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Clinical Characteristics and Medium-Term Outcomes of Patients Exposed to a Wildland-Urban Interface Fire: A Retrospective Cohort Study from İzmir, Türkiye

Wildland-Kentsel Ara Yüz Yangınına Maruz Kalan Hastaların Klinik Özellikleri ve Orta Vadeli Sonuçları: İzmir, Türkiye'den Retrospektif Bir Kohort Çalışması

İbrahim KORKMAZ* 0000-0001-6874-5277
Özge EREN KORKMAZ 0000-0002-9476-4938**
Duygu Gizem YILDIRIM* 0009-0001-0549-0382
Naz EREN* 0009-0001-4156-5388
Safiye Dilan TAHTASIZ* 0009-0005-9106-9218
Fatmana SARAÇ* 0009-0006-5440-9778

* İzmir Şehir Hastanesi, Acil Tıp Kliniği, İzmir
**İzmir Dokuz Eylül Üniversitesi Tıp Fakültesi, Epidemiyoloji Bilim Dalı, İzmir

Yazışma Adresi: İbrahim KORKMAZ
İzmir Şehir Hastanesi, Acil Tıp Kliniği, İzmir
E-mail adresi: abrahamkorkmaz11@gmail.com

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Abstract

Objective: In 2024, we aimed to evaluate the clinical and laboratory characteristics of individuals admitted to the emergency department during the forest fire that occurred in Izmir Yamanlar region and to determine the risk factors associated with hospital readmission during the 6-month follow-up period. We also aimed to reveal the prevalence of short- and medium-term health effects in individuals exposed to fire and biomarkers that can be used to predict these effects.

Methods: This single-center, retrospective cohort study included 98 patients who presented with fire-related symptoms between August 13-18, 2024. Demographic and clinical data and laboratory results were obtained retrospectively from hospital records and the national health system.

Results: The median age of the patients was 33.0 years and 66.3% were male. The most common reasons for presentation were dyspnea (37.8%), trauma (25.5%), nausea (14.3%), headache (13.3%) and conjunctival hyperemia (13.3%). Within six months, 19.4% were readmitted to the hospital. Multivariate analysis identified advanced age (Adjusted OR (AOR): 1.04; p = 0.023) and low pH levels at admission (AOR: 0.09; p = 0.029) as independent predictors of hospital readmission. Respiratory reasons (dyspnea 26.4%, cough 15.8%) accounted for 72.7% of readmissions. No significant correlation was found between pH, lactate, COHb, HCO3 and troponin levels and the duration of readmission (p > 0.05).

Conclusion: Exposure to fire smoke causes medium-term health problems, especially in elderly individuals and those presenting with low pH. These findings emphasize the importance of early detection and regular follow-up of at-risk groups.

Keywords: Emergency Service, Hospital ; Environmental Exposure; Wildfires

Öz

Amaç: 2024 yılında İzmir Yamanlar bölgesinde meydana gelen orman yangını sırasında acil servise başvuran bireylerin klinik ve laboratuvar özelliklerini değerlendirmek ve 6 aylık izlem sürecinde hastaneye tekrar başvuru ile ilişkili risk faktörlerini belirlemek amaçladık. Ayrıca, yangına maruz kalan bireylerde kısa ve orta vadeli sağlık etkilerinin yaygınlığını ve bu etkileri öngörmede kullanılabilecek biyobelirteçleri ortaya koymayı hedefledik.

Yöntem: Tek merkezli, retrospektif kohort tasarımında yürütülen bu çalışmaya, 13–18 Ağustos 2024 tarihleri arasında yangına bağlı semptomlarla başvuran 98 hasta dahil edildi. Demografik ve klinik veriler ile laboratuvar sonuçları hastane kayıtları ve ulusal sağlık sisteminden retrospektif olarak elde edildi.

Bulgular: Hastaların median yaşı 33,0 yıldı ve %66,3'ü erkekti. En sık başvuru nedenleri dispne (%37,8), travma (%25,5), mide bulantısı (%14,3), baş ağrısı (%13,3) ve konjonktival hiperemi (%13,3) idi. Altı ay içinde, %19,4'ü hastaneye tekrar başvurdu. Çok değişkenli analizde ileri yaş (Düzeltilmiş OR (AOR): 1.04; p = 0.023) ve başvuru sırasındaki düşük pH seviyeleri (AOR: 0.09; p = 0.029) hastaneye tekrar başvurunun bağımsız belirleyicileri olarak tanımlandı. Solunumsal nedenler (dispne %26,4, öksürük %15,8) tekrar başvuruların %72,7'sini oluşturdu. pH, laktat, COHb, HCO3 ve troponin düzeyleri ile tekrar başvuru süresi arasında anlamlı bir ilişki bulunmadı (p > 0.05).

