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Operational hazards and injury patterns in frontline emergency responders

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A B S T R A C T

Occupational trauma among first responders remains a significant yet under characterized public health concern in India. Police officers and firefighters operate in high-risk environments involving vehicular hazards, structural instability, heat exposure, and physical confrontation. Understanding how operational exposure, protective compliance, and fatigue influence injury outcomes is essential for improving responder safety. This study compared occupational and clinical profiles of police and firefighting personnel presenting with work-related trauma and identified predictors of hospital admission.

Method: This prospective observational study was conducted in the emergency department of a tertiary care teaching hospital in India between 2021 and 2025. All uniformed personnel presenting with confirmed on-duty traumatic injuries were enrolled. Demographic, operational, health, and protective equipment variables were recorded using standardized forms. Multivariable logistic regression identified independent predictors of hospital admission, and effect modification was assessed across injury mechanisms and PPE use.

Results: Among approximately 7,200 annual trauma cases, 308 (4.3%) involved uniformed personnel (156 police; 152 firefighters). Firefighters had higher injury severity (ISS ≥9: 28.3% vs. 17.9%) and longer return-to-duty duration (10.8 vs. 9.6 days). Police personnel reported greater fatigue and more assault-related injuries. Absence of PPE tripled admission risk, while helmet use markedly reduced head injuries. Firefighter role independently predicted hospital admission (adjusted OR 2.39).

Conclusion: Distinct occupational exposures drive differential injury severity and recovery patterns among first responders. Strengthening PPE adherence, fatigue mitigation, and task-specific safety strategies is critical to reducing injury burden in frontline emergency personnel.

1. Introduction

First responders, including police officers and firefighters, are central to emergency response systems and play a critical role in protecting life and property during crises. Their duties encompass hazardous operations such as firefighting, rescue, hazardous material control, law enforcement, and high-risk vehicular pursuits. These activities expose them to substantial physical and environmental hazards, including heavy exertion, extreme temperatures, high-speed driving, and violent encounters, which collectively increase the risk of occupational injury and illness (1).

Occupational trauma among first responders represents a significant global health burden. The International Labour Organization estimates injury rates three to six times higher than those of the general workforce (2). In the United States, police and firefighters sustain approximately 400–600 injuries per 10,000 workers annually compared with 100 per 10,000 in the general workforce, with musculoskeletal trauma accounting for nearly half of all cases (3). Similar patterns have been reported in the United Kingdom and Australia, where emergency service personnel demonstrate among the highest occupational injury claim rates. In India, trauma accounts for approximately 39% of emergency department visits; police officers face a 1.8-fold higher occupational injury risk, while firefighters frequently experience burns, crush injuries, and musculoskeletal trauma associated with prolonged duty hours and limited protective equipment (4,5).

Despite operating within the same emergency response framework, firefighters and police officers face distinct occupational hazards. Firefighters commonly sustain musculoskeletal injuries and burns related to thermal exposure and heavy protective equipment, whereas police personnel are more frequently affected by assault-related trauma and vehicular incidents (1,6). Differences in protective practices further influence injury risk: more than 90% of firefighters reportedly comply with full personal protective equipment, while nearly half of police personnel report only partial PPE use, increasing vulnerability to injury (7). However, few studies have examined these two responder groups within a unified clinical framework

2. Methodology

2.1. Study Design:

This was a prospective observational study conducted in the emergency department (ED) of a tertiary care academic hospital in South India, which functions as a regional referral center for trauma and occupational emergencies from March 2021 to November 2025. The study evaluated all cases of work-related traumatic injuries among uniformed service personnel, including police officers and firefighters, who presented to the ED during the study period. Data were prospectively collected using a structured Performa to ensure completeness and uniformity across cases. All eligible cases were enrolled consecutively to minimize selection bias. A screening log was maintained to ensure complete case capture during the study period.

2.2. Study Setting and Population:

The ED receives an estimated 7,200 trauma cases annually, encompassing civilian and occupational injuries. For this analysis, only on-duty police officers and firefighters sustaining acute, work-related trauma were included. All cases were verified as occupational injuries based on workplace incident documentation, supervisor reports, or corroborative evidence from the field. Each eligible participant was evaluated and enrolled upon presentation to the ED after obtaining informed consent.

