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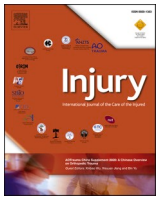

Urban-rural disparities in fatal and non-fatal paediatric injuries after trauma – A national retrospective cohort study

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ABSTRACT

Introduction: Paediatric trauma is a leading cause of death, with correlations between trauma outcomes and geographical locations. Certain rural regions of Norway face a higher risk of trauma-related fatalities compared to the nationwide population. Among adults, the risk of both fatal and non-fatal injuries rises with increased rurality. The study aimed to investigate whether there is an increased risk of fatal and non-fatal injuries for children in rural areas across the entire country, as well as any changes over two decades.

Materials and methods: We conducted a retrospective cohort study of fatal and non-fatal paediatric injuries by accessing two national registries for all trauma-related patients under the age of 18. All cases were stratified into six groups according to level of centrality based on a national index used as a proxy for rurality. For inter-group comparison, urban-rural disparities were evaluated using Pearson`s Chi-square test, linear regression, and relative risk (RR).

Result: 1,059 paediatric deaths were included in the study period from 2002 to 2021. The mortality rate increased linearly with increased rurality ($r = 0.985$, $p < .001$). The overall mortality risk was 2.4 times higher in the most rural group compared to the most urban (RR = 2.37, 95 %CI 1.78 – 3.14, $p < .001$). Most deaths occurred pre-hospital (73 %), the total number of fatalities was highest in the age group 16 to 17 (42 %), and transport-related injury (32 %) was the most common cause of death. The relative risk of non-fatal injury was significantly higher for all centrality groups compared to most urban, and the highest rate was seen in sub-rural areas (RR = 1.39, 95 %CI 1.37 - 1.42, $p < .001$).

Conclusion: The mortality rate increased linearly across all levels of centrality, and the relative risk was 2.4 times higher in the most rural population compared to the most urban population. To effectively target primary prevention and enhance trauma care for paediatric patients in rural areas, a deeper epidemiological understanding and more comprehensive studies are essential.

Introduction

Trauma is a leading cause of death, accounting for 10 % of the global burden of disease and leaving numerous people with long-term disability [1,2]. Traumatic injuries rank highly among causes of paediatric deaths in Europe, with one trauma-related fatality for every two children who die from medical causes [3]. Children and adolescents surviving severe trauma have a greater risk of reduced work capacity, adverse financial consequences, and mental and physical disability, all of which increase the risk of premature death and immune-mediated

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illness later in life [2].

Rural areas consistently show higher mortality rates compared to urban areas following traumatic injuries [4–10]. A previous Norwegian study on trauma-related deaths found higher mortality risks in rural areas for individuals over 16 years of age [11]. Similar geographical disparities in paediatric trauma-related deaths were reported in a 2012 article, where the mortality rate in the most rural county was three times the national average [12]. Despite a 50 % reduction in all child fatalities due to trauma over the last two decades, a 2019 follow-up study revealed that the risk associated with rurality remained unchanged [13].

The higher mortality risk in rural areas has been attributed to a combination of factors, including delayed injury identification, long geographical distances, and extended response times for prehospital and primary healthcare services [14]. In 2006, a national trauma plan was implemented within the Norwegian healthcare system to ensure equal access to critical care, regardless of geographical location [15]. Norwegian hospitals with acute trauma care functions must meet the same criteria regarding training, preparedness, and facilities

Previous research has shown that children in certain rural regions of Norway face a higher risk of trauma-related fatalities compared to the nationwide population. Among adults, the risk of both fatal and non-fatal injuries rises with increased rurality. The study aimed to investigate whether there is an increased risk of fatal and non-fatal injuries for children in rural areas across the entire country, as well as any changes over two decades.

Methods

Study design and data collection

A retrospective cohort study of fatal and non-fatal paediatric injuries in Norway in the period 2002–2021 based on two national registries: The Norwegian Cause of Death Registry (CODR) and the Norwegian Patient Registry (NPR). Paediatric patients were defined as those under the age of 18.

Classification of rurality

Statistics Norway's centrality index from 2020 was used as a proxy for rurality. The calculation of the index is based on the number of workplaces and different service functions accessible by car within 90 min from the populated statistical units [16]. The calculation incorporates distance to service functions, including healthcare services, but it does not differentiate among trauma centres, hospitals with acute trauma care designation, or other local hospitals. Norway consists of 357 municipalities in 2024. Each municipality receives a value reflecting its degree of centrality from 1 to 1000. Then the municipalities are grouped into six centralities. Group 1 (930–1000) includes the most urban areas, particularly those in and around the capital, Oslo. Group 2 (870–929) comprises Norway's second most densely populated cities. Groups 3 (770–869) and 4 (650–769) consist of municipalities with the highest population numbers outside the largest cities. Finally, Groups 5 (550–649) and 6 (295–549) encompass the most rural areas, though they still include a substantial number of municipalities to minimise uncertainty in the dataset due to low population figures.

