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Epidemiology of EMS-Attended Motorcyclist Injuries in Slovakia: A Nationwide Retrospective Study, August 2018–August 2023

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ABSTRACT

Background: Motorcyclists are vulnerable road users, yet their nationwide prehospital epidemiology in Slovakia is insufficiently described. Objective: To characterize emergency medical service (EMS)-attended motorcyclist injuries and quantify temporal and regional variation. Methods: This retrospective study analysed anonymized national EMS records from 1 August 2018 to 31 August 2023. Cases had an ICD-10 V20–V29 code in at least one crew diagnosis field. Concurrent crew records matched on call-acceptance time, location, age and sex were grouped into episodes. Eurostat regional populations supplied person-time denominators. Results: Among 946 crew records, 869 episodes were identified. Patients were predominantly male (83.9%); median age was 38 years (interquartile range 27–49). Summer accounted for 52.0% and weekends for 40.6% of episodes. The annualized national rate was 3.14 per 100,000 person-years (95% CI 2.93–3.36); Žilina had the highest regional rate (5.84). Collision with a car, pick-up truck or van was the leading mechanism (33.4%), and lower-extremity injury codes were most frequent (31.8%). Median response time was 8.6 minutes. Twenty-four episodes (2.8%) ended in prehospital death. Calendar-month-adjusted rates decreased by an average 9.5% per year (rate ratio 0.91, 95% CI 0.87–0.95). Conclusion: The burden was concentrated among men aged 25–64 years, in warm months and on weekends, with marked regional variation. The findings support seasonal prevention and region-specific EMS planning.

1. Introduction

Road traffic injury remains a major public-health problem. Approximately 1.19 million people die on the world's roads each year, and road injury is the leading cause of death among people aged 5–29 years [1]. Powered two- and three-wheeler users are particularly vulnerable because they lack a protective vehicle structure, are less conspicuous in traffic and are exposed directly to impact energy. Almost 30% of global road traffic deaths involve powered two- and three-wheelers [2].

The European burden is also disproportionate. More than 3,500 motorcyclists were killed in the European Union in 2019, representing 16% of all road fatalities, although motorcycles account for a much smaller share of travel. European motorcyclist fatalities are predominantly male, strongly seasonal and concentrated during daytime and weekends; the risk of death per distance travelled is substantially higher than for car occupants [3]. These patterns make motorcycle injury prevention a priority within a Safe System approach.

Police and hospital statistics describe only parts of the injury pathway. Emergency medical service (EMS) data add the prehospital perspective: where and when injuries occur, what resources are dispatched, which interventions are performed and how patients leave the scene. National EMS data can therefore inform both prevention and operational planning, provided that multiple crew records referring to the same event are recognized and population denominators are used carefully.

In Slovakia, published nationwide evidence on EMS-attended motorcyclist injuries is limited. This study aimed to describe the demographic, temporal, geographic, mechanistic and clinical profile of motorcyclist injury episodes attended by EMS between August 2018 and August 2023. Secondary aims were to estimate population-based annualized and regional rates, examine calendar-month-adjusted temporal change, compare regional response times and characterize prehospital outcomes.

2. Literature Review

2.1 European and seasonal patterns

European surveillance consistently shows that motorcycle injury is shaped by exposure, weather and leisure travel. The European Road Safety Observatory reported a steep warm-season gradient, high weekend daytime mortality and a predominance of men among fatalities [3]. In neighbouring Poland, national police data for 2016–2023 similarly identified summer and weekends as peak periods, passenger cars as the most frequent crash counterpart and adults aged 25–59 years as prominent groups; overall crashes and injuries declined moderately across the study interval [4]. A large hospital series also demonstrated strong seasonality and a marked male predominance, although its younger age distribution reflects a different setting and population at risk [5].

The denominator is central to interpretation. Population rates measure the health-system burden within a resident population, but they do not directly measure riding risk. Motorcycle registrations, kilometres travelled, riding days, road type and weather can vary substantially by region and year. European analyses consequently recommend exposure-based denominators when available, while recognizing that consistent motorcycle travel data are often absent [3].

