48 (0.73)	0.23	0.05–0.95	0.043
Age	-0.005 (0.013)	0.995	0.97–1.02	0.691
Proximity to explosion	0.77 (0.35)	2.17	1.10–4.27	0.025
Gender	0.87 (0.42)	2.40	1.06–5.42	0.035
Nicotine use	-0.16 (0.41)	0.85	0.38–1.91	0.698
Caffeine use	0.20 (0.39)	1.22	0.57–2.61	0.607
Alcohol use	-0.22 (0.39)	0.80	0.37–1.74	0.584

(Continued)

Table 6 (Continued).

Predictor Variable	B (SE)	OR	95% CI	p-value
Recreational substance use	0.33 (0.61)	1.39	0.42–4.57	0.586
Psychiatric history	−0.61 (0.54)	0.54	0.19–1.57	0.262
Sleep disorder history	0.12 (0.59)	1.12	0.35–3.62	0.838
Hypnotic usage	1.16 (0.36)	3.19	1.59–6.48	0.001

Notes: Logistic regression analysis of factors associated with insomnia symptoms. The model explains 10.1% of the variance (McFadden's pseudo- $R^2 = 0.101$). Odds ratios (OR), 95% confidence intervals (CI), and p-values for all included variables are shown.

PTSD

Approximately 31% of participants had an IES-R score of 33 or higher, indicating probable PTSD. A chi-square test revealed no significant association between proximity to the explosion and the proportion of individuals crossing the PTSD threshold on the IES-R scale 4 years following the explosion ($p = 0.717$): Specifically, 29.5% of individuals within 6 km of the explosion exceeded the PTSD threshold, compared to 31.9% of those more than 6 km away (results not shown in a table).

Direct exposure to the Beirut explosion was significantly associated with PTSD ($\chi^2 = 4.33$, $p = 0.037$), with 39.7% of affected individuals reporting PTSD compared to 25.6% of those not directly affected (see Table 5).

Depression and Anxiety

The presence of possible depression and anxiety was analyzed using the PHQ-4 questionnaire.

No significant association was found between proximity to the explosion and long-term depression or anxiety symptomatology. The chi-square test also showed no significant difference based on proximity for either depression ($p = 0.359$) or anxiety ($p = 0.537$) (results not shown in a table).

No significant association was found between direct exposure and the persistence of depressive symptoms ($\chi^2 = .00$, $p = 0.984$) or anxiety symptoms ($\chi^2 = 1.93$, $p = 0.165$) 4 years after the explosion, with 33.8% and 48.8% of affected participants reporting these symptoms, respectively, compared to 33.9% and 38.8% among those not directly affected (see Table 5).

Substance Use

The relationship between proximity to the explosion and substance use (nicotine, caffeine, alcohol, and recreational drugs) was explored. A significant association was found for alcohol ($p = 0.017$) and recreational drugs ($p = 0.03$), with individuals closer to the explosion more likely to report increased use following the explosion. No significant associations were observed for nicotine ($p > 0.05$) or caffeine ($p > 0.05$).

Discussion

This study examines the long-term impact of the Beirut port explosion on mental health, focusing on sleep disturbances, which emerged as the most persistent outcome four years later. When using a cutoff score of 8 on the ISI, which includes mild (subclinical) cases of insomnia, we found the overall prevalence of insomnia to be 62.1% in our sample. This was notably higher than the 47.1% prevalence reported by Karaki et al (2017),¹² and the 44.5% reported by Chami et al (2019).¹¹ Several methodological differences, including the use of different insomnia measures and criteria, may account for these discrepancies.

Beyond methodological differences, the context of our study offers an additional explanation for the higher prevalence of insomnia. Both Karaki et al (2017) and Chami et al (2019) examined insomnia in general populations prior to significant societal stressors. Chami et al collected data between March and May 2014, and Karaki et al between August 2017 and April 2018, both before the onset of Lebanon's economic crisis, the COVID-19 pandemic, and the Beirut explosion, which may all have partly contributed to the increase in the rates of insomnia observed in our sample. To account for these confounding factors and better isolate the potential impact of the Beirut blast, we introduced an

additional level of analysis by examining differences in insomnia rates between individuals residing within the blast radius and those outside of it.

