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Geographical risk of fatal and non-fatal injuries among adults in Norway

Vegard Andersen[a,1], Vilde Ravnsborg Gurigard[a,1], June Alette Holter[a], Torben Wisborg[a,b,c,*]

[a] Interprofessional Rural Research team, Faculty of Health Sciences, University of Tromsø, The Arctic University of Norway, N-9600 Hammerfest, Norway
[b] Department of Anaesthesia and Intensive Care, Hammerfest Hospital, Finnmark Health Trust, N-9613 Hammerfest, Norway
[c] Norwegian National Advisory Unit on Trauma, Division of Emergencies and Critical Care, Oslo University Hospital, N-0424 Oslo, Norway

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ABSTRACT

Introduction: A rural gradient in trauma mortality disfavoring remote inhabitants is well known. Previous studies have shown higher risk of traumatic deaths in rural areas in Norway, combined with a paradoxically decreased prevalence of non-fatal injuries. We investigated the risk of fatal and severe non-fatal injuries among all adults in Norway during 2002–2016.

Methods: All traumatic injuries and deaths among persons with a residential address in Norway from 2002–2016 were included. Data were collected from the Norwegian National Cause of Death Registry and the Norwegian Patient Registry. All cases were stratified into six groups of centrality based on Statistics Norway's classification system, from most urban (group one) to least urban/most rural (group six). Mortality and injury rates were calculated per 100,000 inhabitants per year.

Results: The mortality rate differed significantly among the centrality groups ($p<0.05$). The rate was 64.2 per 100,000 inhabitants/year in the most urban group and 78.6 per 100,000 inhabitants/year in the most rural group. The lowest mortality rate was found in centrality group 2 (57.9 per 100,000 inhabitants/year). For centrality group 6 versus group 2, the risk of death was increased (relative risk, 1.36; 95%CI: 1.11–1.66; $p<0.01$). The most common causes of death were transport injury, self-harm, falls, and other external causes. The steepest urban–rural gradient was seen for transport injuries, with a relative risk of 3.32 (95%CI: 1.81-6.10; $p<0.001$) for group 6 compared with group 1. There was a significantly increasing risk for severe non-fatal injuries from urban to rural areas. Group 2 had the lowest risk for non-fatal injuries (1531 per 100,000 inhabitants/year) and group 6 the highest (1803 per 100,000 inhabitants/year). The risk for non-fatal injuries increased with increasing rurality, with a relative risk of 1.07 (95%CI: 1.02–1.11; $p<0.01$) for group 6 versus group 1.

Conclusions: Fatal and non-fatal injury risks increased in parallel with increasing rurality. The lowest risk was in the second most urban region, followed by the most urban (capital) region, yielding a J-shaped risk curve. Transport injuries had the steepest urban–rural gradient.

Introduction

Traumatic injury is a leading cause of death and disability worldwide, accounting for 10% of the global burden of disease [1]. The main causes are road traffic injuries, suicide, falls, and violence. Traffic injuries are ninth among causes of the global burden of disease, and road traffic deaths continue their climb, topping 1.35 million deaths worldwide in 2016 [1,2].

Norway has an elongated shape and one of the longest and most rugged coastlines in the world, with more than 50,000 islands off its mainland. The country covers 13 degrees northern latitude from south to north. Previous studies have shown associations between trauma outcomes and geographic location [3–10], and several groups have found higher mortality rates in rural compared to urban areas in Norway [11–13]. Kristiansen et al. reported a 33% higher trauma-related mortality rate in rural areas of Norway. Finnmark, the northernmost county in Norway, has a higher injury-related mortality rate than a more central county [13]. A recent study on pediatric injury showed a significantly higher trauma-related mortality rate in rural Finnmark, but conversely showed a significantly reduced risk of non-fatal injuries for

* Corresponding author.
E-mail address: torben.wisborg@uit.no (T. Wisborg).
[1] Shared first authorship.

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children in Finnmark compared to the rest of Norway [14]. Most rural deaths (85%) in northern Norway occur in the prehospital setting within the first hour after an injury [15]. The reason for the high proportion of early deaths is unclear. It has been suggested that this discrepancy is the result of increased trauma severity or reduced trauma care [3], but firm evidence for such assumptions is lacking [16].

