

ORIGINAL PAPER

Neurological disorders as a cause of interventions by National Rescue and Firefighting System units in Poland

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Abstract

Background. The aim of the study was to analyze interventions by the National Rescue and Firefighting System (NRFS) units in incidents related to neurological disorders and deficits.

Material and methods. The study used data from the Decision Support System of the State Fire Service (DSS-SFS). Incidents occurring between January 1, 2020, 00:00 – December 31, 2023, 23:59 were analyzed. Quantitative data were described using the mean and standard deviation (SD). Additionally, a cartogram was created to visualize spatial disparities in incident rates per 1,000 inhabitants. All the statistical analyses were performed using Statistica 13.

Results. Between 2020 and 2023, firefighters were dispatched 1,306 times to operations related to the study aim. The interventions were classified under the category isolated emergency medical incidents (IEMI). The mean number of events was 20.41 (SD=16.73), and the median was 16. Values ranged from 1 to 70, and the interquartile range (IQR) was 22.

Conclusions. The use of specialized equipment available to NRFS entities offers various possibilities for supporting medical rescue entities. Investment in new technologies in rescue operations contributes to the effectiveness of activities. The State Fire Service (SFS) is the primary service cooperating with the State Emergency Medical Services (SEMS) during medical rescue operations.

Keywords: rescue and firefighting operations, isolated emergency medical incidents, medical rescue actions, paresis, seizures

Introduction

The National Rescue and Firefighting System (NRFS) in Poland, established in 1995, creates a cooperation structure that integrates the resources (personnel and equipment) of the State Fire Service (SFS) and the Volunteer Fire Brigade (VFB). This structure is funded centrally (from the state budget) and locally (from municipal budgets). The main objective of the firefighter service is to protect and save the lives and health of citizens, protect animals and property, protect the environment, and identify and neutralize hazards [1].

Firefighter operations are classified according to the registration system of the Decision Support System of the State Fire Service (DSS-SFS): fires (F), local hazards (LH), and false alarms (FA). Combating and neutralizing the effects of more extensive hazards exceeds the capabilities of an ordinary NRFS entity (local unit). More challenging interventions are assigned to Specialist Rescue Groups (SRG) located in various parts of the country. These

specializations include water and diving, chemical and environmental, medical rescue, search and rescue, technical, and high-angle rescue [2,3].

An important area of firefighter interventions consists of procedures in medical rescue at the level of qualified first aid (QFA). The classification of rescue incidents involving injured persons includes direct firefighter actions with the casualty or indirect actions (auxiliary to other services) related to rescuing the casualty: assisting in the transport (transfer) of the casualty, assisting the Emergency Medical Team (EMT) in opening a room containing a casualty, using a drone to search for a person in open terrain, using power generators and lighting equipment, and assisting in driving (towing) an ambulance in difficult terrain (snow, mud) [4,5].

Neurological disorders and deficits pose a serious challenge for rescue services system entities and for the supporting and cooperating entities listed in Polish legal acts – the police, military, border guard, veterinary, forestry, sanitary services, and many others [6,7].

In the practice of EMT interventions in the area of neurological disorders, common reasons for calls include seizures, paresis due to stroke, and exacerbation of chronic neurodegenerative diseases associated with age. Firefighter participation in these incidents is of an auxiliary (supportive) nature for medical teams – patient transport, gaining access to the casualty, and use of specialized equipment. However, if EMT's are dispatched to other incidents or have a longer response time to the call, the medical dispatcher may send firefighters directly to implement medical procedures. According to the DSS-SFS dispatch criteria, this type of intervention is called an isolated emergency medical incident (IEMI) [8-10].

The total number of firefighter units and their location, especially in non-urban areas, means that the number of IEMI events is increasing and constitutes significant support for medical teams. For a casualty, this translates into a chance for improved therapeutic prognosis due to the time of intervention and the implementation of essential rescue procedures [11,12].