Sonuç: Yangın dumanına maruz kalmak, özellikle yaşlı bireylerde ve düşük pH ile başvuranlarda orta vadeli sağlık sorunlarına yol açmaktadır. Bu bulgular, riskli grupların erken tespiti ve düzenli takibinin önemini vurgulamaktadır.

Anahtar Kelimeler: Acil Servis; Çevresel Maruziyet; Orman Yangınları

Introduction

Forest fires are one of the major disasters that threaten public health and are becoming more frequent worldwide due to global climate change and increasing urbanization. Turkey, which is located in the Mediterranean basin, is at high risk of forest fires due to its geographical and climatic characteristics. In recent years, especially in the summer months, fires affecting large areas in various regions of our country have been occurring and causing economic and ecological losses. According to the records of the General Directorate of Forestry for the last ten years between 2014 and 2023, records show that approximately 2,569 forest fires occur on average every year and approximately 23,229 hectares of forest area are burned in these fires (1).

The smoke released during forest fires contains many harmful substances such as carbon monoxide, nitrogen oxides, sulphur dioxide, particulate matter (PM10, PM2.5) and volatile organic compounds. These toxic substances can cause acute and chronic effects, especially on the respiratory and cardiovascular systems. In the literature, an increase in asthma, COPD exacerbations, pneumonia, and other respiratory infections after fire exposure has been reported (2). In addition, cardiovascular events, eye irritation, headache, and psychological stress are among the common health problems (3-5).

It has been shown that there is a 9% increase in emergency room visits and a 4% increase in the risk of hospitalization following exposure to fire smoke (6).

A Brazilian study showed that wildfire waves were associated with a 23% increase in hospitalizations for respiratory diseases and a 21% increase in hospitalizations for cardiovascular diseases (7). The increase in these two hospital-based indicators suggests significant health risks associated with exposure to fire smoke. The most common causes of ED admission after exposure are asthma, exacerbation of chronic obstructive pulmonary disease, pneumonia, acute bronchitis, cardiopulmonary symptoms, and heart failure (8). It has also been reported that there is an increase in emergency department (ED) visits due to headaches and migraines even after short-term forest fires (9).

Between August 13 and 18, 2024, a total area of 4,300 hectares was burned in the forest fire that occurred in the Yamanlar region of Izmir. The fire spread beyond the forest area and affected the residential areas in the region, and many people sought medical attention with complaints related to smoke exposure. The aim of this study was to determine the demographic and clinical characteristics of the patients admitted to our hospital during the fire, to analyze their laboratory parameters, and to evaluate their readmission status in a 6-month period. Our study will contribute to a better understanding of the short- and medium-term health outcomes of patients exposed to forest fires and shed light on future disaster management planning.

Material and Methods

Study Design and Scope

In this single-center retrospective cohort study, we evaluated the clinical characteristics of patients admitted to the ED of a tertiary care hospital during the forest fire that occurred between August 13-18, 2024, in the Yamanlar region of Izmir, and their readmission to the hospital within 6 months. The study protocol was approved by the ethics committee (Decision no: 2025/135 Date: 19.03.25). Informed consent was not obtained as patients were not involved in the design, recruitment, or conduct of the study.

Since there is no direct data in the literature on the frequency of readmission to hospital within 6 months in individuals exposed to forest fire, studies examining similar environmental exposures were used for sample size calculation. In a systematic review by Reid et al. it was reported that the effects of exposure to forest fire smoke on respiratory diseases were consistent and the effect sizes were moderate (2). Therefore, the assumption of medium effect size (Cohen's d = 0.3) was adopted in our study. With this assumption, a total of 88 individuals were aimed to be reached in the calculation using G-Power 3.1 for 80% statistical power and 5% significance level. In our study, the targeted sample size was exceeded by reaching 98 patients.

Participants and Data Collection

Patients who were admitted to the hospital with symptoms related to exposure to forest fires between August 13-18, 2024. Patients whose medical records were incomplete and whose 6-month follow-up data could be accessed were included in the study. Patients admitted for non-fire-related reasons, pregnant patients, pediatric patients, and patients whose data could not be accessed during the follow-up period were excluded from the study.