A study from 1994 [17] showed that death was potentially preventable in 39% of patients who died before reaching the hospital, similar to results from a 2010 study of rural areas in Canada [8]. Kristiansen et al. [11] found that in the working-age population in Norway, 78% of all trauma-related deaths occurred outside hospitals, and the proportion of prehospital deaths increased with lower population density. The proportion of prehospital deaths was higher among trauma victims in rural areas but still high in the more urban areas [3,4,11,16,18]. In some rural areas, there is evidence of an increased risk of death in the emergency department for patients surviving long enough to reach the hospital [8].

Injury is the most frequent cause of death for people under the age of 45 years in Norway. Annually, 10% of residents are registered as injured, with 100,000 needing hospital treatment [19].

The Norwegian healthcare system is publicly funded. The country has 526 ambulances with a total driving distance of 33,198,783 km per year [20]. In addition to ground ambulances, there are 9 dedicated ambulance airplanes and 19 helicopters staffed with anesthesiologists, including 6 search-and-rescue helicopters [21]. Norway has four hospitals defined as trauma centers, located in Oslo, Trondheim, Bergen, and Tromsø. These fulfill and contain facilities, personnel, and preparedness equivalent to American College of Surgeons level-one trauma centers. In addition, 32 hospitals provide trauma care throughout their regions [19], all with defined trauma team composition and requirements for training, response time, and equipment. In total, there are approximately 7000 trauma team activations annually. Of these, 2500 are primary admissions to one of the four trauma centers and 4500 to hospitals with trauma function [22]. A national trauma plan from 2006 was revised and implemented in 2016 with the aim to secure equal high-quality trauma care independent of age, sex, and residential address [19]. All hospitals in Norway delivering trauma services are now committed to fulfilling several criteria concerning training, preparedness, facilities, and trauma team activation. Ambulance personnel are authorized healthcare providers, and the education and competence requirements are now standardized. Additionally, vehicle safety has improved, as has mandated seatbelt use in public transport and speed and anti-intoxication campaigns.

Since the latest studies using data collected during 1998–2007 and 2000–2004 [11,12], there is reason to hope that the high mortality rate in rural Norway has decreased.

In this study, we investigated the risk of fatal and severe nonfatal injuries among all adults in Norway during 2002–2016, with a focus on the degree of rurality.

Methods

Participants and data collection

All traumatic injuries and deaths among persons with a residential address in Norway from 2002–2016 were included. Data were collected from two official national registries, the Norwegian National Cause of Death Registry and the Norwegian Patient Registry, which both include all patients with a Norwegian identity number. All cases were stratified according to six groups of centrality based on Statistics Norway's classification of centrality 2017, with class one of six being most urban [23]. Each of the registries provided data grouped into six categories based on the classification of centrality.

All cases extracted were patients age 16 and above at a national level. Data concerning inhabitants per centrality index level were extracted from Statistics Norway. Index year was set to 2008 as the middle of the study period and used as reference when rates were estimated.

Norwegian National Cause of Death Registry

To describe the number of injuries with a fatal outcome between 2002 and 2016, we used data from the Norwegian National Cause of Death Registry. Traumatic deaths registered with International Classification of Diseases categorization (ICD-10) codes from V01 to Y89 as the primary cause were included. Data were categorized according to cause of death using the ICD-10 codes for transport injury (V01-V99), assault (X85-Y09, Y87.1), fall injury (W0), fire (X00-X09), self-harm (X60-X84, Y87.10), and other (V01-Y89 except the previous).

The Norwegian Patient Registry

The Norwegian Patient Registry registers all patients receiving treatment as inpatients or outpatients in Norwegian hospitals. We extracted data for all inpatient care episodes registered during 2002–2016 with ICD-10 codes S00-T78. With exclusion of outpatient registrations, all cases were considered severe because they required hospital admission. An episode was defined as a period during which a patient received healthcare for the same problem. All elective treatment was excluded.

Variables and definitions

There is no standard definition of rurality in trauma research, and several categorizations exist when comparing rural and urban areas. In this study, we compared statistics for the six groups of centrality based on Statistics Norway's classification [23]. Norway's 430 municipalities consist of approximately 13,500 populated statistical units. Calculation of the index is based on two components: the number of workplaces and the number of different service functions accessible by car within 90 minutes from the populated statistical units. Each municipality receives a value reflecting its degree of centrality (1–1000), and they are grouped into six groups, with group 1 containing the most urban municipalities and group 6 the most rural [23]. The calculation incorporates distance to service functions, including to healthcare services, but it does not differentiate among trauma centers, hospitals with acute trauma care designation, or other local hospitals.