The centrality index was revised in 2020 following a national process of municipal mergers, which reduced the number of municipalities in Norway from 422 to 357. Despite these mergers, the proportion of municipalities in each centrality group remained the same, and the latest version could be used throughout the study period.

All cases were stratified according to the level of centrality from level 1 to 6. The number of inhabitants in various centrality index levels was extracted from Statistics Norway [17].

Setting

The study area was mainland Norway, with 5488,984 inhabitants in 2023, of which 1112,191 (20 %) were under 18. Norway has an elongated shape and constitutes an area of 323,782 km^2. Of the total population, 44 % reside in areas defined as urban (centrality index groups 1–2, 30 municipalities), 41 % in intermediate areas (groups 3–4, 154 municipalities) and 14 % in areas defined as rural (groups 5–6, 238 municipalities) [16].

The health care and emergency medical systems (EMS) are publicly funded and characterised by numerous smaller hospitals and long prehospital transports, especially in rural areas. All parts of the trauma treatment system adhere to the national trauma plan, ensuring uniform requirements and quality control. A long, rugged coastline, mountainous regions, fjords, and Nordic climate are additional challenges to maintain emergency medical services. The EMS is based on 527 ground ambulances, 20 helicopters and ten airplanes. Four hospitals are defined as trauma centres, and 32 provide trauma care nationwide (Fig. 1).

Variables

The CODR issues the official cause of death statistics for Norway and is under the jurisdiction of the Norwegian Institute of Public Health. To describe the number of trauma-related fatal injuries, we used data from the CODR categorised into two periods: 2002 to 2011 and 2012 to 2021. Inclusion criteria were deceased with ICD-10 (International Classification of Diseases, 10th Revision, English version) codes V01-Y89 ("External cause of morbidity and mortality") as the underlying cause of death, excluding deaths due to medical conditions or intervention-related causes (Table 1).

The NPR contains information on patients who have received specialised healthcare at a hospital and is under the jurisdiction of the Norwegian Institute of Public Health. To describe the number of trauma-related non-fatal injuries, we used data from the NPR categorised into two periods: 2009 to 2011 and 2012 to 2021. Data from NPR before 2009 was not uniquely identifiable and could not be linked to other central registries, such as the centrality index, and was therefore excluded. Because of this exclusion, a discrepancy in the study period

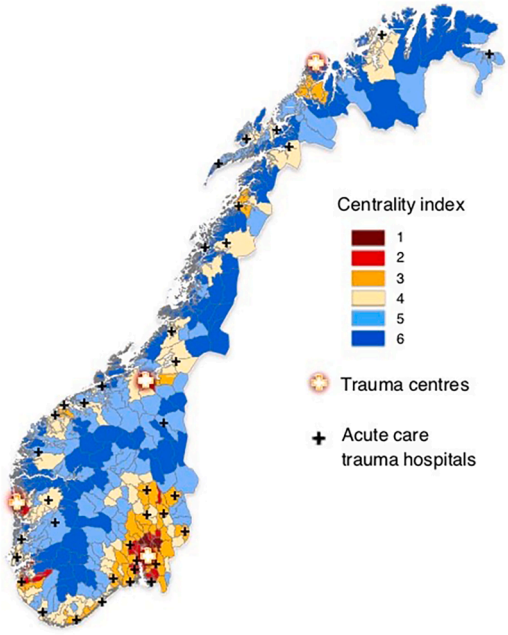

Fig. 1. Map of Norway showing centrality index groups (1 = most urban, 6 = most rural) and locations of hospitals with trauma functions and trauma centres.

Table 1
Variable list for The Norwegian Cause of Death Registry (CODR) and The Norwegian Patient Registry (NPR).

CODR			NPR		
Included	V01-V99, Y85	Transport accidents	**Included**	S00-S09	Injury to the head
	X85-Y09, Y87	Assault		S10-S19	Injury to the neck
	W00-W19	Fall		S20-S29	Injury to the thorax
	X00-X09	Fire		S30-S39	Injury to the abdomen/lower back
	X60-X84	Intentional self-harm		S40-S49	Injury to the shoulder/upper arm
	V01-Y89	Other*		S50-S59	Injury to the elbow/forearm
Excluded	X20-X29	Animal and plants		S60-S69	Injury to the wrist/hand
	X40-X49	Accidental poisoning		S70-S79	Injury to the hip/thigh
	X50-X57	Overexertion		S80-S89	Injury to the knee/leg
	X60-X69	Self-harm by poisoning		S90-S99	Injury to the ankle/foot
	X85-X90	Assault by poisoning		T00-T07	Multiple body regions
	Y06	Neglect/ abandonment		T08-T14	Unspecified part of trunk, limb, or body
	Y10-Y19	Poisoning undetermined intent		T15-T19	Foreign body entering natural orifice
	Y40-Y84	Medical complication		T20-T32	Burn and corrosions
	Y88	Medical sequelae		T33-T35	Frostbite
				T4n-T50	Biological substance
				T51-T65	Toxic effects nonmedical source
				T66-T78	Other and unspecified effects

* Remaining ICD-10 codes under "External cause of morbidity and mortality" that do not go under the main categories or have been excluded due to medical/iatrogenic causes, for example, drowning.

between the COD and NPR was created. We chose to retain the entire period for CODR, as mortality was considered the primary outcome measure. The inclusion criteria were patients registered with ICD-10 codes (Norwegian version) ranging from S00 to T78 (Table 1). Only patients receiving inpatient care, i.e., those recorded with an overnight stay, were included. Elective treatment was excluded, and each injury with the same primary diagnosis was counted once per patient per year.