Re-admission with fire-related complaints was defined as patients re-admitted to hospital with symptoms (such as dyspnea, cough, eye irritation, headache, chest pain, sore throat, skin irritation) attributable to wildfire exposure within 6 months of initial presentation. Whether these complaints were fire-related was determined by the clinician evaluating the patient, taking into account the patient's medical history, the time of onset of symptoms and the results of clinical assessment, and recorded in the patient file. To ensure standardization, patient records were reviewed by two independent investigators during the retrospective evaluation and a third investigator was consulted in doubtful cases.

Demographic information, complaints at admission, vital signs, laboratory values (pH, lactate, carboxyhemoglobin levels, bicarbonate, troponin), hospitalization status and duration, and reasons for readmission were obtained retrospectively from patient files, hospital automation system, and e-Nabız system, which is a centralized system for recording health data in Turkey. The readmissions of all patients to the hospital within a six-month period after their initial admission were evaluated. Patients with ongoing complaints due to fire exposure who were readmitted to the hospital for this reason were identified and the timing of admission, reasons for admission, departments consulted, and clinical outcomes were recorded. Both initial and repeat admission times were calculated in days.

Statistical analysis

Data were analyzed using R software (version 2024.12.0+467). Median [IQR] or mean ± standard deviation (SD) were used for descriptive statistics, and categorical variables were expressed as number (n) and percentage (%). Compliance with normal distribution was evaluated by the Shapiro-Wilk test; the Mann-Whitney U test was used for data that did not fit the normal distribution; and the Chi-square or Fisher's exact test was applied for categorical variables.

Multivariate logistic regression analysis was performed with the "ENTER" method using the independent variables found to be statistically significant. The fit of the model was assessed by Likelihood test, multicollinearity was examined by Variance Inflation Factor (VIF) test and variables with values < 5 were included in the model.

Univariate survival analyses were performed using the Cox regression model ("survival", "survminer" packages) to examine potential influencing factors on hospital readmission time. In this analysis, the effect of each independent variable on event duration (time to readmission) was assessed separately. The limit of statistical significance was set at $p < 0.05$.

Results

A total of 98 patients were included in the study. The median age of the patients was 33.0 years (IQR 18.0), and 66.3% were male. Smoking was present in 45.9% of the patients. The most common presenting symptoms were dyspnea (37.8%), trauma (25.5%), nausea (14.3%), headache (13.3%), and conjunctival hyperemia (13.3%). In laboratory results, the median pH value was 7.39 [IQR: 0.50], lactate was 1.30 [IQR: 0.80], COHb was 1.60 [IQR: 1.80], HCO3 was 25.8 [IQR: 3.9], and troponin was 6.00 [IQR: 5.90] (Table 1).

While 99.0% of the patients were discharged, 1.02% were hospitalized in the intensive care unit. During the 6-month follow-up period, 19.42% of patients were readmitted to the hospital. Reasons for readmission included check-up (31.5%), dyspnea (26.4%), cough (15.8%), headache (10.5%), and dry eye (10.5%). 11.2% Of patients presented repeatedly, but further context is needed to clarify in what manner or frequency this occurred. The median time to first presentation was 20.0 (IQR: 57.0) days and the median time to second presentation was 44.5 (IQR: 55.8) days (Table 2).The most preferred clinical units were pulmonology (36.8%), orthopedics (21.1%), ED (15.8%), and neurology (10.5%) (Table 1).