Using Statistics Norway's classification of centrality, we compared six groups of rurality without comparing predefined different geographical areas. The Norwegian Patient Registry and the Norwegian National Cause of Death Registry contain geographical data based on residential address and not where the injury occurred. Residential address thus determined the degree of centrality in this study.

Settings

The study area is the country of Norway, with a total of 4,737,171 inhabitants living in a geographic area spanning 385,207 km^2 [24]. Of the total population, 42.6% reside in areas defined as urban (centrality index groups 1-2), 43.5% in intermediate areas (groups 3-4), and 14.0% in areas defined as rural (groups 5-6) [23]. Norway had 430 municipalities in 2008. Oslo is the most populous, with 681,071 inhabitants, and Utsira has the smallest population, with only 196 [25].

Statistical analysis

Mortality and injury rates were both calculated per 100,000 inhabitants at risk per year in each of the six groups of centrality based on the average number of inhabitants in 2008 (index year). The population was extracted from the registries and divided into

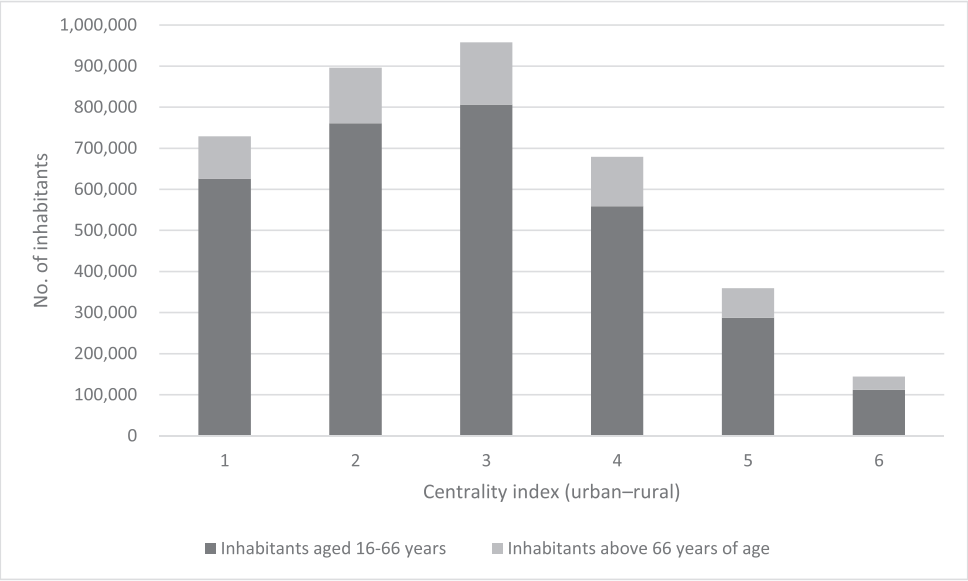

Fig. 1. The adult Norwegian population in the index year 2008, stratified by place of living in the centrality index (1 is most urban) and by age.

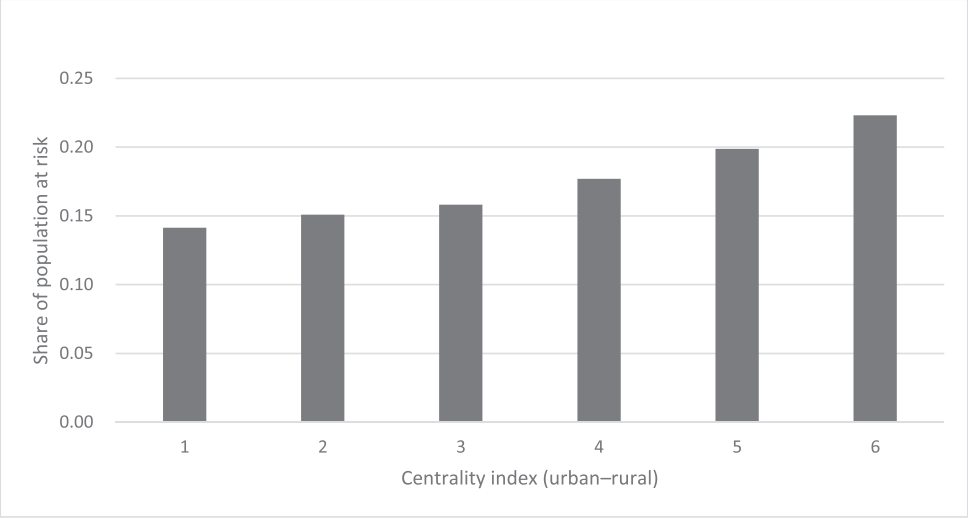

Fig. 2. The share of the population age >66 years at risk in each of the centrality index groups, with group 1 being the most urban area.

subgroups according to age: the working-age population (16–66 years) and the elderly population (age >66 years). PASW Statistics v.25 software (SPSS, Inc., Chicago, IL, USA) was used to perform the statistical analysis using Pearson's chi-square test. Statistical significance was set at $p<0.05$.