Data from CODR was categorised according to the cause of death, age group (0–5, 6–10, 11–15 and 16–17 years), in- or prehospital site of death, and centrality index group for the municipality of residence (Table 3). Data from NPR was categorised according to type of injury, same age groups as data from CODR, number of days hospitalisation, and centrality index group for the municipality of residence. A sensitivity analysis was conducted for the number of days hospitalised, categorising admissions as either one day or more than one day, as an indicator of disparities in injury severity.

Statistical analysis

Mortality and injury rates per 100,000 per year for each period were calculated using the number of cases included relative to the number of inhabitants at risk in respective centrality index groups. For the calculation of mortality rates, 2011 was established as the baseline year, whereas for injury rates, the baseline year was set as 2015. Each was the average index year over the respective study periods drawn from the two registries.

Disparities for mortality, injury and days of hospitalisation rates, causes of death, and injury type and numbers hospitalised between centrality index groups were evaluated using Pearson`s Chi-square test and relative risk. The most urban group, centrality index level 1, was used as a reference. The association between mortality rate and centrality index had a linear shape and was also evaluated using linear regression and the Pearson coefficient test. A two-tailed p-value < 0.05 was considered statistically significant. Analyses were performed using SPSS v.29 (IBM Corp., Armonk, NY, USA).

Ethics

The study was approved by The Regional Committee for Medical and Health Research Ethics in Norway (ref. 2021/230,090) and the Data Protective Officer in the Norwegian Air Ambulance Foundation (29/8/2022, project number 3166). Data from CODR and NPR were delivered in aggregated form to minimise the risk of indirect identification.

Results

Population at risk

In the index years of 2011 and 2015, individuals under the age of 18 constituted 20 % and 22 % of the Norwegian population. The number of inhabitants at risk within the centrality index groups varied from 289,097 in group 3 to 48,544 in group 6 (Table 2 and 4).

Fatal injuries

1059 paediatric deaths due to external causes were included for the study period from 2002 to 2021. The overall mortality rate was 4.8 per 100,000 persons at risk yearly (Table 1). Between 2002–2011 and 2012–2021, the number of fatally injured children decreased from 676 to 383 events, a reduction of 57 %.

The mortality rate increased linearly with increased rurality throughout the study period ($r = 0.985$, $p < .001$). The correlation was highest for the period 2002–2011 ($r = 0.971$, $p = .001$) and lower but still significant for the period 2012–2021 ($r = 0.832$, $p < .04$) (Fig. 2). Lowest mortality rate was found in centrality group 1 (3.2 per 100,000 per year) and highest in centrality group 6, the most rural (7.5 per 100,000 per year). The overall risk of mortality was 2.4 times higher in group 6 compared to group 1 (RR = 2.37, 95 %CI 1.78 – 3.14, $p < .001$). Despite the overall reduction in mortality between the two time periods, a significant urban-rural gradient remained.

Place, age distribution, and causes of death

The majority of deaths occurred pre-hospital (73 %) for all centrality index groups, age groups, and periods. Between centrality groups, there were no significant disparities between the number of pre- and in-hospital deaths ($p = .67$).

The highest numbers of deaths were observed in the age group 16–17 across all centrality levels, except for the most urban, group 1, where the age group 0–5-year was predominant. In total, 42 % ($n = 448$) of all fatalities occurred in the age group 16–17 years (Table 3). In the oldest age groups, 11–15 and 16–17, transport-related injuries and suicide were the most frequent causes of death, whereas the category "other" predominated as the leading cause for the age groups 0–5 and 6–10 years (Fig. 3a).

Transport-related injuries (32 %, $n = 335$) and suicide (28 %, $n = 301$) were the two most common causes of death in all centrality index

Table 2
Mortality rate per 100,000 at risk per year and relative risk after fatal injuries, stratified after centrality index, where 1 is the most urban and 6 is the most rural.