The overall prevalence of insomnia using cutoff on ISI of 8 (subclinical insomnia) was higher among individuals located less than 6 km from the explosion, however, this difference did not reach statistical significance. When applying the stricter insomnia cutoff score of 14 on the ISI (clinically significant insomnia), which we used for the remainder of this study, we observed a significant difference between the two groups. Among individuals located less than 6 km from the explosion the prevalence of clinically significant insomnia was 28.8% as compared to 16.8% among those situated farther away ($p = 0.024$). The significant difference indicates that, although the overall prevalence of insomnia symptoms was elevated in both populations, the traumatic psychological impact of living in closer proximity to the explosion may be more pronounced. These findings of persistent insomnia are consistent with findings on the aftermath of major disasters, including the September 11th attacks,²⁸ the Chernobyl disaster,²⁹ and the Great East Japan Earthquake,³⁰ all of which documented prolonged insomnia among survivors. The observed odds ratio of 2.17, adjusted for confounders, indicates that individuals within the explosion radius are more than twice as likely to experience long-term, clinically significant insomnia.

While the study found a high prevalence of self-reported past or present psychiatric diagnoses, adjusting for this variable in the logistic regression analysis did not reveal any significant influence on the outcomes, particularly insomnia. This suggests that, in our sample, psychiatric history did not substantially contribute to the outcomes in the context of proximity to the explosion.

Direct effects of the explosion, such as personal injury, loss of loved ones, and property damage, were strongly linked to higher insomnia rates, consistent with a previous study.^{3,31}

Female participants were found to be twice as likely to experience insomnia compared to males ($OR = 2.40$, $p = 0.035$). This is consistent with previous findings that women are disproportionately affected by sleep disturbances following traumatic events. The additional stressors associated with family obligations, work and gender role expectations most likely contribute significantly to the findings in women.^{32–35}

It is notable that twice as many females completed the survey than males. This gender disparity in our sample may have influenced our findings, particularly the elevated prevalence of insomnia. Prior research suggests that women are more likely to participate in health-related and online surveys,³⁶ which could result in sampling bias and overrepresentation of female-specific experiences.

Age was not a significant predictor of insomnia within this sample ($p = 0.691$), which is consistent with existing literature.³⁷ However, it is important to note that the age distribution in our sample might not have fully captured the diversity necessary to test this association effectively. Given the sampling method and the mean and SD for age, it is possible that older adults were under-represented, limiting our ability to observe a potential age-related effect. Regardless of age, the type of trauma that one experiences has been identified as an independent predictor of insomnia.³¹

Insomnia is the most common symptom in individuals with PTSD, affecting 80–90% of patients.³⁸ Our findings show that those directly affected by personal injury, loss of loved ones, or property damage had significantly higher levels of insomnia and PTSD. Our analysis found no significant relationship between distance from the explosion and PTSD symptoms, in contrast to short term findings.¹⁷ PTSD was more prevalent among those closest to the blast initially, but over time, the psychological impact may have spread, evolving into a national trauma affecting individuals regardless of proximity, as seen in other large-scale disasters.³⁹

The increased PTSD and insomnia in individuals affected by the explosion may be attributed to the severity of the disaster, ongoing stressors, media coverage, inadequate government response, and lack of closure due to stalled investigations.

No significant association was found between proximity to the Beirut explosion and depression or anxiety four years later, in contrast to short-term studies,^{16,17,40} suggesting that mood outcomes may spread or normalize over time as individuals adapt.

These findings suggest that insomnia symptoms may follow different recovery paths compared to PTSD, depression and anxiety, which may improve or normalize over time. Insomnia may persist longer than other mental health symptoms following trauma due to its strong neurobiological roots. Neurobiological models of trauma-induced insomnia describe

how trauma triggers sustained hyperarousal, driven by increased activity in stress-related neural circuits, that maintains insomnia independently of PTSD's core symptoms.¹ Disruptions in REM sleep, including frequent micro-arousals and fragmented REM, impair emotional memory consolidation and extinction processes, making it harder to “downregulate” trauma responses during sleep.^{41,42}

Targeting sleep disturbances in PTSD not only alleviates insomnia but also provides broader relief of PTSD symptoms, highlighting the importance of differentiated post-disaster mental health interventions that combine targeted sleep support with comprehensive psychological care tailored to symptom-specific trajectories.⁴³

Recent neuroimaging studies further elucidate the neural underpinnings of sleep disturbances in relation to mood disorders. Patients with major depressive disorder (MDD) show distinct brain changes linked to sleep that predict treatment outcomes. Low sleep efficiency is tied to impaired white matter integrity and disrupted brain synchronization.⁴⁴ REM sleep disturbances correlate with reduced interhemispheric connectivity, greater anxiety severity, and changes that track with symptom improvement over time.⁴⁵ Similarly, baseline REM percentage predicts recovery through its effects on brain activity and blood flow.⁴⁶ Resting-state activity in parietal and frontal regions also forecasts symptom improvement, with sleep efficiency mediating these effects.⁴⁷ Overall, disrupted sleep, especially REM, emerges as a neural marker of disease course in MDD.