Ethics

The Regional Committee for Medical and Health Research Ethics for Northern Norway at the University Hospital of Northern Norway, Tromsø (ref. 2018/2531), approved the study.

Results

Population at risk

The total population over age 15 years in the index year 2008 was 3,766,422, of whom 3,152,714 were of working age (16–66 years) and 613,728 were over age 66 years. The population composition is shown in Fig. 1, and Fig. 2 shows the percentage of the population over age 66. In centrality group 1, 14% were over age 66, compared to 22% in group 6.

Mortality rate

In the 15-year study period, there were 36,790 deaths with an "external cause" (ICD-10 code V0-Y89) in the study population. The mortality rate was 65.1 per 100,000 inhabitants/year for all centrality groups combined.

The mortality rate differed significantly by level of centrality. The mortality rate in the most urban group (1) was 64.2 per 100,000 inhabitants/year, whereas in the most rural group (6), it was 78.6. The lowest mortality rate was found in centrality group 2 (57.9 per 100,000 inhabitants/year), which we used as a reference in addition to group 1. There was an increased risk of injury-related death for group 6 versus 2, with a relative risk of 1.36 (95% confidence interval [CI]: 1.11–1.66; $p<0.01$). There was no statistically significant increased risk of injury-related death for centrality groups 2 through 5, respectively, compared with centrality group 1 (Table 1)

We found a significantly higher mortality rate for males compared to females. The total mortality rate was 78.3 per 100,000 male inhabitants/year, compared with 52.2 per 100,000 female inhabitants/year ($p<0.001$). The six groups of centrality did not differ

Table 1
Mortality rates after injury per 100,000 inhabitants at risk/year in the Norwegian population >15 years, stratified by centrality.

Centrality Index	Mortality rate	Relative risk compared to centrality group 1 (95%CI)	Relative risk compared to centrality group 2 (95% CI)
1	64.2	1	1.11 (0.98–1.26, n.s.)
2	57.9	0.90 (0.80–1.02, n.s.)	1
3	67.3	1.05 (0.93–1.18, n.s.)	1.16 (1.04–1.31, p<0.05)
4	66.4	1.03 (0.91–1.18, n.s.)	1.15 (1.01–1.30, p<0.05)
5	71.2	1.12 (0.95–1.29, n.s.)	1.23 (1.06–1.43, p<0.01)
6	78.6	1.23 (1.00–1.50, n.s.)	1.36 (1.11–1.66, p<0.01)

n.s.: not significant; CI: confidence interval.

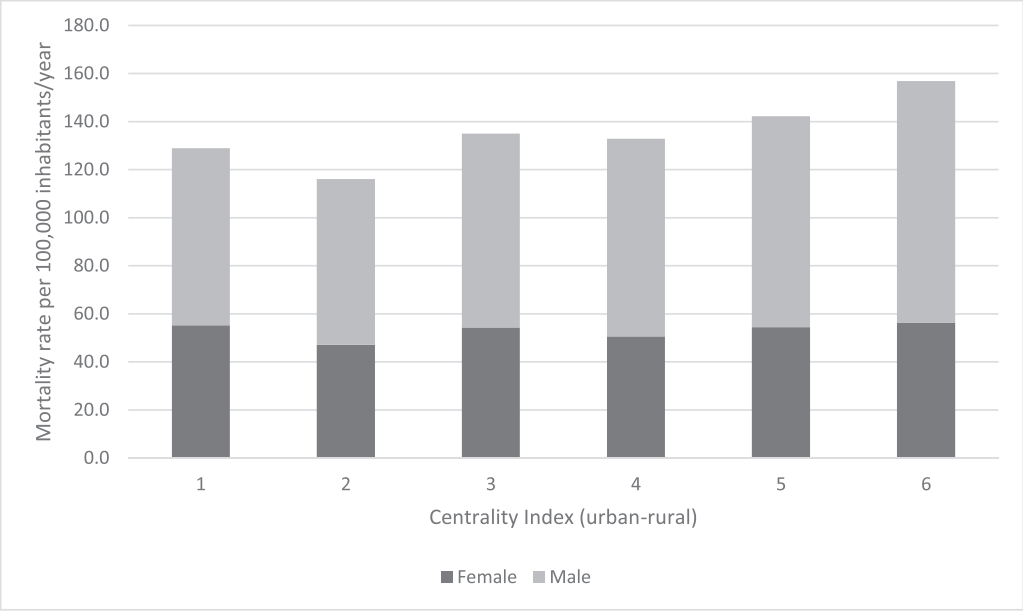

Fig. 3. Mortality rate after injuries per 100,000 inhabitants at risk/year, by sex and centrality group, with group 1 being the most urban area.