2.2 Prehospital epidemiology and injury patterns

Prehospital studies show a recurrent concentration of injuries among working-age men and frequent limb and head trauma. In a 3.5-year EMS series from Kigali, Rwanda, 80% of injured motorcyclists were male, the mean age was 30 years, and lower-extremity and head injuries were common; intravenous access was recorded in 42% of cases [6]. The local dominance of motorcycle taxis and different EMS access make its event rates unsuitable for direct comparison with Slovakia, but the demographic and anatomical patterns are informative. Detailed crash and trauma registries complement EMS data by quantifying injury severity. German in-depth crash research identified the femur, rib cage, lung, tibia and cerebrum as important targets for severe-injury prevention [7]. A large German trauma-registry study showed that the profile of severely injured motorcyclists differs from that of car occupants and evolves over time with changes in vehicle safety and rider characteristics [8]. Such sources provide granular severity measures, whereas routine EMS diagnoses capture broader clinical impressions at the scene.

Nationwide ambulance registries can identify large-scale patterns, but their interpretation depends on data completeness, consistent coding and an explicit unit of analysis. A Swedish registry study illustrated the value of nationwide EMS data for trauma surveillance while also documenting missingness and the distinction between prehospital assessment and definitive hospital diagnosis [9]. The present analysis applies these principles to Slovak motorcycle injury records and explicitly consolidates simultaneous multi-crew responses.

3. Methodology

3.1 Study design and data source

A nationwide retrospective observational study was conducted using an anonymized administrative database of Slovak EMS missions. The source file contained 452,921 crew-level records with dates from 1 August 2018 through 31 August 2023. Variables included dispatch and mission timestamps, age, sex, crew type, location, crew-assigned diagnoses, selected interventions and mission outcome. The data did not include hospital diagnoses, Abbreviated Injury Scale scores, helmet use, alcohol or toxicology results, motorcycle type, rider-versus-passenger status, road class, weather or vehicle-kilometres travelled.

3.2 Case identification and episode construction

Potential motorcyclist injuries were identified when at least one of four crew-assigned diagnosis fields contained an International Classification of Diseases, 10th Revision (ICD-10) code from V20 through V29. These codes cover motorcycle riders injured in transport accidents and can include drivers or passengers. The initial selection produced 946 crew records.Because more than one EMS unit may attend the same patient, the analytical unit was an injury episode rather than a crew record. Records were grouped when they had the same call-acceptance timestamp, location, sex and age. Location was represented by latitude and longitude rounded to five decimal places; if coordinates were unavailable, the region, district, municipality and municipality part were used. The procedure generated 869 episodes. Seventy episodes contained more than one crew record (147 records in total; maximum three). For grouped episodes, diagnosis and intervention fields were combined, physician-led or helicopter involvement was flagged if any responding unit met the criterion, the earliest valid arrival interval was used, and death took priority when outcomes differed between crews.

3.3 Variables and outcomes

Age was described continuously and in five groups (0–14, 15–24, 25–44, 45–64 and ≥65 years). Time was classified by calendar month, season, weekday/weekend and four six-hour periods. Regions corresponded to the eight Slovak NUTS 3 regions. The primary rate outcome was the number of EMS-attended episodes per 100,000 person-years. Mechanism was assigned from the V20–V29 group recorded most often within the episode. Anatomical injury regions were derived from S00–T14 diagnosis codes and were non-mutually exclusive. Prehospital death comprised outcomes recorded as Exitus or Exitus at the address. Response time was calculated from vehicle departure to arrival at the scene; negative values and intervals above 240 minutes were treated as invalid. The earliest valid interval represented the episode-level response time.