Aim of the work

of the aim of the study was to analyze State Fire Service unit interventions in life-threatening conditions of neurological etiology between 2020 and 2023.

Material and methods

Study design

The material for analysis was made available by the National Headquarters of the SFS. Permission was obtained in May 2023. Observations for the years 2020-2023 cover all NRFS system units (nationwide range in Poland) in the category of IEMI. The data come from the DSS-SFS in which all firefighter interventions are processed and archived. Specific data groups can be obtained based on: event category, keywords, and type of rescue procedure performed (within QFA). For the purpose of further analysis, two definitions that are key to the research process were clarified:

- Medical Rescue Actions (MRA) – firefighters support medical entities present at the incident site. Firefighter support is necessary for the effective conduct of actions. QFA procedures in multiple and mass casualty incidents;
- Isolated Emergency Medical Incidents (IEMI) as a sub-type of MRA – firefighters provide assistance to a person in a sudden health emergency when State Emergency Medical Services (SEMS) entities are not yet present at the incident site.

Statistical analysis

The analysis used aggregated annual data covering neurological incident reports from 16 voivodeships over a four-year period. Descriptive statistics were used to summarize the overall case distribution. Normality of distribution was checked using the Shapiro-Wilk procedure, and equality of variances was assessed with Levene's test. When homogeneity assumptions were violated, Welch's ANOVA was used to compare mean differences between regions, followed by Games-Howell post-hoc test to identify specific pairwise contrasts. To examine relationships between incident counts and regional characteristics, given the non-normal distribution of several variables, Spearman's rank correlation was used. Additionally, a cartogram was created to visualize spatial disparities in incident rates per 1,000 inhabitants. Temporal variability was examined both quarterly and annually to capture seasonal and longitudinal trends. All the statistical analyses were performed using Statistica 13 (TIBCO Software Inc., 2017), with the significance level set at $\alpha=0.05$.

Inclusion criteria

1. Incidents in which fire service units intervened in life-threatening conditions related to a neurological deficit or symptoms of a neurological disorder.
2. Incidents falling within the observation date range: January 1st, 2020 (00:00) – December 31st, 2023 (23:59).
3. Successful retrieval from the DSS-SFS databases using defined keywords useful for the analysis, within the IEMI category: seizures, paresis, neurological disease, neurodegenerative disease, paralysis. The keywords were selected based on the most popular terms for neurological disorders from a generally used and applied perspective. It should be noted that emergency callers and SFS commanders who document interventions often lack medical training. The authors used the most popular terms in neurological disorders which could most likely associate the intervention with the purpose of the observation.
4. Only interventions within the territory of Poland were observed. Polish firefighters also intervene outside the country as part of modules for international operations of the Union Civil Protection Mechanism in the areas of:
 - GFFV – Ground Forest Fire Fighting using Vehicles,
 - USAR – Urban Search and Rescue,
 - High Capacity Pumping (HCP) – international flood response operations [13].

Limitations

Our observations have several limitations:

1. Ineffective retrieval of events by keywords. Absence of relevant keywords related to neurological deficit in the call or subsequent event processing – the authors had no influence over the content of the descriptive part of the event or the terminology used by the caller during the report.
2. The SFS data do not include: age and gender of casualties. The quantitative nature of the study focuses on data: month, year, number of interventions, region (voivodeship) of Poland.
3. Clinical details of events were not available: parameters obtained by the EMT, pharmacotherapy, diagnoses according to ICD-10 classification. Medical teams

maintain their own documentation in the DSS-SEMS. These data are not available to firefighters. The SFS is not the lead unit for medical interventions (SFS is only support for EMT). There was no access to patients' clinical data (age, gender, ICD-10 codes, treatment history), which limits the ability to fully interpret the results from a medical perspective [14].