Centrality index	Number of events*	Number at risk**	Mortality rate 2002–2011	Mortality rate 2012–2021	Mortality rate total	RR (95 % CI)	p-value
1	121	190,752	4.0	2.5	3.2	1***	
2	217	278,358	4.9	3.0	3.9	1.23 (0.98 - 1.53)	.068
3	295	286,105	6.4	4.0	5.2	1.63 (1.32 - 2.00)	<0.001
4	209	195,394	7.8	2.9	5.4	1.68 (1.35 - 2.11)	<0.001
5	139	111,820	7.5	4.9	6.2	1.96 (1.54 - 2.50)	<0.001
6	78	51,945	9.7	4.8	7.5	2.37 (1.78 - 3.14)	<0.001
Total	1059	1,114,374	6.2	3.4	4.8		

* Total number of events for the period from 2002 to 2021.
** Inhabitants at risk in the index year 2011.
*** Relative risk compared to the most urban centrality group, 1.

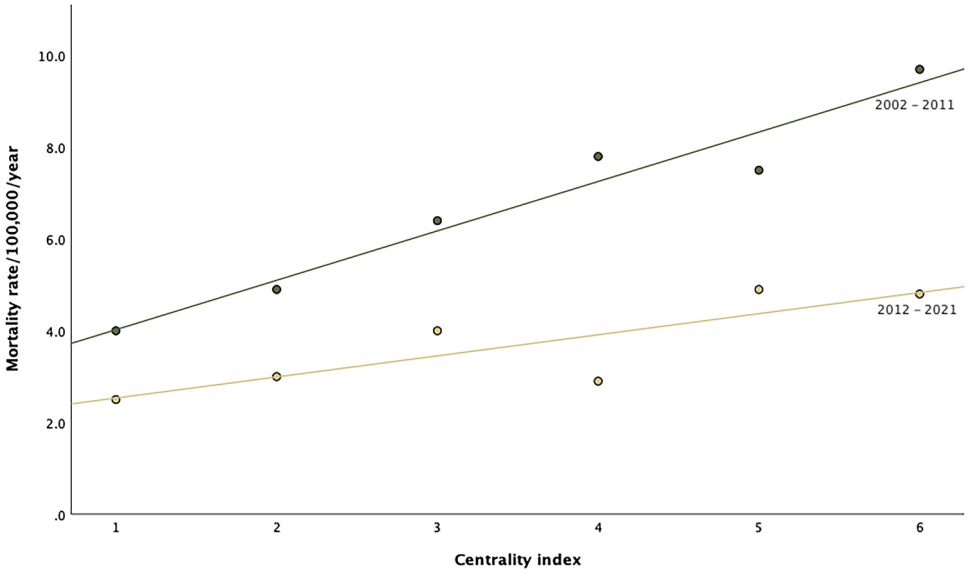

Fig. 2. Mortality rate per 100.000 inhabitants at risk/year, stratified by centrality index and period.

Table 3
Mortality rate and distribution in age groups and causes of death for period 2002 - 2021, stratified after centrality index 1 to 6, where 1 is most urban and 6 is most rural.

	Centrality index							
Number at risk (% of population)	**1** *n = 190 752 (17 %)*	**2** *n = 278 358 (25 %)*	**3** *n = 286 105 (26 %)*	**4** *n = 195 394 (18 %)*	**5** *n = 111 820 (10 %)*	**6** *n = 51 945 (5 %)*	**Total** *n = 1,114,374*	**p-value** *95 % CI*
Mortality rate per 100 000/ year	3.2	3.9	5.2	5.4	6.2	7.5	4.8	< 0.001
Mortality n (% in centrality group)								< 0.05*
0–5 years	39 (32)	38(18)	52(18)	40(19)	23(17)	14(18)	206(19)	
6–10	12(10)	27(12)	29(10)	13(6)	16(12)	<5(5)	101(10)	
11–15	37 (31)	69 (32)	82 (28)	59 (28)	37 (27)	20 (26)	304 (29)	
16–17	33 (27)	83 (38)	132 (45)	97 (46)	63 (45)	40 (51)	448 (42)	
Sum, n (% of total)	121(11)	217(20)	295 (28)	209(20)	139(13)	78(7)	1059	
Cause of death n (% in centrality group)								< 0.001**
Transport	25(21)	58 (27)	101 (34)	68 (33)	56 (40)	28 (36)	335 (32)	
Suicide	26(21)	66 (30)	93 (32)	56 (27)	36 (26)	24 (36)	301 (28)	
Assault	20(17)	19(9)	24(8)	23(11)	7(5)	<5(3)	95(9)	
Fall	<5(3)	<5(1)	5(2)	11(5)	<5(3)	5(6)	31(3)	
Fire	<5(2)	8(4)	7(2)	6(3)	10(7)	<5(4)	37(3)	
Other	44 (36)	64 (30)	65(22)	45(22)	26(19)	16(21)	260 (25)	

* Distribution of fatal cases across age groups among the different centrality groups.
** Distribution of cause of death among the different centrality groups.