3.4 Population denominators

Regional population denominators were obtained from Eurostat dataset demo_r_pjangrp3 (population on 1 January by age group, sex and NUTS 3 region; total age and sex) [10]. For each region-year, the midpoint population was the mean of the 1 January population in that year and the following year. Exposure was prorated to five months in 2018, 12 months in 2019–2022 and eight months in 2023. Regional exposures were summed for the national denominator. These rates quantify EMS-attended episodes relative to population and should not be interpreted as risk per ride or per kilometre.

3.5 Statistical analysis

Counts and percentages were reported for categorical variables. Continuous variables were summarized using mean and standard deviation or median and interquartile range (IQR), as appropriate. Exact 95% confidence intervals (CIs) for crude rates were calculated from the Poisson distribution. Regional rate heterogeneity was tested with a chi-square goodness-of-fit test using expected counts proportional to person-time. Response times across regions were compared with the Kruskal–Wallis test. Age by sex and age by fatal outcome were compared with the Mann–Whitney U test; fatal outcome by sex was assessed with Fisher's exact test. Monthly counts were modelled using Poisson regression with the log of monthly population-time as an offset. Calendar month was included as a categorical term to account for seasonality, and elapsed time was entered continuously. The exponentiated 12-month coefficient is reported as the average annual rate ratio (RR). Seasonality was assessed by a likelihood-ratio test comparing models with and without calendar-month terms. Two-sided p values below .05 were considered statistically significant. Analyses were conducted in Python using pandas, NumPy and SciPy.

3.6 Ethical considerations

The study was a secondary analysis of anonymized routinely collected EMS records and involved neither an intervention nor patient contact. Direct personal identifiers were absent from the analytical file. Individual informed consent was therefore not applicable. Data processing was conducted in accordance with the principles of the Declaration of Helsinki and Regulation (EU) 2016/679.

4. Findings

4.1 Cohort formation and demographic profile

The 946 selected crew records represented 869 probable EMS-attended motorcyclist injury episodes. Men accounted for 729 episodes (83.9%) and women for 140 (16.1%). Mean age was 39.0 years (SD 15.1), and median age was 38 years (IQR 27–49; range 0–98). The 25–44 and 45–64 year groups together comprised 75.4% of episodes. Median age was higher among men than women (39.0 versus 33.5 years; U = 58,399.5, p = .007). Age and sex were complete for all episodes.

Table 1. Characteristics of EMS-attended motorcyclist injury episodes (N = 869)

Characteristic	Category	n or value	%
Sex	Male	729	83.9
	Female	140	16.1
Age, years	Mean (SD)	39.0 (15.1)	—
	Median (IQR)	38 (27–49)	—
Age group	0–14	20	2.3
	15–24	141	16.2
	25–44	400	46.0
	45–64	255	29.3
	≥65	53	6.1
Season	Spring	194	22.3
	Summer	452	52.0
	Autumn	203	23.4
	Winter	20	2.3
Day	Weekend	353	40.6
Time of day	00:00–05:59	15	1.7
	06:00–11:59	202	23.2
	12:00–17:59	475	54.7
	18:00–23:59	177	20.4

Source: Author's analysis of the Slovak EMS database.

4.2 Temporal patterns and trends

The temporal distribution was strongly seasonal. Summer accounted for 452 episodes (52.0%), followed by autumn (23.4%), spring (22.3%) and winter (2.3%). August had the highest aggregate count (214), although August was observed in six calendar years whereas most other months were observed five times. Sundays (n = 188) and Saturdays (n = 165) together accounted for 40.6% of episodes. More than half of episodes occurred from 12:00 to 17:59 (54.7%), and only 1.7% occurred from midnight to 05:59.

Across 27.68 million person-years, the national annualized rate was 3.14 episodes per 100,000 person-years (95% CI 2.93–3.36). The calendar-month-adjusted model indicated an average 9.5% annual decrease (RR 0.91, 95% CI 0.87–0.95; p < .001), while seasonality was strong (likelihood-ratio $\chi^2 = 593.77$, df = 11, p < .001). This average trend should be interpreted alongside the partial-year rebound in 2023 and possible changes in mobility, dispatch or coding during the COVID-19 period.