Table 1: Baseline characteristics and clinical features of patients

Parameters	median [IQR] n(%)
Age	33.0 [18.0]
Gender	
Male	65 (66.3%)
Female	33 (33.7%)
Current smokers	45 (45.9%)
Presenting complaints	
Dry cough	11 (11.2%)
Productive cough	3 (3.06%)
Conjunctival hyperemia	13 (13.3%)
Sore throat	5 (5.10%)
Headache	13 (13.3%)
Dyspnea	37 (37.8%)
Nausea	14 (14.3%)
Vomiting	11 (11.2%)
Anxiety	1 (1.02%)
Trauma	25 (25.5%)
Burn	1 (1.02%)
Fracture	5 (5.1%)
Laboratory findings:	
Heart Rate	80.0 [5.0]
Systolic blood pressure (SBP)	130 [5.0]
Diastolic blood pressure (DBP	80.0 [4.0]
Respiratory rate (RR), mean±SD	16.2 ± 1.34
pH	7.39 [0.50]
Lactate	1.30 [0.80]
Carboxyhemoglobin (COHb)	1.60 [1.80]
Bicarbonate (HCO3)	25.8 [3.9]
Troponin	6.00 [5.90]
Hospitalization status:	
Discharged	97 (99.0%)
ICU admission	1 (1.02%)
Revisit	19 (19.4%)
Reasons for revisit (n=19):	
Follow-up examination	6 (31.5%)
Headache	2 (10.5%)
Dyspnea	5 (26.4%)
Dry eyes	2 (10.5%)
Cough	3 (15.8%)
Syncope	1 (5.3%)
Repeated visits:	11 (11.2%)
First admission duration (days):	20.0 [57.0]
Second admission duration (days):	44.5 [55.8]
Admission department:	
Emergency Department	3 (15.8%)
Pulmonology	7 (36.8%)
Ophthalmology	2 (10.5%)
Neurology	2 (10.5%)
Orthopedics	4 (21.1%)
Burn unit	1 (5.26%)
SD: Standart deviation	

The median age of patients readmitted to the hospital within 6 months was significantly higher (40.0 [IQR: 19.0] vs. 31.0 [IQR: 17.0], p = 0.006). There was no statistically significant difference between the groups in terms of gender, smoking, and most clinical symptoms. However, readmitted patients had a significantly lower initial pH value (7.36 [IQR: 0.03] vs. 7.40 [IQR: 0.05], p = 0.008). In multivariate logistic regression analysis, older age and low pH levels at admission were found to be independent predictors of readmission within six months.

Each one-year increase in age increased the probability of hospital readmission by 4% (AOR: 1.04; 95% CI: 1.00-1.08; p = 0.023). Furthermore, each 0.1 unit decrease in pH level increased the risk of readmission by approximately 91% (AOR: 0.09; 95% CI: 0.00-0.61; p = 0.029) (Table 2).

Table 2: Comparison of Baseline Characteristics and Factors Associated with 6-Month

	Revisit Patient	**None**			
	N=19	***N=79***			
	N(%) / median [IQR]	**N(%) / median [IQR]**	**p**	**Adjusted OR (95% CI)**	**p**
Age, year	40.0 [19.00]	31.0 [17.00]	**0.006**	1.04 (1.00-1.08)	**0.023**
Gender			0.551		
Male	11 (16.9%)	54 (83.1%)			
Female	8 (24.2%)	25 (75.8%)			
Smoking status	11 (24.4%)	34 (75.6%)	0.363		
Dry cough	2 (18.2%)	9 (81.8%)	1.000		
Productive cough	2 (66.7%)	1 (33.3%)	0.095		
Conjunctival hyperemia	3 (23.1%)	10 (76.9%)	0.712		
Sore throat	0 (0.00%)	5 (100%)	0.580		
Headache	4 (30.8%)	9 (69.2%)	0.272		
Dyspnea	9 (24.3%)	28 (75.7%)	0.484		
Nausea	2 (14.3%)	12 (85.7%)	1.000		
Vomiting	1 (9.09%)	10 (90.9%)	0.686		
Anxiety	0 (0.00%)	1 (100%)	1.000		
Trauma	7 (28.0%)	18 (72.0%)	0.245		
Heart rate (HR)	80.0 [0.0]	80.0 [5.80]	0.873		
Diastolic blood pressure (DBP)	80.0 [0.0]	80.0 [5.00]	1.000		
Respiratory rate (RR), mean $\pm$ $\boldsymbol{SD}$	16.4 $\pm$ 1.67	16.0 $\pm$ 1.20	0.657		
pH*	7.36 [0.03]	7.40 [0.05]	**0.008**	0.09 (0.00-0.61)	**0.029**
Lactate	1.70 [1.15]	1.30 [0.68]	0.575		
Carboxyhemoglobin (COHb)	1.60 [1.10]	1.60 [2.20]	0.603		
Bicarbonate (HCO3)	25.3 [4.10]	26.0 [3.90]	0.251		
Troponin	4.70 [1.70]	8.50 [5.60]	0.245		

*pH (per 0.1 unit), OR:Odds Ratio, CI: Confidence Interval, SD: Standart Deviation
Nagelkerke R^2: 0.50, Likelihood Ratio Test p<0.001

According to the results of univariate Cox regression analysis, no statistically significant correlation was found between the duration of readmission and age, pH, lactate, carboxyhemoglobin (COHb), bicarbonate (HCO3) and troponin levels (p > 0.05). HR: 0.98 (95% CI: 0.94-1.02) was found for the age variable and it was observed that age had no significant effect on the time to readmission.