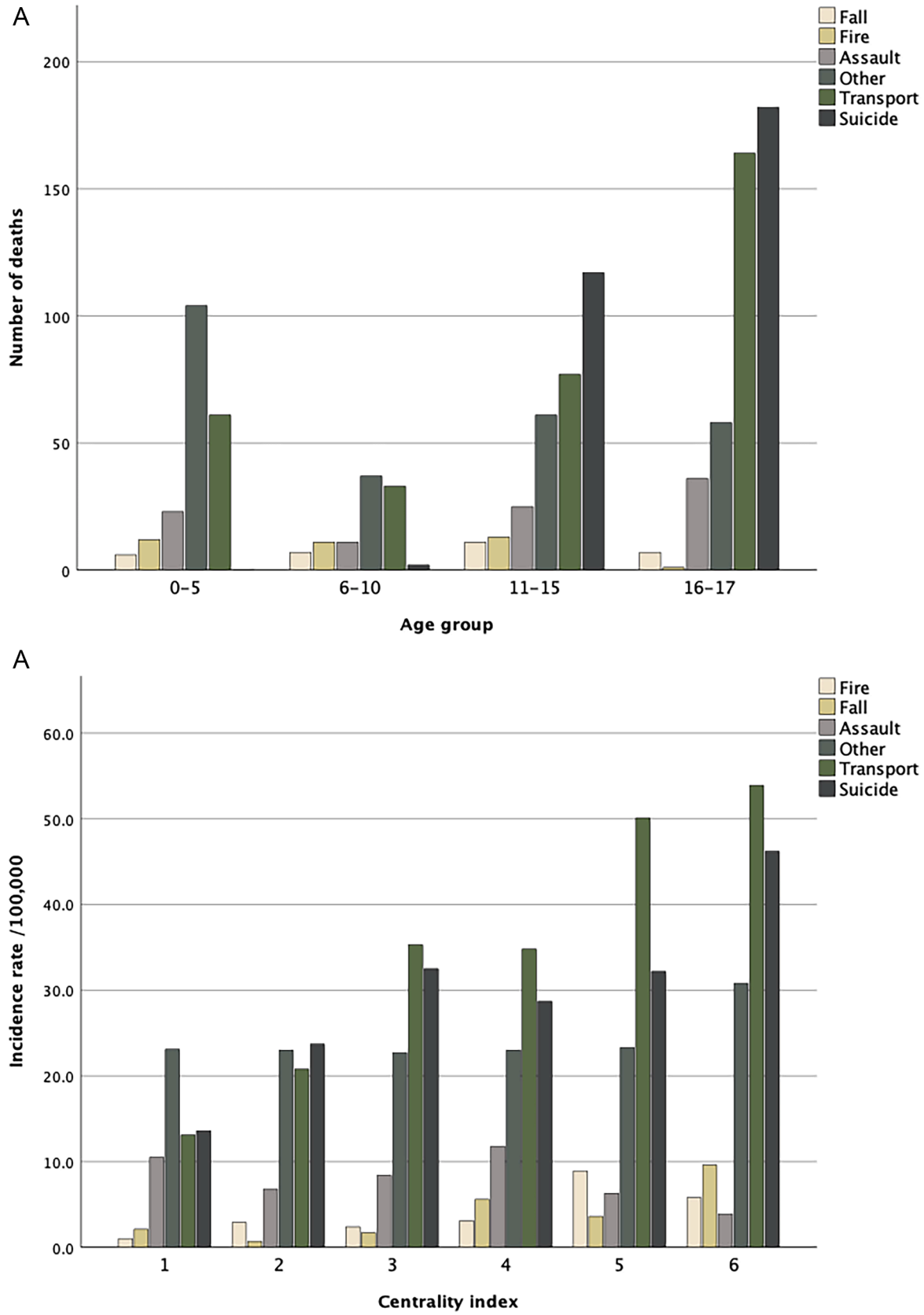

Fig. 3. a. Numbers of deaths according to cause, stratified by age groups.
Figure 3b Incidence rate of death by cause per 100,000, stratified by centrality index.

groups. Transport-related incidents had the most significant reduction between the two time periods, decreasing from 253 to 82 fatalities. The proportion of assault-related deaths was significantly higher in the most urban group, accounting for a total of 17 % ($n = 20$). Transport-related fatalities accounted for 40 % ($n = 56$, group 5) and 36 % ($n = 28$, group 6) of the cases in the two most rural groups and had the highest urban-rural gradient (Fig. 3b). The code "other" was used in a total of 25 % of all deaths ($n = 260$) (Table 3).

Non-fatal injuries

A total of 119,567 injuries were registered throughout the study period of 13 years, giving a total injury rate of 817 per 100,000 per year. The highest injury rate, stratified after the centrality index, was in group 4, with 939 injuries per 100,00 per year. The injury rate increased with increased rurality from the lowest in group 1 (675 per 100,00 per year) to 911 per 100,000 yearly in group 6 with an S-shaped curve (Fig. 4). Over the two periods, the overall injury rate was consistent for all levels of centrality. The relative risk of injury was significantly higher for all centrality groups compared to centrality index group 1, and highest for group 4 (RR = 1.39, 95 %CI 1.37 - 1.42, $p < .001$) (Table 4).