Table 2. Annualized national rates of EMS-attended motorcyclist injury episodes

Year	Months observed	Episodes	Rate per 100,000 PY	95% CI
2018	5	104	4.58	3.74–5.55
2019	12	198	3.63	3.14–4.17
2020	12	179	3.28	2.81–3.80
2021	12	137	2.52	2.11–2.98
2022	12	124	2.28	1.90–2.72
2023	8	127	3.51	2.93–4.18

Source: Author's analysis; population denominators from Eurostat demo_r_pjangrp3. PY, person-years. Rates for 2018 and 2023 are based on partial years.

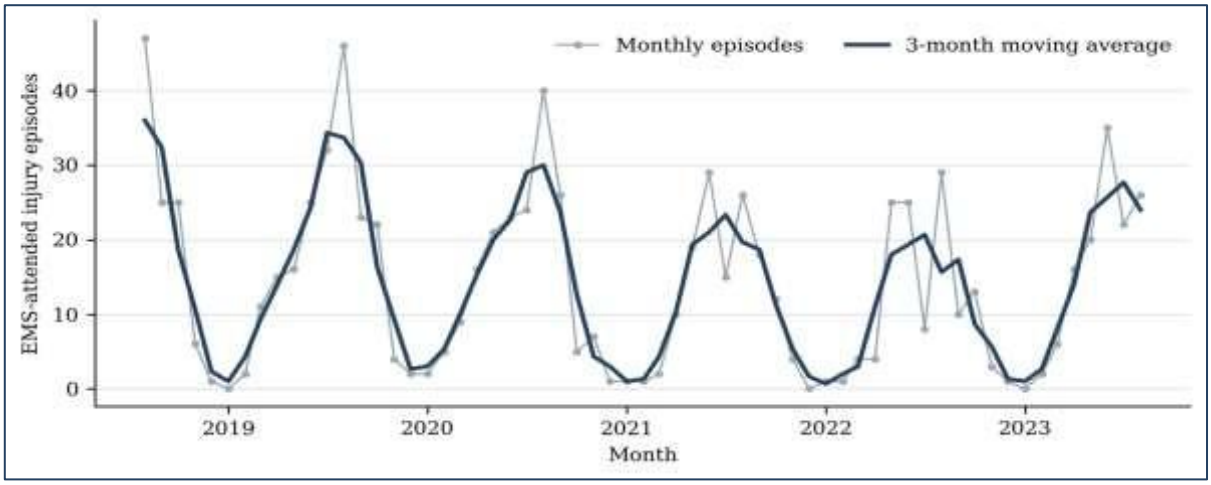

Figure 1. Monthly EMS-attended motorcyclist injury episodes and three-month moving average, August 2018–August 2023
Source: Author's analysis of the Slovak EMS database.

4.3 Geographic distribution and response times

Four episodes lacked a recorded region. Among the remaining episodes, Žilina had both the highest count (n = 205) and the highest population-based rate (5.84 per 100,000 person-years, 95% CI 5.07–6.70). Bratislava ranked second by rate (3.94), whereas Banská Bystrica (1.64) and Nitra (1.70) had the lowest rates. Regional count heterogeneity relative to population-time was substantial (χ^2 = 142.38, df = 7, p < .001). The rate in Žilina was approximately 3.6 times that in Banská Bystrica.

Table 3. Regional rates of EMS-attended motorcyclist injury episodes

Region	Episodes	Rate per 100,000 PY	95% CI
Žilina	205	5.84	5.07–6.70
Bratislava	139	3.94	3.32–4.66
Prešov	130	3.13	2.61–3.71
Trenčín	91	3.09	2.49–3.80
Košice	124	3.08	2.56–3.67
Trnava	65	2.26	1.75–2.88
Nitra	58	1.70	1.29–2.19
Banská Bystrica	53	1.64	1.23–2.15

Source: Author's analysis; population denominators from Eurostat demo_r_pjangrp3. Four episodes with missing region are excluded. PY, person-years.