in mortality among females. In contrast, relative risk was increased for males in group 6 compared to those in group 1 (relative risk, 1.36; 95%CI: 1.05–1.77; p<0.02) (Fig. 3).

The mortality rate for the working-age population (16–66 years) was 38.6 per 100,000 inhabitants at risk/year. The most urban group, group 1, had a mortality rate of 38.0 per 100,000 inhabitants in this age group/year, and the most rural group, group 6, had a mortality rate of 44.3 per 100,000 inhabitants (Fig. 4). The levels of centrality showed no significant differences in this comparison (p>0.2).

In the group over age 66 years, the total mortality rate was 201.1 per 100,000 inhabitants at risk/year. The centrality groups also showed no differences across this age level (p>0.05).

Causes of death

The most common causes of death were transport injuries, self-harm, falls, and other external causes. “Other external causes” had the highest mortality rate at 26.8 per 100,000 inhabitants/year (41% of the total deaths). Urban and rural areas did not differ significantly in this group. Falls caused 14.9 deaths per 100,000 inhabitants/year (23%), and self-harm caused 14.3 deaths per 100,000 inhabitants/year (22%) (Fig. 5). Deaths caused by transport injuries had a total mortality rate of 6.8 per 100,000 inhabitants/year. The steepest urban–rural gradient was seen in the transport category, with a relative risk of 3.32 (95%CI: 1.81–6.10; p<0.001) for group 6 compared to group 1. There was also a significant difference between group 6 and group 1 in deaths caused by fire, with a relative risk of 1.79 (95%CI: 1.28–2.50; p<0.001). The centrality groups did not differ significantly for the other causes of death.

Non-fatal injuries

In the 15-year study period, there were 942,844 non-fatal injuries recorded as requiring hospital admission. The non-fatal injury rate is shown in Table 2. This rate differed significantly by level of centrality (p<0.001). Group 2 had the lowest risk of non-fatal injuries (1531 per 100,000 inhabitants/year) and group 6 the highest (1803 per 100,000 inhabitants/year). The risk of non-fatal injuries increased with degree of rurality, with a relative risk for group 6 vs. group 1 of 1.07 (95%CI: 1.02–1.11; p<0.01) (Fig. 6).

Non-fatal injuries according to age

The non-fatal injury rate differed significantly by level of centrality (p<0.001) in both the working-age population (16–66 years) and those >66 years. In the working-age population, group 2 had the lowest risk of non-fatal injuries (1065 per 100,000 inhabitants/year) and group 6 the highest (1264 per 100,000 inhabitants/year). The non-fatal injury risk increased with a higher degree of rurality, with a relative risk of 1.16 (95%CI: 1.10–1.23; p<0.001) for group 6 vs. group 1 (Table 3).

For those over age 66 years, however, the results showed the reverse pattern, with a decreased risk of non-fatal injuries in the most rural group (group 6: 3680 per 100,000 per inhabitants/year) compared with group 1 (5323 per inhabitants/year). The risk of non-fatal injuries decreased with a higher degree of rurality, with a relative risk of 0.35 (95%CI: 0.33–0.37; p<0.01) for group 6 compared with group 1 (Table 3).