Head injury was the most common cause of injury (31 %) for all centrality levels and age groups, followed by injuries to the elbow (17 %) and leg (8 %) without any significant urban-rural disparities. Although head injuries accounted for one-third of all in-hospital contacts, only 11 % of those hospitalised for more than one day received a primary diagnosis of this condition.

Days of hospitalisation

The rates of patients hospitalised following injury varied significantly between the centrality groups, both hospitalisation for one and more than one day ($p< .001$). The lowest rate of hospitalised days, regardless of duration, was in the most urban group 1 and the highest in groups 4 to 6 (Fig. 5).

Discussion

Fatal injuries

Throughout the study period, the mortality rate increased linearly with an increased grade of rurality. The mortality rate in the most rural group was 2.4 times higher than in the most urban group. Despite differences in previously used definitions for centrality, this increasing mortality for paediatric trauma patients in rural versus urban areas is now shown in four different studies over a total of 23 years [11–13]. Overall, this lowers the likelihood of inaccuracies in these study results, even though the number of child fatalities due to trauma is relatively low.

A total of 1059 paediatric trauma-related deaths occurred over the 18-year study period, with an overall mortality rate of 4.8 per 100,000 children at risk per year. This mortality rate corresponds with previous findings for the same population [12,13]. The significant reduction in the number of events, halving them between the two time periods in our study, aligns with both European and global decreases in trauma-related deaths [1]. In our study, this reduction is mainly explained by the number of transport-related deaths decreasing from 253 to 82 between the two periods. This general decline in deaths may indicate better prevention, especially for transport, but the gradient between urban and rural areas has persisted. We recommend using established trauma registries that provide detailed information on each incident, including outcomes in terms of lost functional life years, for a better understanding of this disparity.

Place, age distribution, and causes of death

Transport-related fatal injuries showed the strongest urban-rural gradient and the highest total incidence numbers. This corresponds with road traffic accidents as the primary contributor to trauma-related death among children globally [1]. The same urban-rural gradient is described in a systematic review from Australia, which estimated the impact of rurality as the most important risk factor for transport-related deaths [18]. A prospective study of severely injured children involved in motor vehicle collisions in Norway revealed that injury severity was associated with restraint misuse, and an observational study on a rural, high-speed road revealed that two-thirds of individuals were improperly restrained [19,20]. With an increasing proportion of transport-related fatalities in areas of increasing rurality, preventative efforts in traffic safety for those under 18 years of age would be particularly beneficial.

The proportion of pre-hospital deaths was high (overall at 73 %) regardless of the level of rurality. This reduces the possible impact of regional differences in the competency among EMS providers and

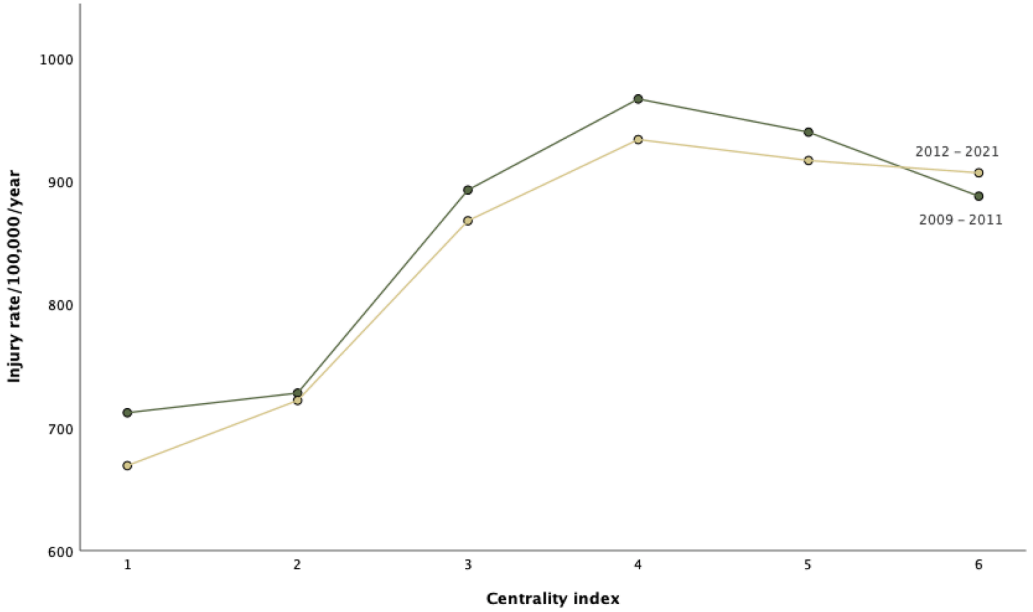

Fig. 4. Injury rate per 100.000 inhabitants at risk per year stratified by centrality index for two periods: 2009 to 2011 and 2012 to 2021.