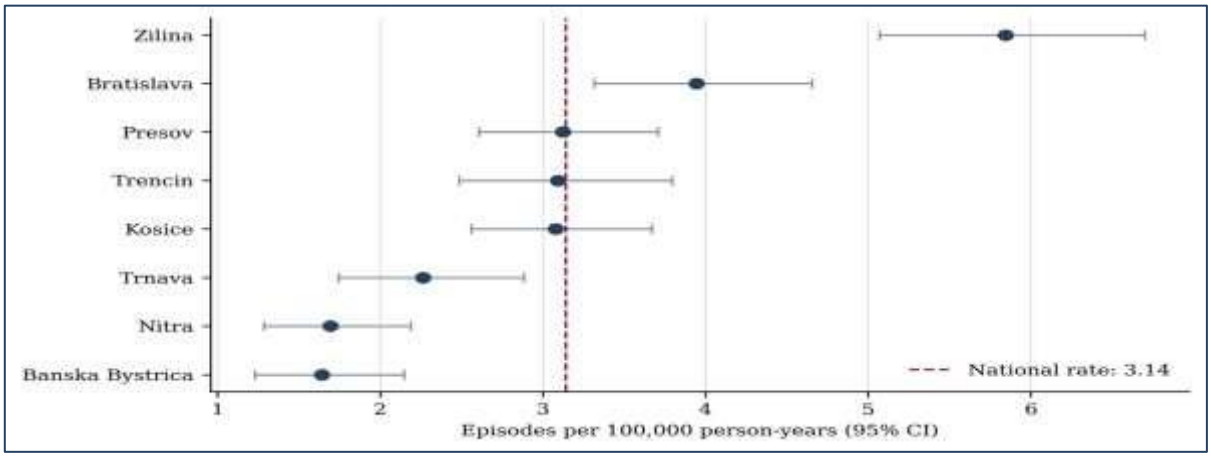

Figure 2. Regional rates of EMS-attended motorcyclist injury episodes with exact 95% confidence intervals
Source: Author's analysis; population denominators from Eurostat demo_r_pjangrp3.

A valid episode-level response interval was available for 857 episodes (98.6%). The national median was 8.6 minutes (IQR 5.4–13.2). Regional medians ranged from 7.4 minutes in Banská Bystrica to 13.5 minutes in Trnava, with evidence of regional differences (Kruskal–Wallis H = 26.76, p < .001). These unadjusted times describe the database and do not account for urban–rural geography, dispatch priority, traffic, distance or case severity.

4.4 Mechanism, anatomical pattern, EMS care and outcome

Collision with a car, pick-up truck or van was the most frequent V-code mechanism (33.4%), followed by non-collision transport accidents (24.1%), other or unspecified motorcycle accidents (19.3%) and collision with a fixed or stationary object (11.7%). Lower-extremity injury codes were recorded in 31.8% of episodes, upper-extremity codes in 25.0% and head injury codes in 15.5%. Because patients could have injuries in more than one region, anatomical percentages are not mutually exclusive. No S00–T14 anatomical injury code was present in 16.9% of episodes.

Table 4. Recorded crash mechanism and anatomical injury region (N = 869)

Domain	Category	n	%
Mechanism (V code)	Car, pick-up truck or van	290	33.4
	Non-collision transport accident	209	24.1
	Other or unspecified motorcycle accident	168	19.3
	Fixed or stationary object	102	11.7
	Pedestrian or animal	39	4.5
	Two- or three-wheeled motor vehicle	35	4.0
	Other mechanism (V21, V24–V26)	26	3.0
Anatomical injury code*	Lower extremity	276	31.8
	Upper extremity	217	25.0
	Head	135	15.5
	Thorax	77	8.9
	Multiple body regions	55	6.3
	Abdomen/lower back/pelvis	52	6.0
	Neck	13	1.5
	Other/unspecified	8	0.9
	No anatomical code recorded	147	16.9

Source: Author's analysis. *Anatomical categories are non-mutually exclusive and may sum to more than 100%.