Inclusion Criteria

- Active-duty police officers or firefighters sustaining a work-related traumatic injury.
- Presentation to the ED within 7 days of injury.
- Availability of complete demographic and clinical documentation.

Exclusion Criteria

- Off-duty injuries or trauma unrelated to occupational activities.
- Delayed presentation beyond 7 days after injury.
- Refusal to participate.
- Non-traumatic medical emergencies (e.g., cardiac events, heat exhaustion).

2.3. Sample size:

An a priori sample size estimation was performed for the primary outcome of hospital admission using a two-sided comparison of independent proportions. Based on conservative assumptions derived from occupational trauma literature, hospital admission rates were estimated at 25% among police personnel and 40% among firefighters (absolute difference 15%). With a two-sided alpha of 0.05 and 80% power, the minimum required sample size was calculated as 134 participants per group (total $n \approx 268$) under equal allocation. To ensure adequate statistical power for multivariable logistic regression, subgroup analyses and potential variability in admission rates, the calculated minimum sample size was conservatively inflated by approximately 15%. This yielded a target enrollment of approximately 308 participants.

2.4. Study Protocol:

All patients were evaluated upon arrival following Advanced Trauma Life Support (ATLS) principles. Primary survey included airway, breathing, circulation, disability, and exposure assessment. Secondary survey comprised a comprehensive examination to identify injury patterns, mechanism, and associated risk factors.

A detailed history was obtained, including mechanism of injury, duty assignment at the time of incident (routine vs. high-risk), use of PPE, fatigue level, hours of sleep, recent call volume, and previous 12-month injury history. Injury Severity Score (ISS) was calculated for all participants (8). Fatigue was assessed using a single-item Numeric Rating Scale (0–10), where 0 indicated no fatigue and 10 indicated extreme exhaustion. The fatigue NRS has demonstrated strong reliability and construct validity in clinical populations (Gladman et al., 2020) (9). The scale was self-reported at the time of ED presentation using standardized verbal anchors. To reduce variability, emergency physicians were trained in uniform administration procedures, and fatigue assessment was conducted prior to clinical disposition decisions to minimize bias. The decision for hospital or critical care admission and operative intervention was made by the attending emergency physician in consultation with trauma surgery teams. PPE use was categorized as none, partial, or full based on compliance with standard operational gear (helmet, gloves, body armor, turnout gear, or reflective protection) (10). Multicollinearity among predictors was assessed using variance inflation factors (VIF). A VIF > 5 was considered indicative of significant collinearity.

2.5. Data collection

Data were recorded prospectively using a standardized case record form to ensure consistency and completeness. Collected variables encompassed a comprehensive range of demographic, occupational, and clinical parameters. Demographic data included age, sex, and years of service. Health and fitness indicators captured body mass index (BMI), smoking status, presence of chronic musculoskeletal pain, and engagement in regular fitness training. Operational factors comprised hours into the shift at the time of injury, number of calls attended in the preceding 24 hours, duty assignment category, and on- or off-duty status along with anatomical location of injury.

Personal protective equipment (PPE) use at the time of injury was categorized a priori as none, partial, or full based on completeness of the recommended operational protective ensemble, in accordance with National Responder Safety guidelines and National occupational safety framework. No PPE indicated absence of protective equipment appropriate for the task. Partial PPE referred to use of one or more protective components without full ensemble compliance. Full PPE denoted use of the complete recommended protective configuration. For firefighters, this included helmet, turnout coat and trousers, gloves, boots, face-eye protection, and breathing apparatus when indicated. For police personnel, full PPE included helmet, gloves, duty boots, high visibility vest, and ballistic body armor, when operationally required. PPE status was documented during emergency department evaluation based on direct reporting by the injured personnel and observation of protective equipment at presentation, with cross-verification using duty records.

Clinical outcomes assessed were hospital admission, ICU stay, operative intervention, emergency department length of stay, days off duty, and time to return to active service. Participants were followed until documented return to active duty or completion of prescribed medical leave. Return-to-duty data were obtained through departmental occupational health records and confirmed where necessary through follow-up communication. No participant was lost to follow-up for primary outcomes. All data were cross-checked and verified independently by two investigators prior to final database entry to ensure accuracy and reliability. Data were recorded contemporaneously at the time of ED presentation by the treating emergency physician using a standardized structured proforma. Final statistical analysis was performed after completion of patient enrollment in November 2025.