Similarly, pH (HR: 0.91; 95% CI: 0.24-3.48; p = 0.901), lactate (HR: 1.05; 95% CI: 0.69-1.59; p = 0.818), COHb (HR: 1.24; 95% CI: 0.69-2.23; p = 0.467), HCO3 (HR: 1. 01; 95% CI: 0.93-1.10; p = 0.750) and troponin (HR: 0.99; 95% CI: 0.92-1.08; p = 0.948) levels did not significantly affect readmission time (Table 3).

Table 3: Univariate Cox Regression Analysis of Risk Factors Associated with Length of Hospital Readmission

Variables	HR (exp(coef))	95% CI	p
Age	0.98	0.94 – 1.02	0.322
pH*	0.91	0.24 – 3.48	0.901
Lactate	1.05	0.69 – 1.59	0.818
Carboxyhemoglobin (COHb)	1.24	0.69 – 2.23	0.467
Bicarbonate (HCO3)	1.01	0.93 – 1.10	0.750
Troponin	0.99	0.92 – 1.08	0.948
HR: Hazard Ratio, Cl: Confidence Interval, *pH (per 0.1 unit)			

Discussion

This retrospective cohort study evaluated the clinical characteristics and 6-month follow-up outcomes of patients admitted to the ED of a tertiary hospital during the forest fire in the Yamanlar region of Izmir. The most important finding of our study was that 19.4% of the patients were readmitted to the hospital with complaints related to fire exposure during the 6-month period, and these patients had significantly higher mean age and lower baseline pH values. These findings demonstrate that wildfires have not only acute but also medium-term health effects and highlight the importance of developing strategies for early identification and follow-up of individuals at risk.

Respiratory symptoms are the leading health effects on fire. In our study, the most common presenting complaint was shortness of breath. In the literature, it has been reported that respiratory complaints are the most common reason for admission after forest fire exposure (6,10-12). Wah et al. emphasized that inflammatory processes developing after fire exposure may cause irritation and airway reactivity, especially in the respiratory tract, and may increase asthma and COPD exacerbations (13). The majority of the readmissions in our study were due to respiratory complaints (dyspnea, cough), confirming the clinical reflection of this pathophysiologic process.

It has been shown in many studies that exposure to fire smoke causes an increase in hospital admission rates. Liu et al. reported that health effects after exposure to wildfire smoke may not be limited to the acute period, and respiratory symptoms, espically, may last for weeks (14). Wah et al. reported that respiratory symptoms due to fire exposure persisted for a long time, and new asthma diagnoses were even made in some cases (13). In our study, the rate of readmission within 6 months was found to be 19.4%, which is consistent with the data in the literature and demonstrates the importance of medium-term effects, especially in communities directly exposed to fire.

In our study, the mean age of the individuals who were re-admitted to the hospital was significantly higher among those exposed to fire, revealing that elderly individuals are more vulnerable to the health effects of forest fires. In the literature, it has been stated that this situation is related to multidimensional physiopathological and environmental reasons. Liu et al. (2017) and Chen et al. (2021) reported that the effects of fire smoke may be more pronounced in elderly individuals due to decreased respiratory reserve, susceptibility to inflammation and low physiological tolerance to toxic gases such as carbon monoxide (15,16). Requia et al. (2021) showed that elderly individuals had a higher rate of post-fire health service application because they usually have more comorbidities (7). However, Sorensen et al. (2021) emphasised that fire-related symptoms in the elderly may not be evident in the acute period, but the tendency to present with longer-lasting or recurrent complaints increases in the following weeks (17). Our study suggests that the reasons for readmission, which were mostly based on subacute respiratory or general symptoms (dyspnoea, cough, headache, dry eyes) rather than cardiovascular symptoms, indicate that physiological frailty and health-seeking behaviour, which increase with age, contribute to this clinical picture. In our study, the increased likelihood of readmission to the hospital in individuals with low initial pH levels suggests that systemic metabolic disturbances are more prominent in these patients after exposure to fire smoke. In the literature, it has been reported that fire-related PM2.5 and CO exposure disrupts mitochondrial functions and increases reactive oxygen species (ROS), resulting in tissue hypoxia and metabolic acidosis (2,6,7,13,16,18,19). This acidosis may contribute to cellular dysfunction and long-term clinical symptoms, especially in vulnerable individuals. Therefore, assessment of acid-base status at initial presentation after fire exposure may be important in predicting both short- and medium-term health outcomes.