4. Lack of medical data – continuation of hospital treatment, EMT management.
5. Interventions with a general reason for call, such as “unconscious”, “collapse”, “sudden cardiac arrest”, could not be included in the neurological disorder category due to the absence of a medical diagnosis at the firefighter intervention stage. The authors are aware that some clinical conditions leading to loss of consciousness or cardiac arrest are caused by an acute neurological disorder/condition or exacerbation of a neurological disease entity; however, due to the lack of tools to effectively select these events, many events were excluded from the analysis.
6. In 2024, the National Headquarters SFS changed the data collection system for the IEMI category. Due to differences in coding and presentation of events, the authors ended their own study in 2023. The new version of the database divides IEMI events into more than a dozen detailed reasons for intervention; moreover, an “OTHER” category has been introduced, to which events that cannot be clearly assigned to another category based on the reason for the call are allocated.

Results

After applying the inclusion and exclusion criteria based on a series of keyword searches in the DSS-SFS databases, 1,306 firefighter interventions were included in the analysis.

The mean number of events was 20.41 (SD=16.73), and the median was 16 (Table 1). Values ranged from 1 to 70, and the interquartile range (IQR) was 22. This indicates considerable heterogeneity and a right-skewed distribution – while most cases cluster around lower values, the presence of several extreme outliers raises the overall mean.

Table 1. Characteristics of included events

Variable	N	Min	Max	Sum	M	SD	Me	IQR
Neurological disorders	64	1	70	1306	20.41	16.73	16	22

The analysis was based on 64 aggregated observations, representing annual neurological incident counts across 16 voivodeships over a four-year period (16 voivodeships $\times$ 4 years). The descriptive statistics presented below refer to the number of incidents per voivodeship per year. The mean number of incidents per observation was 20.41 (SD=16.73), with a median of 16. Values ranged from 1 to 70, and the interquartile range (IQR) was 22. This indicates considerable heterogeneity and a right-skewed distribution, with most voivodeship-year observations reporting relatively low numbers of incidents, while a small number of observations with substantially higher counts increased the overall mean.

Welch's ANOVA results ($F=10.02$, $df_1=15$, $df_2=17.95$, $p<0.001$) confirm the presence of statistically significant differences in the incidence of neurological events across voivodeships, justifying the use of post-hoc tests to identify specific regional contrasts. The Games-Howell procedure, selected for its robustness to unequal variances, showed that Wielkopolska had a consistently higher incidence of neurological events compared to several other voivodeships, particularly Lublin ($p=0.006$), Lubusz ($p=0.006$), Lesser Poland ($p=0.048$), Subcarpathia ($p=0.032$), and Podlaskie ($p=0.005$). Furthermore, Lublin recorded significantly fewer incidents than Subcarpathia ($p=0.03$). The data are presented in Figures 1, 2.