2.6. Outcome measure

The primary objective of this study was to identify predictors of hospital admission following occupational trauma among uniformed service personnel. The secondary objectives included comparing demographic, operational, and clinical characteristics between police officers and firefighters, evaluating the association between PPE use, fatigue, and injury mechanisms with injury severity and recovery duration, and assessing how PPE compliance, age, injury mechanism, and injury severity might modify the risk of hospital admission

2.7. Ethical considerations

The study was conducted in accordance with the ethical principles of the Declaration of Helsinki (2013 revision) and was approved by the Institutional Ethics Committee of KIMS (Approval No.: KIMS/IEC/FC002/2021-EC). Written informed consent was obtained from all participants prior to enrollment. Participant confidentiality was strictly maintained throughout the study. All identifiable personal and occupational information was removed prior to analysis, and the dataset was de-identified to ensure privacy and compliance with institutional data protection policies. Access to the study database was restricted to the study investigators.

2.8. Statistical analysis:

All data were analyzed using IBM SPSS Statistics for Windows, Version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD) or median (interquartile range, IQR), and categorical variables as frequencies and percentages. Group comparisons were performed using the Student’s t-test or Mann Whitney U test for continuous variables and the Chi-square test for categorical variables, as appropriate. Variables with $p < 0.10$ in univariate analysis and those considered clinically relevant were included in a multivariable logistic regression model to identify independent predictors of hospital admission. Adjusted odds ratios (aORs) with 95% confidence intervals (CI) were reported. To evaluate effect modification, stratified logistic regression models were performed across levels of personal protective equipment (PPE) use, injury mechanism, age category, and injury severity score (ISS). Statistical significance was defined as $p \leq 0.05$. Model discrimination was assessed using the area under the receiver operating characteristic curve (AUC). Model calibration was evaluated using the Hosmer–Lemeshow goodness-of-fit test (10 deciles of predicted risk), calibration slope and intercept, and the Brier score. Multicollinearity was assessed using variance inflation factors (VIF), with VIF >5 considered indicative of significant collinearity. Influence diagnostics (Cook's distance and DFBETA) were examined to identify influential observations, and model specification was evaluated using the Pregibon link test. Pre-specified sensitivity analyses were conducted to assess the robustness of the primary association between occupational role and hospital admission. These included multiple imputation for missing covariates, exclusion of training-related injuries, restriction to on-duty on-scene injuries, Firth's penalized logistic regression, and redefinition of the primary outcome using Injury Severity Score >15. Effect modification was assessed by introducing multiplicative interaction terms between occupational role and potential modifiers (PPE use, injury mechanism, age, and injury severity score) in the multivariable logistic regression model. Statistical significance of interaction terms was evaluated using Wald tests.

3. Results

The ED managed an estimated 7,200 trauma cases annually, of which 308 involved uniformed service personnel who sustained injuries during active duty were included in the study. This subgroup comprised 156 police officers (50.6%) and 152 firefighters (49.4%) presenting with confirmed work-related trauma.

Firefighters were older and had longer service duration than police officers (mean age 35.5 ± 5.2 vs 33.7 ± 4.8 years; median service 10.3 vs 8.9 years). The cohort was predominantly male (78.6%), with a higher proportion among firefighters than police (89.5% vs 67.9%). Police officers had a higher mean BMI (26.4 ± 3.2 vs 25.2 ± 2.9)

and reported greater fatigue (5.2 ± 1.8 vs 4.4 ± 1.9). In contrast, firefighters more frequently reported regular fitness training (77.6% vs 53.2%) and demonstrated higher adherence to PPE use (98.0% vs 82.7%) (Table 1)

Table 1. Demographic and Operational Characteristics of Injured Police and Firefighting Personnel