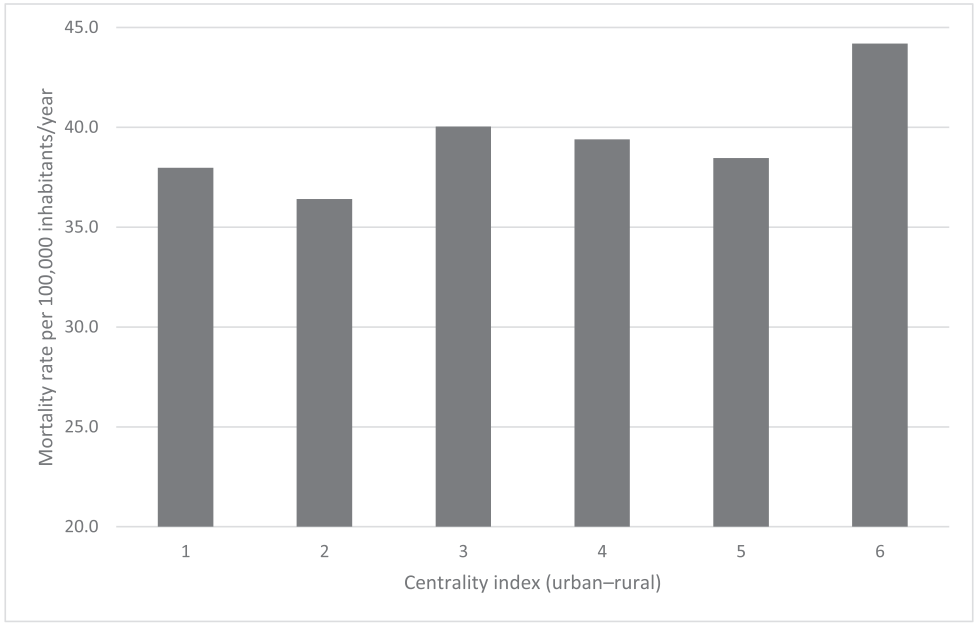

Fig. 4. Mortality rate after injuries in Norwegian adults ages 16–66 years, per 100,000 inhabitants at risk/year. The population is stratified into centrality groups, with group 1 being the most urban area.

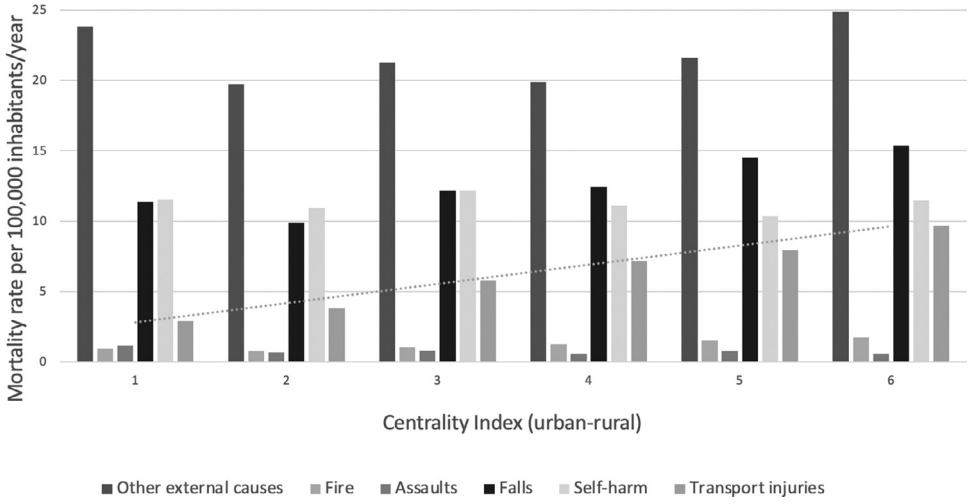

Fig. 5. Mortality rate after injuries in adults per 100,000 inhabitants at risk/year, by centrality group and cause, with centrality group 1 being the most urban area. The dotted trend curve represents road traffic injuries.

Table 2
Non-fatal injury rate in centrality groups 1 to 6 per 100,000 inhabitants at risk/year.

Centrality index	Rate of non-fatal injuries	Relative risk compared to group 1 (95%CI)
1	1690	1
2	1531	0.90 (0.88–0.93, p=0.01)
3	1694	1.00 (0.98–1.01, n.s.)
4	1714	1.01 (0.99–1.04, n.s.)
5	1761	1.04 (1.01–1.07, p=0.01)
6	1803	1.07 (1.02–1.11, p=0.01)

n.s.: not significant; CI: confidence interval.

Discussion

This retrospective registry study on the adult population in Norway during 2002–2016 documented a significantly increased risk in rural areas for fatal as well as non-fatal injuries. The curves for the mortality and non-fatal injury rates could best be described as J-shaped, with a somewhat elevated risk in the most urban (capital) area, the lowest risk in the second most urban area, and a definitely increased risk in the most rural areas.