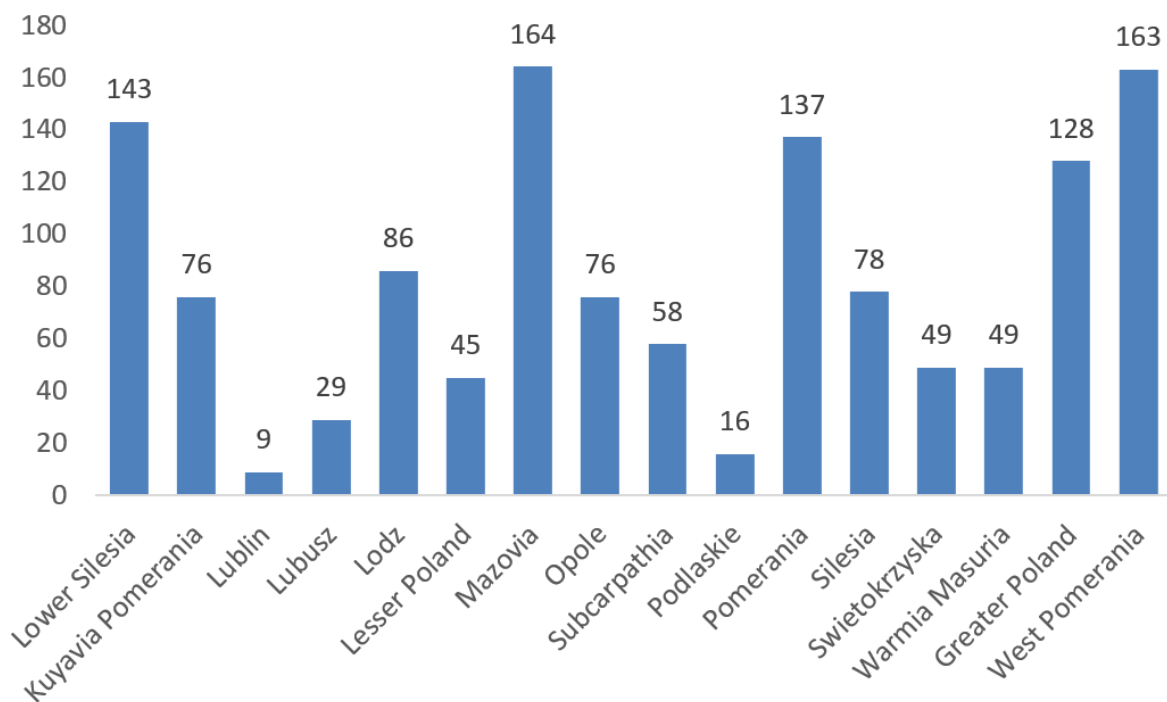


Figure 1. Number of interventions by voivodeship

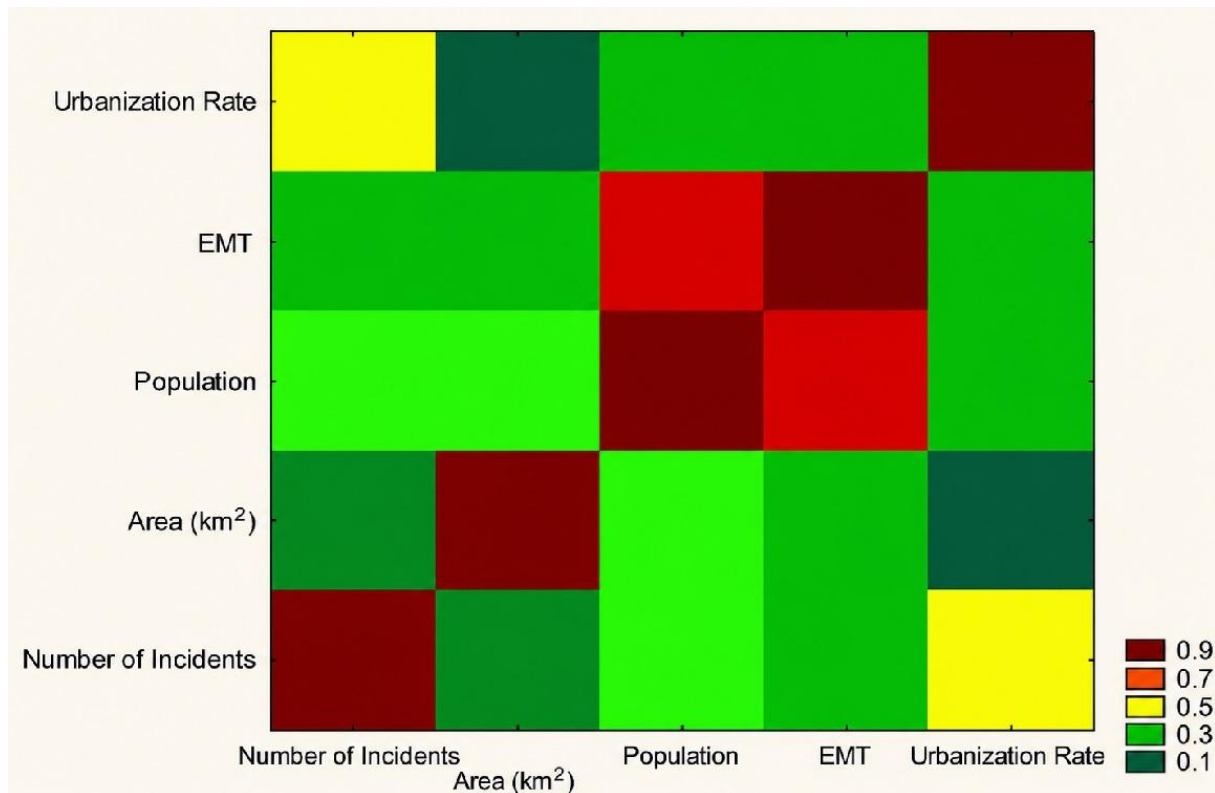


Figure 2. Correlation between number of events and voivodeship area, population, number of EMT, and urbanization rate

Spearman's rank correlation analysis was performed to identify factors associated with the number of incidents. The results indicate that the urbanization rate shows the strongest positive correlation with incident frequency ($\rho=0.463$, $p<0.05$), suggesting that more densely populated urban areas experience a moderately higher number of incidents. A weaker but significant positive correlation was also found with population size ($\rho=0.379$, $p<0.05$), confirming that larger populations generally report more incidents in absolute terms. Interestingly, although the number of EMT alone shows a weak positive correlation with incident count ($\rho=0.261$, $p<0.05$), this is likely a reactive allocation of resources rather than a causal factor, as the number of EMT