Variable	Overall (n=308) n (%)	Police (n=156) n (%)	Firefighters (N=152) n (%)	p-value
Demographics				
Age, years (M ± SD)	34.6 ± 5.1	33.7 ± 4.8	35.5 ± 5.2	0.001
Male sex	242 (78.6%)	106 (67.9%)	136 (89.5%)	<0.001
Years of service median (IQR)	9.5 (7.8 11.8)	8.9 (7.4–10.9)	10.3 (8.4–12.3)	<0.001
Health & Fitness				
BMI (M ± SD)	25.8 ± 3.1	26.4 ± 3.2	25.2 ± 2.9	0.004
Regular fitness training	201 (65.3%)	83 (53.2%)	118 (77.6%)	<0.001
Current smoker	54 (17.5%)	33 (21.2%)	21 (13.8%)	0.086
Chronic back/joint pain	73 (23.7%)	41 (26.3%)	32 (21.1%)	0.298
Prior traumatic injury (12 months)	61 (19.8%)	31 (19.9%)	30 (19.7%)	0.964
Fatigue, Alertness & Substance Use				
Fatigue score (1–10) M ± SD	4.8 ± 1.9	5.2 ± 1.8	4.4 ± 1.9	0.001
Sleep <6 hours prior	83 (26.9%)	39 (25.0%)	44 (28.9%)	0.475
Caffeine use before shift	171 (55.5%)	88 (56.4%)	83 (54.6%)	0.752
Alcohol use within 24 hour	9 (2.9%)	6 (3.8%)	3 (2.0%)	0.314
Operational Profile and Workload				
Hours into shift at injury (M± SD)	6.1 ± 2.9	6.2 ± 2.9	6.0 ± 2.9	0.475
Number of calls in preceding 24 hour (M ± SD)	4.1 ± 2.3	5.2 ± 2.5	2.9 ± 1.7	< 0.001

Assigned to high-risk duty	112 (36.4)	74 (47.4)	38 (25.0)	< 0.001
On-duty at time of injury	293 (95.1)	148 (94.9)	145 (95.4)	0.846
Mechanism of Injury				
Fall	71 (23.1)	41 (26.3)	30 (19.7)	0.192
Vehicular Collision	64 (20.8)	43 (27.6)	21 (13.8)	0.004
Assault/Physical Altercation	49 (15.9)	39 (25.0)	10 (6.6)	< 0.001
Burns/Thermal Exposure	38 (12.3)	5 (3.2)	33 (21.7)	< 0.001
Structural Collapse/Impact	28 (9.1)	9 (5.8)	19 (12.5)	0.031
Other / mixed mechanisms	58 (18.8)	19 (12.2)	39 (25.7)	0.003
Anatomical Region Affected				
Upper-body musculoskeletal injury	118 (38.3)	74 (47.4)	44 (28.9)	0.001
Lower-body musculoskeletal injury	84 (27.3)	35 (22.4)	49 (32.2)	0.059
Multiple-region or polytrauma	36 (11.7)	15 (9.6)	21 (13.8)	0.267
Head injury	24 (7.8)	13 (8.3)	11 (7.2)	0.742
Other traumatic injury (fractures, crush, laceration)	31 (10.1)	14 (9.0)	17 (11.2)	0.549
Mental-health or stress-related	15 (4.9)	9 (5.8)	6 (3.9)	0.462
Protective Measures at Time of Injury				
Use of PPE (any)	278 (90.3%)	129 (82.7%)	149 (98.0%)	<0.001
Helmet use at time of injury	256 (83.1%)	107 (68.6%)	149 (98.0%)	<0.001
Body armour use (police only)	—	92 (59.0%)	—	—
M: Mean, SD: Standard Deviation, PPE: Personal Protective Equipments, BMI: Body Mass Index, IQR: Interquartile range				

Firefighters demonstrated greater injury severity, with ISS ≥9 in 28.3% of cases compared with 17.9% among police officers. Thermal injuries were substantially more common in firefighters (17.8% vs 2.6%), whereas assault-related trauma predominated among police (7.7% vs 2.0%). Absence of PPE was associated with higher hospital admission rates (28.9%), and lack of helmet use tripled head injury incidence. Operational strain—defined as ≥5 calls within 24 hours or fatigue scores ≥6—was more frequent among police and corresponded with longer recovery, with ≥14 days off duty required in 24.3% of police versus 14.1% of firefighters (Table 2).