In a study conducted in patients with heart failure in North Carolina, it was reported that moderate-severe or intense smoke exposure increased 7- and 30-day hospital readmission rates, but no significant individual factor associated with readmission time was found (20). This finding is in parallel with the fact that no significant relationship was found between the duration of readmission and parameters such as age, carboxyhemoglobin, troponin and bicarbonate levels in our study. This suggests that post-fire health effects may develop as a result of a multifactorial and complex interaction rather than individual factors.

In our study, headache was one of the most prominent symptoms in both the first admissions and re-admissions, and ocular complaints such as conjunctival hyperemia and dry eye were also significantly observed.

Elser et al. reported that short-term exposure to fire smoke caused a significant increase in tension-type and other primary headaches (9). Headache is thought to develop as a result of hypoxia due to carbon monoxide exposure and central nervous system inflammation triggered by particles in fire smoke (11). In the literature, it has been shown that emergency admissions with eye irritation, dryness, and conjunctivitis-like symptoms increase during wildfire periods (4). Schwarz et al. emphasized that wildfire-induced particulate matter may not only have physical but also neurotoxic effects and cause long-term effects on the eye and nervous system (21). In light of this information, it is thought that the headache and ocular complaints found in our study may be both direct effects of acute exposure and clinical reflections of the ongoing inflammatory process after the fire.

In the literature, some studies have reported increased cardiac effects due to fire (7,22,23), while others have not shown this relationship (2,3,15,24). Cardiovascular effects of fire smoke are not as consistent and predictable as respiratory effects. In our study, no significant elevation in troponin levels was found, and one of the possible reasons for this is that our patients presented to the emergency department with more acute symptoms and in the early post-exposure period. It is thought that cardiac biochemical changes were not yet clinically evident during this early presentation and sufficient time may not have elapsed for biomarkers such as troponin to be elevated. Moreover, the presence of fire-induced cardiovascular effects is influenced by many factors such as patient profile, exposure duration, individual physiological differences and follow-up period. In this context, in order to evaluate the cardiovascular effects after fire more accurately, repeated measurements should be performed by considering the dynamic change of biomarkers and longer duration of follow-up.

Finally, the fact that the Izmir fire also affected residential areas classified this event as a “wildland-urban interface” (WUI) fire. It has been emphasized that such fires may contain more toxic components, have higher particulate matter density, and therefore their effects on public health may be more pronounced (13). The high rate of ED admissions, multisystem symptoms, and a significant rate of re-admissions in the 6-month follow-up found in our study show that WUI fires may cause not only short-term but also medium-term health consequences, and these effects cannot be ignored in the population living in urban areas.

This study has some limitations. Its generalizability is limited due to its single-center and retrospective design. Another important limitation is that the level and duration of exposure to fire smoke at the individual level could not be measured. Exposure levels may differ between patients and this makes it difficult to evaluate the dose-response relationship. Factors such as proximity to the fire zone, duration of time indoors/outdoors, personal protective measures and ventilation conditions may affect the individual exposure level.

In future studies, it is recommended that more sensitive exposure assessments be made using data from air quality monitoring stations, personal exposure measurement devices and detailed questionnaires. Nevertheless, the 6-month follow-up period and detailed examination of the reasons for readmission make an important contribution to the literature.

Conclusion

Our study demonstrates the importance of both acute and medium-term health effects in individuals exposed to forest fires. It has been observed that biomarkers such as low pH at the time of admission may be helpful in predicting the risk of re-admission. Advanced age has been identified as a significant risk factor for fire smoke-related health problems. These findings may contribute to the development of strategies for early identification of individuals at risk after fires, close monitoring, and appropriate protective measures. In addition, considering the increasing frequency of WUI fires, early warning systems should be strengthened to protect the population living in urban areas. Special protection protocols for vulnerable populations (elderly, children, those with chronic diseases) should be developed, expansion of air quality monitoring networks should be implemented, capacity building of emergency health services should be prioritized, and public health policies such as community education should be developed. In addition, regular training of healthcare workers on triage, diagnosis and treatment protocols specific to fire situations and the establishment of equipment and preparedness plans for effective response in field conditions are also critical.

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