Transport to a healthcare facility was recorded for 748 episodes (86.1%). Forty-seven patients (5.4%) refused transport and 42 (4.8%) were treated at the scene. Twenty-four episodes ended in prehospital death (2.8%). Fatal outcome was not significantly associated with sex (Fisher's exact p = .405), and median age did not differ significantly between fatal and nonfatal episodes (35.5 versus 38.0 years; p = .264). Physician-led ground or helicopter crews were involved in 321 episodes (36.9%), including helicopter EMS in 37 (4.3%). Intravenous access was recorded in 395 episodes (45.5%); mechanical ventilation and endotracheal intubation were each recorded in 25 (2.9%), and cardiopulmonary resuscitation in 16 (1.8%).

4.5 Discussion

4.5.1 Principal findings

This nationwide EMS analysis identified five principal findings. First, motorcyclist injury episodes were concentrated among men and adults aged 25–64 years. Second, the burden was highly seasonal, with half of episodes in summer and a large weekend and afternoon component. Third, the national population-based EMS-attendance rate averaged 3.14 per 100,000 person-years and decreased on average after adjustment for calendar month, although 2023 showed a partial-year rebound. Fourth, regional rates varied more than threefold, and unadjusted response times also differed between regions. Fifth, car collisions were the leading coded mechanism, limb injuries dominated the anatomical codes, and 2.8% of episodes ended in prehospital death.

4.5.2 Demographic and temporal profile

The male proportion of 83.9% is consistent with the strong male predominance reported in motorcycle studies, although it is lower than the 95% reported among European motorcyclist fatalities [3]. The difference is expected because the present cohort includes EMS-attended injuries of all recorded severities rather than fatalities alone. The age distribution was older than the mean age of 30 years in Kigali and 26 years in the Iranian hospital series [5, 6], but it aligns with the broad 25–59-year concentration reported in Poland [4]. Country-specific riding patterns, motorcycle use and study inclusion criteria likely explain much of the variation.

Warm-season, weekend and afternoon peaks closely mirror European findings and are plausibly related to higher riding exposure, leisure travel and favourable weather rather than an intrinsic seasonal change in crash risk [3, 4]. This distinction matters for prevention: population rates rise when more people ride, even if per-kilometre risk is unchanged. The adjusted annual decline is encouraging, but it cannot be attributed to a specific intervention. Pandemic-related mobility, changing motorcycle activity, EMS access, data recording and regression to the mean are alternative explanations.

4.5.3 Regional variation and EMS implications

Žilina's rate was well above the national value, while Banská Bystrica and Nitra had the lowest rates. Potential explanations include motorcycle ownership and mileage, road-network characteristics, mountainous or recreational routes, tourism, traffic density, population mobility, EMS utilization and coding practice. Population denominator differences alone do not establish that one region is intrinsically more dangerous for an individual rider. Linking EMS episodes with motorcycle registrations, road segments, meteorological data and vehicle-kilometres would help separate exposure from risk.

The 8.6-minute median response interval provides an operational benchmark for the study period, but regional differences should not be interpreted as a league table of EMS performance. The observed interval begins at vehicle departure rather than call receipt, and it is affected by station geography, road access, dispatch priority and multi-unit response. Future work should model dispatch-to-scene and on-scene intervals separately, stratify by urbanity and severity, and evaluate associations with clinically meaningful outcomes.

4.5.4 Mechanism, injury pattern and outcome

The predominance of collisions with cars is consistent with evidence from Poland and with the large car-collision share in the Kigali EMS study [4, 6]. Non-collision events and collisions with fixed objects together represented more than one-third of episodes, supporting prevention measures directed at both multi-vehicle conflict and loss of control. European evidence similarly indicates that single-vehicle events form an important share of serious motorcycle crashes [3].