Table 2. Comparative Injury Severity, Mechanistic Correlates, and Effect Estimates Between Police Officers and Firefighters with Occupational Trauma

Clinical & Mechanistic Domain	Police	Firefighters	Relative Risk (95% CI)	Effect Size (Cramer's V)
Injury Severity Profile				
ISS ≥ 9	17.90%	28.30%	1.58 (1.03–2.42)	0.16
Polytrauma (≥2 regions)	9.60%	13.80%	1.44 (0.77–2.68)	0.09
Head/neck involvement	8.30%	7.20%	0.87 (0.40–1.87)	0.03
Mechanism–Outcome Correlations				
Thermal injury	2.60%	17.80%	6.85 (2.53–18.6)	0.33
Vehicular collision needing surgery	8.30%	3.30%	0.40 (0.15–1.05)	0.14
Assault injuries requiring ≥10 days off duty	7.70%	2.00%	0.26 (0.08–0.89)	0.18
Falls resulting in minor injury	26.30%	19.70%	0.75 (0.50–1.13)	0.1
Protective Equipment and Injury Modulation				
Full PPE worn	39.10%	67.80%	—	—
Hospital admission (full PPE)	14.80%	22.10%	Ref	—
Hospital admission (no PPE)	44.40%	66.70%	2.9 (1.6–5.3)	0.31
Helmet use	68.60%	98.00%	—	—
Head injury incidence (no helmet vs. helmet)	17.9% vs. 4.7%	—	3.8 (1.5–9.4)	0.27
Operational Burden and Recovery Indicators				
Fatigue score ≥6	28.80%	20.40%	1.41 (0.89–2.25)	0.12
≥5 calls in last 24 hours	52.60%	28.30%	1.86 (1.33–2.59)	0.29
Days off duty (median (IQR))	4.4 (3.7–5.4)	4.7 (3.8–5.9)	SMD = 0.15	0.15
Return to duty ≥14 days	14.10%	24.30%	1.72 (1.07–2.75)	0.19

RR: Relative Risk comparing firefighters with police officers; PPE: personal protective equipment; ISS: Injury Severity Score; IQR: interquartile range; SMD: Standardized Mean Difference

In multivariable logistic regression, firefighter role was independently associated with higher odds of hospital admission compared with police officers (OR 2.39). Age, sex, and years of service were not significant predictors. Although ISS was not independently associated with admission, full PPE use showed a protective trend (OR 0.55), while fall-related injuries demonstrated a borderline association with increased admission risk (OR 1.78). Multicollinearity diagnostics showed acceptable variance inflation factors for all predictors (VIF <2), indicating no significant collinearity within the model (Table 3).

Model performance demonstrated good discrimination (AUC 0.78, 95% CI 0.72–0.84) and adequate calibration (Hosmer–Lemeshow $\chi^2 = 7.19$, $p = 0.617$; calibration slope 0.96; intercept ≈0), with a Brier score of 0.178. Additional diagnostics confirmed stable model specification, with low VIF values (maximum 1.41), no influential observations (maximum Cook's distance 0.045), and a non-significant Pregibon link test (p = 0.774). Sensitivity analyses yielded consistent estimates for firefighter role (adjusted OR range 2.39–2.61) across multiple models, including multiple imputation, exclusion of training injuries, restriction outcome to definition using ISS >15

Table 3. Multivariable Logistic Regression for Predictors of Hospital Admission

Predictor	**Adjusted OR**	**95% CI**	**P Value**
Firefighter (ref: Police)	2.39	1.37–4.18	0.002
Age	—	—	0.61
Male sex	1.14	0.59–2.21	0.695
Years of service (per year)	1.02	0.96–1.08	0.571
Injury Severity Score	—	—	0.19
Full PPE worn	0.55	0.29–1.04	0.066
Partial PPE worn	0.77	0.37–1.58	0.472
Mechanism: Assault	1.51	0.78–2.93	0.222
Mechanism: Fall	1.78	0.98–3.25	0.059

The association between occupational role and hospital admission remained robust across key modifiers. Firefighters continued to have a higher risk of admission compared to police officers, particularly among those with no PPE (OR 3.11), though this risk was reduced with full PPE use (OR 1.94). The increased risk for firefighters was consistent across both motor vehicle collision (MVC) and non-MVC injuries, with MVC-related trauma showing slightly higher odds of admission (OR 2.72). This trend held steady across different age groups and injury severity levels, suggesting that the impact of occupational role on hospitalization was largely independent of these factors (Table 4). Formal interaction testing demonstrated no statistically significant effect modification by PPE use (p = 0.441), injury mechanism (p = 0.628), age (p = 0.719), or injury severity score (p = 0.383).