The cultural context in Lebanon may also influence the prioritization of sleep and somatic complaints over psychological issues. The mental health stigma that is prevalent in Lebanon often deters individuals from seeking help, leading them to focus on somatic symptoms.⁴⁸ In contrast, sleep issues may be perceived as less stigmatizing, prompting individuals to report these symptoms more readily. Alternatively, the lower depression and anxiety in our cohort may reflect the population's resilience, supported by strong familial bonds and social networks, influenced by cultural factors in Lebanon during crises.

Emerging evidence indicates that insomnia is a powerful independent risk factor for suicidal ideation and behavior, even in populations beyond depression, such as individuals with first-episode psychosis.⁴⁹ This further highlights the urgent need for integrating sleep-focused interventions into post-disaster care not only to address insomnia itself but also to mitigate downstream risks to life.

Finally, our analysis showed that participants closer to the explosion reported a higher increase in recreational substance use ($p = 0.03$), and alcohol consumption ($p = 0.017$) compared to those living further away. This suggests that the traumatic event may have led to maladaptive coping strategies, such as increased substance use. Previous research has demonstrated that exposure to traumatic events is often associated with increased substance use.⁵⁰ The absence of increased caffeine and nicotine use suggests that not all substances are equally prone to misuse following trauma, noting that smoking (cigarettes/waterpipe) and caffeine use are already highly prevalent in Lebanon.⁵¹ Incorporating substance use prevention and treatment into post-disaster mental health services is crucial.

In Lebanon's low-resource setting, developing integrated, culturally sensitive interventions that address both sleep disturbances and substance use will be crucial for supporting long-term recovery and resilience in affected communities.

Limitations

The reliance on self-reported measures without clinical evaluations may introduce response bias, as some participants could overreport or underreport symptoms due to stigma in Lebanese culture. Additionally, the sample may not fully represent the broader Lebanese population, as those most severely affected may have been less likely to participate. Recruitment through social media platforms may have introduced selection bias, favoring younger, more educated, and tech-savvy participants. This could limit the generalizability of findings to older adults or less digitally connected populations, potentially underrepresenting groups with different exposure or symptom profiles. Furthermore, the overrepresentation of females in the sample could affect the findings and their applicability to the general population, despite adjustments for gender in the analyses. Lastly, although data collection occurred approximately 3 to 4 years after the Beirut explosion, this timeframe may not fully capture the long-term trajectory of psychological effects, which could evolve beyond this window.

Conclusion

The Beirut explosion had lasting mental health effects, with insomnia notably higher among those closer to the blast. Nearly 30% of participants within 6 km reported clinically significant insomnia, often linked to direct exposure. While PTSD symptoms were elevated, depression and anxiety showed no long-term association with proximity. Increased substance use near the site raises important public health concerns.

These findings emphasize the need for early sleep health screening in post-disaster settings, as sleep complaints may serve as a culturally acceptable entry point for mental health interventions in Lebanon. Policymakers should prioritize integrating long-term psychological support, with a focus on sleep disturbances, into disaster response, especially in resource-limited regions. Beyond their immediate burden, chronic sleep disturbances have broader consequences for mental health, including increased risk of suicidal ideation and behavior. Incorporating evidence-based sleep interventions into post-disaster care is therefore not only critical for reducing insomnia itself, but also for mitigating downstream psychiatric morbidity and suicide risk.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work, the author(s) used QuillBot in order to paraphrase some sentences to enhance the clarity and style of language. After using this tool, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

Research Data for This Article

Due to the sensitive nature of the data collected, including participants' location during the Beirut explosion and other personal details, raw data cannot be shared. Participants were assured of confidentiality, and their data will remain confidential.

Ethics Approval and Consent to Participate

This study was approved by the Institutional Review Board (IRB) at the American University of Beirut (IRB ID: SBS-2021-0218), in accordance with the principles of the Declaration of Helsinki. Informed consent was obtained from all study participants prior to study commencement. No patient identifiable features are included in this paper.

Consent to Publish

Participants provided informed consent to participate in the study, which included acknowledgment that the results would be published in a peer-reviewed journal. No identifiable personal data is included in this paper.

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Disclosure

The authors report there are no competing interests to declare.

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