itself is strongly correlated with population size ($\rho=0.788$, $p<0.05$). No significant statistical relationship was demonstrated between the geographic area of a region and the number of incidents, indicating that incident frequency depends on population density and urbanization rather than on the physical size of the territory.

Figure 3 illustrates a cartogram that reveals clear regional disparities in event rates per 1,000 inhabitants. West Pomerania recorded the highest rate in the country (0.096), making it an area of clear priority, followed by Opole (0.077) and Pomerania (0.058). In contrast, Lublin

recorded an exceptionally low event rate (0.004), while Lesser Poland (0.013) and Podlaskie (0.014) also showed very favorable results. The remaining voivodeships, including Lower Silesia (0.049) and Świętokrzyskie (0.04), fall within the lower to middle range of this spectrum.

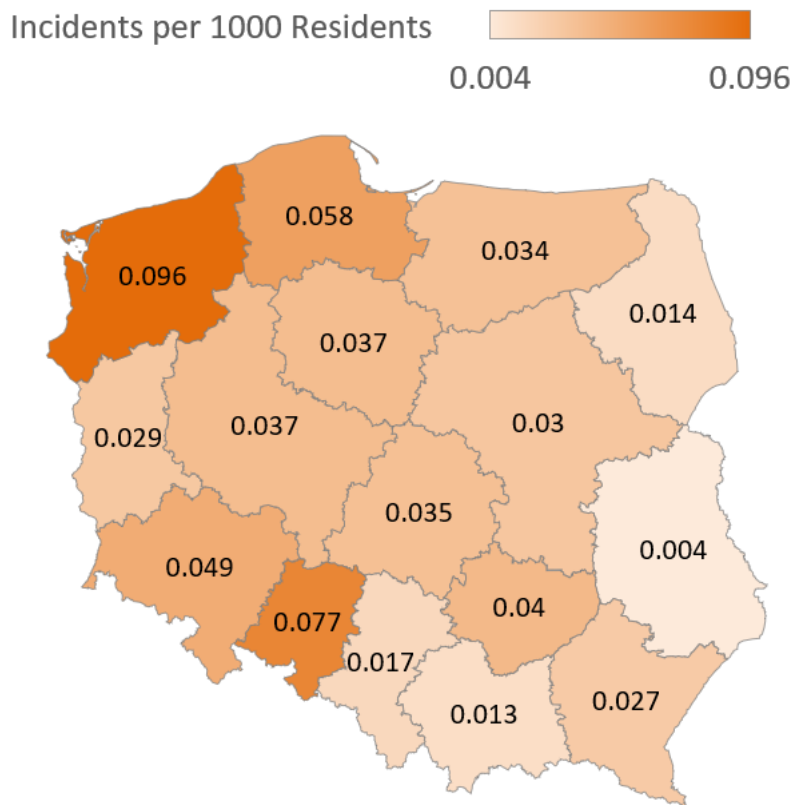


Figure 3. Cartogram – index of events included in the analysis per 1,000 inhabitants