Lower- and upper-extremity diagnoses were common, while head and thoracic codes were less frequent. The lower-limb finding is consistent with the Kigali prehospital series and with German in-depth evidence identifying the femur and tibia as priorities for severe-injury prevention [6, 7]. However, the present percentages reflect broad crew-assigned ICD-10 codes, not systematic whole-body assessment or AIS severity. Under-recording is likely when external-cause codes or the immediately life-threatening problem take precedence, as illustrated by the 16.9% of episodes without an anatomical S00–T14 code.

The 2.8% prehospital fatal-outcome proportion cannot be compared directly with hospital or 30-day mortality. It excludes deaths after transfer and depends on EMS activation and documentation. Conversely, it includes patients found dead at the scene. The high transport proportion and frequent intravenous access indicate substantial EMS resource use; physician-led or helicopter participation in more than one-third of episodes further underlines the operational relevance of motorcycle trauma.

4.6 Strengths and limitations

The principal strengths are nationwide coverage, a five-year observation window, explicit consolidation of multi-crew records, population-time adjustment for partial calendar years, exact rate confidence intervals and seasonally adjusted trend modelling. The study also combines demographic, temporal, geographic, operational and prehospital clinical information in a single analysis.

Several limitations require emphasis. Case identification depended on crew-assigned ICD-10 coding and may miss motorcyclists coded only by injury or include miscoded events. The grouping rule could theoretically merge two people of the same age and sex at the same location and timestamp, although it mainly addressed clear multi-unit responses. Conversely, small timestamp or location discrepancies could leave duplicates unmerged. Rider and passenger status could not be distinguished. Injury codes were neither independently validated nor severity-scored, and hospital diagnoses and later outcomes were unavailable. Four episodes lacked region and 12 lacked a valid response interval. The population denominator does not measure riding exposure; regional and temporal rate differences may therefore reflect motorcycle use rather than injury risk. Finally, the study period begins in August 2018 and ends in August 2023, so annualized values for these two years are based on partial-year data, and the COVID-19 period may have altered travel and service use.

4.7 Public-health and service implications

Prevention should be timed and located according to observed demand. Warm-season campaigns and enforcement can focus on men aged 25–64 years, weekend and afternoon riding, conspicuity, speed management, cornering and interactions between motorcycles and passenger cars. Road authorities should examine high-rate corridors in Žilina and Bratislava using crash-location and exposure data before selecting engineering countermeasures. EMS planners can use seasonal forecasts to align advanced clinical resources, trauma-system readiness and interfacility capacity with predictable peaks. Standardized national EMS documentation should capture rider or passenger status, helmet use, suspected alcohol or drugs, road environment, injury severity and linkage to hospital outcomes.

5. Conclusion and Recommendations

5.1 Conclusion

Between August 2018 and August 2023, Slovak EMS attended an estimated 869 distinct motorcyclist injury episodes identified from 946 crew records. Most involved men aged 25–64 years, occurred during summer, weekends and afternoons, and resulted in transport to hospital. The national annualized rate was 3.14 per 100,000 person-years, but regional rates differed markedly. Calendar-month-adjusted rates declined on average, although the partial 2023 data show that continued surveillance is necessary. Collision with passenger cars was the leading mechanism, limb injury codes were common and approximately one in 36 episodes ended in prehospital death.

5.2 Recommendations

- Concentrate rider and driver safety campaigns, visible enforcement and trauma preparedness in the warm season, especially on weekends and afternoons.
- Investigate high-rate regions and corridors using motorcycle registrations, traffic exposure, road design, weather and geocoded crash data before attributing differences to road danger or EMS performance.
- Strengthen EMS documentation with structured fields for rider/passenger role, helmet use, suspected impairment, road environment, injury severity and prehospital physiology.
- Link EMS, police, hospital and mortality records to measure definitive injury severity, 30-day outcomes and preventable deaths while preserving privacy.

- Repeat the analysis prospectively with complete calendar years and motorcycle-specific exposure denominators to verify the temporal trend.

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