Table 4. Effect Modification of Hospital Admission Risk by Key Variables

Effect Modifier	***Level***	***Adjusted OR (Firefighters vs Police)***	***95% CI***	***P Value***
Personal protective equipment (PPE)	***None***	***3.11***	***1.46–6.63***	***0.441***
	Partial	***2.57***	***1.21–5.45***	
	Full	***1.94***	***0.94–4.01***	
Mechanism of injury	***Motor vehicle collision (MVC)***	***2.72***	***1.20–6.18***	***0.628***
	Non-MVC	***2.34***	***1.30–4.19***	
Age (Years)	***30 years***	***2.48***	***1.38–4.47***	***0.719***
	40 years	***2.33***	***1.26–4.30***	
Injury Severity Score (ISS)	***ISS 5***	***2.26***	***1.30–3.93***	***0.383***
	ISS 10	***2.47***	***1.38–4.43***	

P-values represent tests for interaction between occupational role and the specified modifier. OR: Odds ratio

The multivariable logistic regression model demonstrated that being a firefighter was independently associated with higher odds of hospital admission (OR 2.39, 95% CI 1.37–4.18). Full PPE use showed a protective trend, lowering admission likelihood (OR 0.55, 95% CI 0.29–1.04). Falls were marginally associated with increased admission risk (OR 1.78, 95% CI 0.98–3.25), while demographic factors such as sex and years of service were not significant predictors (Figure 1).

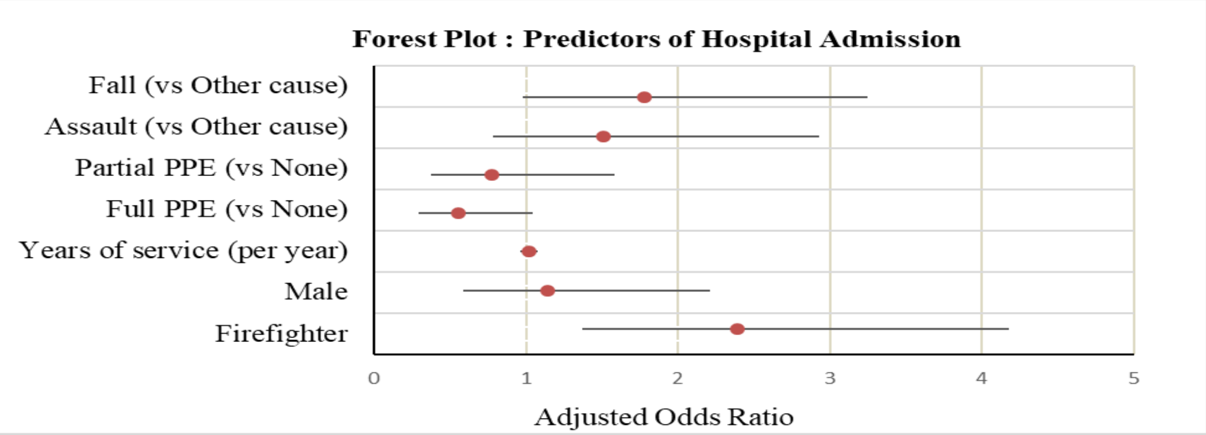

Figure 1: Forest plot showing adjusted odds ratios for predictors of hospital admission among uniformed personnel.

4. Discussion

Occupational trauma among uniformed first responders represents a critical yet under-characterized component of workplace morbidity in low- and middle-income settings (4). The present study provides a comparative analyses of on-duty traumatic injuries among police officers and firefighters. The findings reveal distinct occupational risk profiles, with firefighters experiencing greater injury severity and longer recovery times, while police officers faced a higher incidence of fatigue-related injuries and trauma associated with assaults. This contrast reinforces global observations that operational exposure and task environment, rather than demographic variation, predominantly govern injury severity and clinical outcomes (6,11). The strong protective association of comprehensive PPE and helmet use against hospitalization and craniofacial trauma aligns with U.S. National Fire Protection Association NFPA (2021) and Australian Fire Service reports, which attribute a 50–60% reduction in serious injuries to optimal protective compliance (12,13).