Previous studies from Norway found a mortality rate of 28 per 100,000 inhabitants/year in the population aged 16–66 years [11]. Among those <64 years of age, with exclusion of low-energy in-

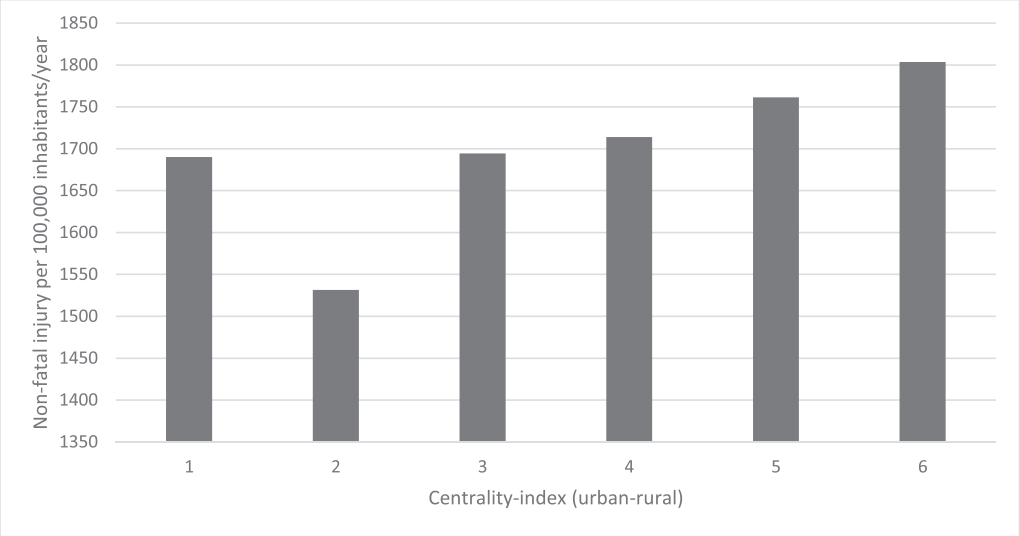

Fig. 6. The rate of non-fatal injury per 100,000 inhabitants at risk/year stratified into centrality groups, with group 1 being the most urban area.

Table 3
Non-fatal injury rate in centrality group 1 to 6 per 100,000 inhabitants at risk/year, stratified by age.

Centrality Index	Rate of non-fatal injuries (16–66 years)	Relative risk compared to group 1 (95%CI)	Rate of non-fatal injuries (>66 years)	Relative risk compared to group 1 (95%CI)
1	1092	1	5323	1
2	1065	0.98 (0.94–1.01, n.s.)	4155	0.40 (0.39–0.41, p<0.001)
3	1236	1.13 (1.10–1.17, p<0.01)	4135	0.40 (0.39–0.41, p<0.001)
4	1244	1.14 (1.10–1.18, p<0.001)	3900	0.38 (0.36–0.39, p<0.001)
5	1248	1.14 (1.10–1.19, p<0.001)	3102	0.37 (0.35–0.38, p<0.001)
6	1264	1.16 (1.10–1.23, p<0.001)	3680	0.35 (0.33–0.37, p<0.001)

n.s.: not significant; CI: confidence interval.

juries, this rate was 33 per 100,000 inhabitants/year in Finnmark, the most rural county, and 19 per 100,000 inhabitants/year in the urban municipality of Bergen in a previous study [12]. A comparable 2015 study from Finland found a mortality rate of 53.8 per 100,000 inhabitants/year [26]. These studies did not have exactly the same inclusion criteria, but their results are in keeping with the current findings. Several other studies from other countries also are consonant with the finding of higher trauma-related mortality in rural areas [3,6,9,27].

Using the new centrality index as a proxy for rurality, we also show here that there is an urban–rural gradient for trauma-related deaths and morbidity in Norway. This gradient has been identified before, although for earlier time periods and using different urban/rural definitions. Bakke et al. documented this for the rural county of Finnmark compared to Hordaland county without Bergen, and the city of Bergen itself [12]. Kristiansen et al. found a higher mortality rate for children and adults with a residential address in areas of low population density (inhabitants per square kilometer) [11]. Holter and Wisborg found higher trauma-related mortality in Finnmark for children compared to the rest of Norway [14]. The findings of the current study are in agreement with these earlier results for Norway.

The lowest rate of fatal and non-fatal injury regardless of age and cause was in centrality group 2, the second most urban, whereas the most urban group, group 1, had higher rates. Group 1 includes Oslo and five neighboring municipalities, and we speculate that the crime rate and proportion of people experiencing social and economic deprivation in Oslo might in part explain this finding. Centrality index group 2 includes the three other large cities in Norway, all of them with university hospitals with trauma centers. Areas more rural to these two groups seem to have in common an increased risk of fatal and non-fatal injury.