Quarterly analysis of incident rates revealed a significant seasonal effect, as confirmed by the Kruskal-Wallis test ($p < 0.001$). While mean incident rates in the first three quarters remained relatively stable, ranging between 1.39 and 1.65, a marked increase was observed in the fourth quarter ($M = 2.45$, $SD = 3.35$). Further post-hoc comparisons using the Dunn-Bonferroni test confirmed that the fourth quarter had a significantly higher rate compared to both the first and second quarters (Table 2).

Table 2. Comparison by quarters

Neurological disorders	I (M±SD)	II (M±SD)	III (M±SD)	IV (M±SD)	<i>p</i>
	1.39±2*	1.46±2.02*	1.65±1.93	2.45±3.35	<0.001

Notes: * = significant compared to the 4th quarter.

The box plot in Figure 4 illustrates the distribution of incident counts between 2020 and 2023. The results of the Kruskal-Wallis test showed no statistically significant differences in incident counts between the analyzed years, with a p -value of 0.2334. This suggests that the observed fluctuations in median incident counts over this period are likely due to chance rather than a consistent year-on-year trend.

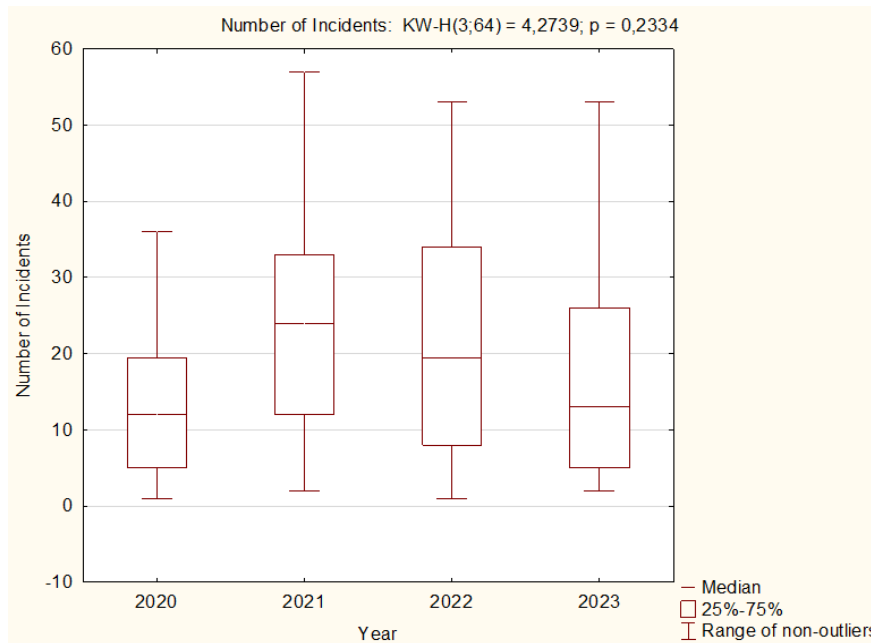


Figure 4. Comparison by year – number of interventions as annual totals for 16 voivodeships

Discussion

Contemporary operational practice clearly indicates that the role of the fire service in the health security system is undergoing a significant redefinition, extending beyond the classic paradigm of firefighting and technical operations. The increasing dispatch of firefighters to IEMIs should be interpreted as a manifestation of systemic adaptation to the growing burden on prehospital emergency care and the limited availability of EMT. This phenomenon is part of a broader trend towards the integration of rescue services, observed both in Poland and in international systems [15-17]. Functionally, firefighters currently act as a “first response” element, providing early access to the patient and support for medical teams at the prehospital stage.