Musculoskeletal trauma constituted the predominant injury pattern, followed by burns, contusions, and blunt polytrauma. This distribution mirrors international surveillance data from the U.S. National Fire Protection Association (NFPA, 2021) and SafeWork Australia (2022), where musculoskeletal injuries account for approximately 40–55% of first responder trauma (13,14). Large cohort studies similarly identify musculoskeletal injuries as the leading occupational hazard among emergency personnel, largely attributable to physically demanding tasks such as heavy lifting, prolonged exertion, and high-stress operational environments (15). Firefighters most commonly sustain upper and lower limb injuries associated with structural collapse and thermal exposure, consistent with findings from NFPA and Australian datasets. In contrast, police officers more frequently experience extremity and trunk injuries related to vehicular collisions, physical altercations, and pursuit-related falls (16). These patterns likely reflect differences in operational exposure, with firefighters operating in heat-intensive hazardous environments and police personnel facing dynamic scenarios that predispose them to blunt-force trauma (7).

Sprain and strain injuries account for nearly half of firefighter trauma, predominantly affecting the lower (58%) and upper limbs (24%), consistent with multicentric analyses and NFPA fireground injury surveillance (17). Indian registry data similarly indicate that extremity and back injuries constitute almost two-thirds of trauma among uniformed personnel (18). Mechanistically, blunt trauma predominates among police, whereas firefighters experience mixed mechanisms including burns, crush injuries, and falls. The higher burn prevalence observed in tropical settings may reflect climatic exposure, limited recovery intervals, and suboptimal turnout gear compared with Western fire services (3). Assault-related injuries were substantially more frequent among police, mirroring U.K. Home Office data reporting a 21% increase in assaults on officers in recent years (19).

Anatomically, extremity and spinal injuries predominate across responder cohorts, consistent with international surveillance findings. Australian NHMRC data report extremity injuries as the leading pattern (lower limb 36%, upper limb 22%), with sprain–strain injuries comprising nearly 48% of cases (17). Police personnel demonstrate a similar musculoskeletal profile but with increased cervical and shoulder injuries, likely related to biomechanical strain during physical restraint and arrest activities. Although head and facial trauma were relatively uncommon, helmet use was associated with markedly lower head injury incidence, consistent with NFPA estimates that proper helmet use reduces cranial trauma by up to 70% (10). These observations reinforce global recommendations emphasizing protective equipment in mitigating injury severity. Severity distribution in our cohort was comparable to Canadian firefighter injury surveys, where moderate injuries requiring time off work accounted for 25-30% of cases and severe injuries necessitating hospitalization comprised 5-10% (20).

Penetrating trauma was rare in our cohort, contrasting with U.S. law enforcement data reporting approximately 45,500 firearm-related emergency department visits annually, representing 1.7% of the 2.67 million firearm injuries nationwide, with handguns involved in nearly 80% of cases (21). Notably, officer-involved firearm injuries demonstrate lower fatality rates (3%) than civilian cases (12%), largely attributed to ballistic protection, rapid evacuation, and advanced trauma care systems. The disparity with our findings likely reflects differences in threat exposure and operational context, as firearm violence is considerably more prevalent in U.S. policing. In contrast, Indian law enforcement encounters are more commonly characterized by blunt trauma, vehicular incidents, and physical altercations, reflecting stricter firearm access and less frequent weapon deployment.

PPE compliance in our study surpasses developing-nation averages (70–85%) but lags behind Scandinavian benchmarks (>95%) (22). Complete PPE use correlated with lower hospital admission and fewer burns, echoing the 2022 European Firefighter Safety Report, which documented a 40% reduction in severe burns with full gear use. Partial PPE, common among police typically armor without helmets offered incomplete protection against blunt impacts (23). Korean tactical-unit research found concussion risk doubled when headgear was omitted. Heat stress remains a major ergonomic barrier to PPE adherence in tropical regions (10). Studies from Civil Defense Force show next generation composite gear reduced internal body temperature by 1.4°C during drills, improving endurance and compliance (24). These findings can highlight the urgent need for localized PPE innovation in South Asian climates.

Approximately one-third of responders required hospital admission and 7% required ICU care, comparable to U.S. and European trauma registry data (25). Similar triage patterns are reported in Scandinavian systems, where structured prehospital triage contributes to efficient emergency department flow (26). Operative intervention occurred in roughly one-fifth of cases, consistent with Canadian and Japanese responder datasets, with firefighters more frequently requiring surgery for burns and fractures and police primarily for vehicular trauma. ICU admission rates were comparable to the 6–8% reported in U.S. responder studies (3). Shorter ED stays in our cohort likely reflect resource-driven turnover rather than lower injury acuity.