Table 4
Injury rate for hospitalised children per 100,000 at risk per year and relative risk after non-fatal injuries, stratified after centrality index, where 1 is most urban and 6 is most rural.

Centrality index	Number of events*	Number at risk**	Injury rate 2009 - 2011	Injury rate 2012 - 2021	Injury rate total	RR (95 % CI)	p-value
1	17,666	201,258	712	669	675	1**	
2	26,551	283,378	728	722	721	1.07 (1.05 - 1.09)	<0.001
3	32,769	289,097	893	868	872	1.29 (1.27 - 1.31)	<0.001
4	23,855	195,395	967	934	939	1.39 (1.37 - 1.42)	<0.001
5	12,980	107,932	940	917	925	1.37 (1.34 - 1.40)	<0.001
6	5746	48,544	888	907	911	1.35 (1.31 - 1.39)	<0.001
Total	119,567	1,125,604	839	813	817		

* In total, for the period from 2009 to 2021.
** Inhabitants at risk in the index year 2015
***Relative risk compared to centrality group 1, most urban.

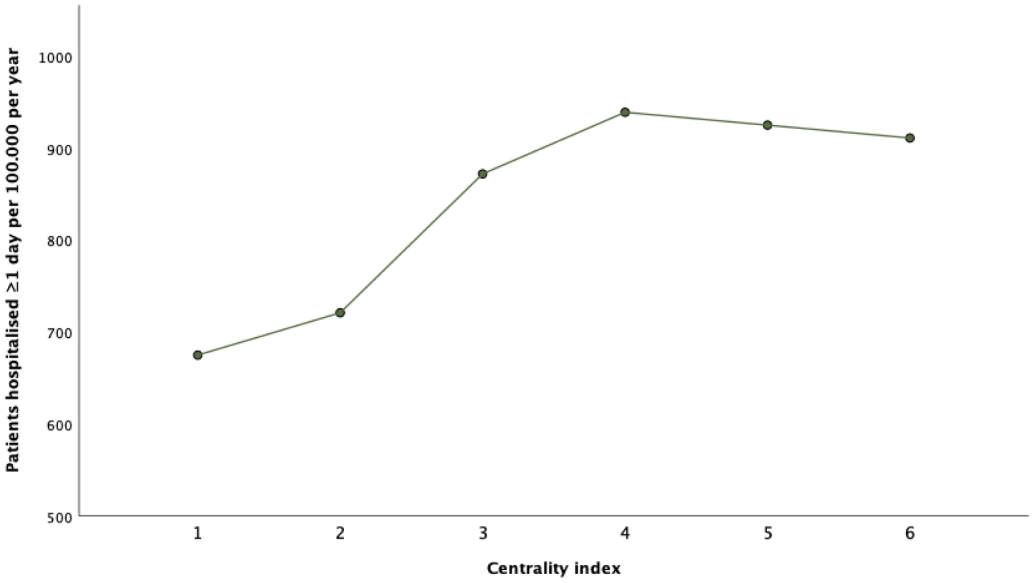

Fig. 5. Patients hospitalised per 100.000 inhabitants at risk per year, stratified by centrality index.

hospital trauma teams. The Norwegian health care system and EMS are publicly funded and must fulfil the same criteria concerning training, preparedness, and facilities. The recognition ability, effectiveness, and basic, crucial first aid techniques, such as ensuring open airways of non-medical first responders, have been proven satisfactory in rural areas [21]. Thus, assuming the competency of EMS and first responders is comparable in urban and rural areas, the importance of primary prevention for reducing mortality in rural areas should be further emphasised.

The 16–17-year-old age group experienced the highest number of trauma-related deaths in centrality groups 2 through 6. In centrality group 1, the highest mortality rate was observed in the 0–5-year-old age group. In the most rural centrality class, deaths in the age group 16–17 years constituted 51 % of the total number of deaths, compared to group 1, where it only accounted for 27 %. This difference is likely related to the varying distribution of causes of death across different centrality levels. Transport-related deaths and suicide dominate all centrality groups, but assault was more prevalent in centrality group 1 than in rural areas. These findings have been described in previous international population-based studies, enhancing the representativeness of our study [22]. Group 1 also had the highest proportion of deaths categorised as "other" (36 %), a category that has unfortunately often been used as a catch-all, also called garbage code, option when completing death certificates [23]. We call for improved registry quality and more autopsy reports to minimise the use of this code in the future.

Non-fatal injuries

As with the mortality, rates for non-fatal injuries also increased overall with increased rurality. Contrary to mortality rates, the curve for the most rural centrality class paradoxically flattened and declined slightly, giving an S-shaped curve. The same pattern was seen for the number of hospitalised days, including sensitivity analysis for more or less than one day. These results partially align with a sub-group analysis of the same population conducted in 2019, which compared the most rural county of Norway to the rest of the population, revealing a similar paradox of a lower injury rate but a higher mortality rate in the most rural population. In our study, we included all counties and municipalities, finding that the total rates of non-fatal injuries correspond more closely with the curve for those of fatal injuries. However, contrary to the pattern observed in mortality rates, the highest rate of injuries is found in group 4 rather than in group 6. These findings do not support that younger residents of predominantly rural areas exhibit more risk-taking behavior. This may suggest that unintended events occur less often but are more severe in most rural areas. The reasons for this are beyond the scope of data collected for this study.