The reasons for the increased rate of fatal and non-fatal injuries in more rural areas have long been debated. Results of a U.S. study performed in Washington State suggested that one reason could be a lower proportion of healthcare workers trained in advanced life support in rural areas [28]. In Norway, education and competence requirements are standardized and should be equal according to the national trauma system. Long distances and longer transportation times might be part of the explanation, although findings from other countries are somewhat contradictory [5,27-30]. With a high share of prehospital deaths, the relative importance of the training of hospital trauma teams and experience of ambulance personnel may have shifted. Training the general public to act as first responders where the injury occurs may yield better outcomes. A study from northern Norway, focused on municipalities largely in centrality groups 4–6, found that in 97% of trauma incidents, lay persons present on the scene administered first aid. In most cases, the aid was administered correctly and for the appropriate indication [31].

We found no geographical gradient for female trauma victims when assessing fatal injury, whereas there was a 1.36 increase in relative risk for male victims in group 6 compared with those in group 1. There also was no difference between urban and rural rates in the elderly population over age 66 years. This finding may argue against trauma care as a reason for a higher rural mortality rate, assuming no difference between age and sex in time to hospital and quality of treatment. It seems that the biggest difference arises before the incident occurs, in the epidemiology of the trauma, rather than after, in the chain of emergency care.

The most common cause of death was “other external causes,” associated with approximately 15,000 deaths (41% of the total). Of these, intoxication represented one-third, and half of them were unspecified injuries. This category has unfortunately been

functioning as a garbage-can code by doctors filing death certificates, which are the main source for the Norwegian cause-of-death registry [32]. A recent review of this code indicates that in reality, most of these deaths are caused by falls and suicide [33].

Transport-related injuries showed the greatest urban–rural gradient, with most of the observed difference attributable to this category. Many studies have shown similar results [2,3,14]. Several investigations have revealed more severe injuries after traffic incidents in rural areas, with higher speed, less frequent seatbelt use, more intoxicated drivers, and older vehicles in rural vs. urban areas [16,28]. One study from rural Finnmark county showed a higher traffic-related mortality rate but a paradoxically lower prevalence of road traffic incidents, indicating a higher severity in the rural incidents compared to urban areas [13].

Previous studies in Norway also have shown a paradoxically decreased rate of non-fatal injuries in Finnmark, a rural county [12,14]. In the current nationwide study, we found an increased risk for non-fatal injury in rural areas compared to urban areas, in contrast to this earlier report. Thus, increased rural risk seems to apply to non-fatal injuries, as well.

Limitations

The national registries we used here have some limitations. The databases rely on data registered by individual physicians, and the variation in how doctors determine and register the cause of death is well known [32]. The large amount of data and the fact that this possible bias is expected to be similar across all centrality groups reduces the importance of this variation. Despite this, the registries are robust. Only 31 patients from the Norwegian Cause of Death Registry were excluded because of non-existent residential addresses.

We also relied on Statistics Norway's classification of centrality when defining degree of rurality, thus using distance to working places and service functions rather than geographical location as a measure for rurality. Service functions include health services, but hospital or trauma centers are not weighted higher than other service functions in these classifications. A previous study in Norway involved assessment of three centrality measures and found similar but not identical results [34]. The new centrality index [35] was not included in that study. Although differences in indices may cause some variation, we feel certain that the increased rural risk we have documented here is real.

This study employed residential address as the determinant of rurality. Ideally, the site of injury should have been used as a descriptor of rurality in each specific trauma case. This information is, however, unfortunately not available in present Norwegian statistics. We assume that mobility of the population is bi-directional, with some injured in more central or rural areas as compared to their address of living, thus mitigating the effects of this obvious weakness.

We chose 2008, the middle of the study period, as the index year for calculating injury rates. Demographic changes during the period could be a source of bias. Demographic centralization has been ongoing during the last decades in Norway, as in most other European countries. We believe that such centralization has been more or less similar during the study period, before and after the index year 2008.

Conclusions

In this study, we found a 1.36 times higher relative risk for traumatic death in the most rural areas compared to the second most urban region, with a slightly increased risk in the capital area compared with the second most urban group, as well. An increased mortality rate was found only in males, and transport injuries had the steepest urban–rural gradient. Because of a high rate of prehospital deaths, most of the difference seems to be attributable to trauma epidemiology rather than to trauma care. The increased rural fatality rate was parallel to a similarly increased risk of non-fatal injuries, both of which tracked with degree of rurality.

Declarations of interest

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

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