National analyses indicate that the scope of fire service activities within IEMI is multidimensional, encompassing both direct patient care and broadly defined logistical and

technical support. Dudziński et al. demonstrated that firefighters participate in patient care, perform auxiliary tasks in cooperation with EMT, and secure the incident scene, which in practice translates into increased overall intervention effectiveness [18]. Such a wide range of operational competencies indicates that the fire service no longer fulfils only a supporting role but is becoming an active component of the medical rescue system. Importantly, the nature of these interventions is not limited to trauma or acute somatic conditions.

A study covering the years 2020-2022 showed that a significant proportion of firefighter interventions concerned incidents related to behavioral disorders, including mental disorders and suicide attempts. This observation underscores the growing clinical complexity of situations in which rescue services are engaged, and the need to prepare firefighters to operate in conditions beyond classic rescue scenarios. Consequently, IEMIs should be perceived not only as an organizational problem but also as a competency challenge, requiring the expansion of training to include crisis communication, risk assessment, and intersectoral cooperation [15].

These conclusions are confirmed in a literature review by Maczulski et al., which indicates that firefighters provide significant support to medical teams, especially in situations requiring an increased number of rescuers, the use of specialized equipment, or operations in hazardous environments [17]. The authors also emphasize the need for further standardization of cooperation procedures and systemic integration between the fire service and the State Medical Rescue System. From a systemic perspective, this means redefining operational models and recognizing firefighters as full participants in the chain of survival.

Similar trends are observed in international literature, where fire and rescue services are an integral part of first responder systems. A study by Svensson et al. showed that in the case of out-of-hospital cardiac arrest, the response times of EMT, fire and rescue services, and volunteer responders are analyzed in parallel, confirming the established role of firefighters in the medical response structure [18]. This importance is particularly evident in rural areas, where limited availability of medical resources means that each additional layer of the first response system can significantly affect patient prognosis. In this context, fire service involvement should be regarded as a compensatory mechanism reducing inequalities in access to emergency services.

Further confirmation is provided by the international consensus by Metelmann et al., in which firefighters were unequivocally classified as “on-duty first responders”, alongside police and other uniformed services [19]. Standardizing terminology in this area is important because it indicates a global convergence of organizational models and formal recognition of the role of

non-medical services in responding to emergencies. Consequently, IEMIs can be interpreted as a local manifestation of a broader systemic process, rather than merely a specificity of the national rescue model.

Many factors locally influence the prolonged response time of the SEMS, e.g. demographic and environmental factors, population density, mass incidents, the dispatch of all medical entities to other events, or a less favorable location of rescue entities relative to the incident site compared to firefighters [20]. The COVID-19 period in Poland is an example of the burden and operational difficulties faced by medical entities, which required support from firefighters [21].

In most European countries, the share of firefighters with full medical education is clearly lower, and systems are based rather on basic life support training than on integrating medical competencies into the structure of the service. For example, a comparative analysis of SEMS in Europe indicates that in countries such as Austria, Denmark, or Italy, firefighters do not routinely perform medical functions; their role is limited to logistical support and operations in hazardous environments. In other countries, such as the Czech Republic or Latvia, “firefighter-paramedic” models are being developed, but they are selective and involve a small proportion of personnel, not the entire firefighter population. Exceptions are more integrated systems, such as in Belgium or Romania, where the fire service may provide ambulance services, but even there, the proportion of firefighters with full medical qualifications is limited and supplemented by dedicated SEMS personnel [22].