Median return-to-duty time was approximately 10 days, shorter than Western averages of 14–21 days but longer than Asian military cohorts (10). Firefighters' longer recovery parallels Australian findings linking heat strain to delayed musculoskeletal recovery (13). Limited access to structured rehabilitation may contribute to earlier discharge but incomplete recovery, highlighting gaps in occupational aftercare. International data consistently report responder injury rates three to six times higher than the general workforce, including 35–40 serious claims per 100 FTE workers in Australia and >30% annual injury prevalence among U.K. police (13,19,27). Indian trauma registries similarly attribute nearly 40% of emergency department trauma to occupational causes, underscoring the high injury burden among emergency services (18).

Fatigue and high call volume were associated with increased injury risk, consistent with Canadian paramedic studies where 12-hour shifts doubled incident rates (20) and Japanese emergency worker data showing higher injury odds with >5 dispatches per shift (28). Fatigue-mitigation strategies, including duty-hour regulation and structured rest periods used in Finnish fire services, may offer relevant operational models (29).

Seasonal injury patterns reflected global observations, with burn injuries increasing during summer and vehicular trauma peaking during monsoon periods, similar to meteorological trends reported in Thailand and southern China (30). In India, festival seasons and election periods often require extended responder deployment, increasing fatigue and exposure risk. Comparable surges in responder injuries have been documented internationally, including Queensland Fire Service deployments and the 2019 Hong Kong demonstrations, where police injuries increased fourfold (31). Indian law enforcement similarly reports elevated injury risk during political rallies and religious gatherings (32), underscoring the importance of adaptive staffing and fatigue-management strategies.

Responders operating in insurgent or high-threat zones face substantially greater injury severity. Israeli trauma data report a mean Injury Severity Score of 12.6 during terror incidents compared with 6.4 during routine duty (33). Indian personnel deployed in Naxal-affected regions similarly demonstrate approximately 30% higher odds of blast trauma than non-deployed counterparts (34). These findings highlight the importance of structured deployment rotation and decompression protocols to mitigate cumulative physical and psychological strain among responders in high-risk environments.

Centralized safety registries in the U.K. and Australia have reduced responder injury rates through systematic monitoring and data-driven policy reforms (13,22). India currently lacks a comparable national surveillance system. Establishing a responder injury registry aligned with the WHO Minimum Dataset for Injury could facilitate benchmarking and policy development. Although psychological outcomes were not systematically assessed in this study, mental health remains an important occupational concern among responders (2). Meta-analyses report PTSD prevalence of 10–22% in this population, with Indian police studies indicating clinical stress in nearly 30% of personnel. Peer-support programs, such as those implemented in Canada, have demonstrated reductions in sick leave and may help address this under recognized burden (35). Integrated strategies combining ergonomic PPE design, fatigue monitoring, and behavioral health support remain essential for responder safety.

This study has several strengths, including its prospective design, standardized data collection, and its contribution as one of the first comparative analyses of occupational trauma among police and firefighters in an Indian emergency department setting. However, certain limitations should be considered. As a single-center study conducted in a tertiary referral hospital, the findings may be influenced by referral bias, with more complex injuries preferentially transferred to higher-level facilities. Institutional practice patterns, including admission thresholds and trauma management protocols, may also affect hospitalization estimates. Furthermore, the predominantly urban study setting may limit extrapolation to rural or resource-limited regions, where responder deployment patterns, infrastructure, and access to protective equipment differ. Multicenter studies and integrated trauma registry systems across diverse geographic settings are needed to improve national representativeness. Despite these limitations, the injury patterns observed remain broadly consistent with international evidence and provide relevant insights for improving occupational safety among emergency responders.

5. Conclusion

Occupational trauma among first responders remains a critical yet under recognized public health concern in India. This study demonstrates that injury severity and hospitalization risk among uniformed personnel are predominantly influenced by occupational role, protective compliance, and fatigue rather than demographic factors. Firefighters sustained more severe and heat-related injuries, while police officers experienced greater fatigue-related and assault-associated trauma. Consistent PPE use, structured fatigue mitigation, and task-specific operational training significantly reduce adverse outcomes.

A coordinated national strategy—integrating standardized injury surveillance, mandatory PPE adherence, evidence-based duty-hour regulation, and targeted rehabilitation—is imperative to strengthen occupational safety frameworks for frontline emergency personnel in developing regions.

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