The study excluded patients whose injuries were managed solely by a general practitioner in an emergency room outside of a hospital. Although the greater distances in rural areas might result in more non-fatal injuries being treated locally rather than in a hospital, the observed difference in relative risk for non-fatal injuries is substantial enough to suggest that local treatment alone does not fully account for this discrepancy.

Rural trauma

Rural areas have consistently higher mortality compared to urban ones following traumatic injuries. Using the national centrality index to represent rurality, this study confirmed a similar urban-rural gradient for children in Norway. This raises the question: Why are fatal injuries more prevalent in rural parts? The relation between rurality and mortality is described as a combination of delayed identification of injuries, long geographical distances, long response time for primary health care, delayed surgical treatment and less adequate competence in advanced trauma-related treatment [14]. On the other hand, rurality encompasses more than access to absolute healthcare services and emergency medical readiness. Instead of referring to rurality as a single risk factor, the various aspects that define rurality within a population should be explored, such as economic, social, and cultural conditions.

Strengths and limitations

The population-based approach and relatively long study period strengthen the representativeness of the results presented. Rurality was categorised based on a national standard that included multiple predictors, thereby reflecting the complexity of this dimension. On the other hand, this index does not differentiate among trauma centres, hospitals with acute trauma care designation, or other local hospitals.

Data collected included no further information about gender, injury severity, travel distance to a hospital, time of day, autopsy results or involvement of confounders such as drugs, socioeconomic and cultural conditions. The study did not include patients with injuries treated only by a general practitioner in an emergency room outside a hospital setting. Even though the CODR has high coverage, this registry is based on certificates of death, often done by a single physician, and the autopsy rate is low [24]. In our dataset, 25 % of the deaths were categorised as 'other external causes,' which means that we do not know the specific cause of death for at least a quarter of the study population.

This study employed residential address as the determinant of rurality. Ideally, the injury site should have been used as a descriptor of rurality in each specific trauma case. A substantial proportion of Norwegian citizens have access to a holiday home and spend considerable time away from their residential municipality. Using their registered residential address as a proxy for the rurality of the injury site may lead to either an over- or underestimation of the relative risk of mortality and injury across the centrality groups. Unfortunately, this information was only available for portions of the data set and of variable quality. We, therefore, retained the address of residence to facilitate comparison with previous studies.

Before 2009, the NPR was <50 % complete, could not be linked to other central registries, and exhibited regional skewness. Due to this, the study period for non-fatal injuries was shortened to 13 years from the initially planned 18 years. For a high proportion of injuries, the registry lacks information on the circumstances that led to the injury and thus cannot provide any details about external causes.

The datasets from CODR and NPR were sourced from different ICD-10 chapters. This resulted in discrepancies in the inclusion and exclusion criteria. For instance, some of the codes included from NPR were of a medical cause (T4n-T50, T51-T65, T66-T78). The corresponding codes from CODR (X20-X29, X50-X57, X60-X69, Y10-Y19) were, however, excluded. A sensitivity analysis demonstrated that the proportion of patients with these codes was evenly distributed across the centrality groups and constituted 10 % of the total events ($n = 13{,}037$). Thus, we believe that this discrepancy did not influence the main outcomes of the study.

Conclusion

Our study found an increased risk of trauma-related deaths with increased rurality for children under the age of 18 years. The mortality rate had a linear relationship through all six centrality levels, and the relative risk was 2.4 times higher in the most rural compared to the most urban group.

The majority of deaths were declared outside of the hospital, and the most common causes of traumatic death were transport injuries and suicide. The rates of non-fatal injuries and in-hospital days presented a paradoxical discrepancy, with the highest incidence not in the most rural group 6, as observed with mortality rates, but rather in the sub-urban group 4.

Our findings correspond with previous findings, stating that the burden of paediatric trauma is unevenly distributed in an urban-rural gradient. To effectively target primary prevention and enhance trauma care for paediatric patients in rural areas, a deeper epidemiological understanding and more comprehensive studies are essential.

Declaration of generative AI and AI-assisted technologies

During the preparation of this work, the first author used ChatGPT-4 to improve readability, grammar, and language. After using this tool, the author reviewed and edited the content as needed and takes full responsibility for the publication's content.

CRediT authorship contribution statement

June Alette Holter: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Elisabeth Jeppesen:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Trond Dehli:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Eyvind Ohm:** Writing – review & editing, Conceptualization. **Torben Wisborg:** Writing – review & editing, Supervision, Methodology, Conceptualization.

Declaration of competing interest

All authors state that they have no competing interests to declare.

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