International literature emphasizes that the dominant model remains the concept of the “on-duty first responder”, in which firefighters are trained to provide first aid and perform basic resuscitation procedures, while advanced medical procedures remain the domain of specialized EMT. In this context, the relatively high proportion of firefighters with formal medical education in Poland may constitute a systemic advantage, increasing operational flexibility and the potential to carry out IEMI. At the same time, it should be noted that even in developed systems, the number of firefighters with full medical qualifications remains limited, and their role is complementary to SEMS structures, as confirmed by the global standardization of first responder terminology and functions. European data indicate that rescue systems are developing rather towards a hybrid model, in which firefighters constitute the first line of response, while advanced medical care remains the domain of specialized services. In this view, the share of firefighters with medical education should be regarded as a factor strengthening system effectiveness, not its primary pillar [23].

The first responder concept refers to the first professional or semi-professional entity to reach the patient and initiate life-saving actions before the arrival of specialized EMT. In practice, this means that firefighters – alongside police and community responders – constitute an important link in the so-called chain of survival, particularly in life-threatening conditions such as sudden cardiac arrest. European analyses indicate that this model is particularly developed in the Nordic countries. In Sweden, firefighters function as “medical first responders”, with the task of shortening the time to patient contact in areas with limited accessibility of medical teams [18].

In an analysis by Rantala et al., it was shown that the effectiveness of first responder actions – including firefighters – is strongly dependent on communication coordination, clear role delineation, and shared training. The authors indicate that a lack of interoperability and insufficient procedural integration may limit the potential benefits of rapid arrival at the scene. In this view, the role of firefighters as first responders should be analyzed not only through the lens of response time but also through the quality of systemic interaction [24].

The study was limited to the territory of Poland. It is worth noting the structures prepared for international operations among Polish firefighters. Rescue modules, comprising over 150 firefighters-rescuers and several dozen vehicles, have intervened in many places around the world: (Greece, 2021 – forest fire), (Germany, 2021 – flood), (Czech Republic, 2022 – forest fire in the national park), (Türkiye, 2023 – earthquake), (Lebanon, 2020 – port explosion), (Nepal, 2015 – earthquake). International interventions may have generated additional events fitting the present analysis. However, this study does not cover international operations, which may be the subject of further secondary analyses [25].

Another area of firefighter support for the SEMS concerning individuals with cognitive deficits (whether due to neurological or mental disorders, or congenital intellectual disabilities) is the search for missing persons. In many cases, cooperation with other services – police, forestry services, maritime and mountain rescue services, fire protection units – is essential and crucial for the successful conclusion of operations, and time is key during such activities. New technologies, including drones adapted for searching for people, are helpful in the work of the services [26].

Analysis of foreign reports confirms national observations regarding the cooperation of firefighters with medical entities. In Brazil, firefighters form a crisis response team for calls related to suicide and suicide attempts, as well as crisis situations, and they also use a tool well-known in emergency medicine for assessing the state of consciousness: the Glasgow Coma

Scale (GCS). The scale is useful in neurological assessment. GCS is one of the most widely used neurological assessment tools in the pre-hospital setting. It is a simple, useful diagnostic tool employed by emergency medical teams and specialized rescue units staffed by medically trained personnel. It enables rapid assessment of the casualty and allows rescue procedures to be tailored to specific needs and the patient's clinical condition [27].

Conclusions

The participation of firefighters in medical incidents is important for ensuring public safety. Firefighters constitute significant support for medical entities in interventions for emergency events. During the observed period, no significant increasing trend in included events was observed between years. The rate of neurological disorders depending on location (regions) of Poland is associated with demographic conditions such as total population and population density. The obtained data may have planning implications concerning the location of SEMS mobile teams, indicating certain gaps or underestimations that should be addressed to ensure public safety.

Disclosures and acknowledgements

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The authors did not seek approval from a bioethics committee due to the completely anonymous and retrospective nature of the analysis and quantitative data. The data used in the study do not contain identifying information: incident addresses, personal data of casualties, personnel data, or codenames of service vehicles. The analysis was limited only to data on regions of the country: Polish voivodeships.

Artificial intelligence (AI) was not used in the creation of the manuscript.

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