Original article

Analysis of the Epidemiology of Traumatic Vertebral Column Injuries in Eastern European Countries

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Vertebral column fractures (VCF), despite their relatively small proportion in the overall structure of human musculoskeletal trauma, represent a significant medical and social problem. Even injuries not accompanied by neurological deficits often lead to persistent impairments in the functional capacity of the affected individuals, significantly affecting their quality of life, employability, and social activity. The epidemiology of spinal trauma is insufficiently understood, largely due to the difficulty in accurately assessing its true frequency. Existing literature on the epidemiology of vertebral column trauma is mostly based on single-center or multicenter studies focused on specific region.

Objective. To conduct a preliminary analysis of the epidemiological features of vertebral column trauma in Eastern European countries.

Materials and Methods. Statistical data from the Global Burden of Disease database were analyzed to investigate the epidemiology of spinal trauma. The study focused on countries located entirely within the European part of the Eurasian continent. A 30-year period prior to the onset of the COVID-19 pandemic (1990–2019) was selected as the optimal time frame to reflect the current state of the problem. The main analysis parameters included disease incidence and years lived with disability.

Results. It was found that the relative frequency of vertebral column trauma is higher in countries with a higher gross domestic product. Over the analyzed period, all Eastern European countries exhibited a declining trend in the relative frequency of vertebral column trauma. In the overall structure of musculoskeletal trauma, vertebral column trauma accounts for 3.5–4.5% in Eastern European countries, and this figure is progressively increasing. Armed conflicts in the Republic of Moldova in 1992 and in Ukraine starting from 2014 are characterized by an increase in the frequency of vertebral column trauma. The proportion of males among those with vertebral column trauma is relatively stable and specific to each of the examined countries. In contrast to the conflict in Transnistria, the armed conflict in eastern Ukraine did not significantly alter the gender structure of vertebral column trauma patients, indicating a larger proportion of civilians among the affected individuals. Analysis of the causes of vertebral column injuries revealed that, on average, unintentional injuries account for approximately 81%, injuries resulting from road traffic accidents account for 16%, intentional injuries represent about 3%, with the latter two gradually decreasing. Almost half (42–46%) of vertebral column trauma cases occur in the age group of 20–44 years. In countries with a high gross domestic product, a significantly higher frequency of injury among elderly and senile population is recorded, possibly due to more efficient diagnostic methods.

Conclusions. Gender and age characteristics of vertebral column trauma have a relatively stable pattern specific to each of the examined countries. Numerous socio-economic and behavioral factors influence the frequency of vertebral column trauma, but the significance of these parameters requires further research.

Keywords: *vertebral column trauma; Eastern Europe; epidemiology; age and gender characteristics*

Introduction

Vertebral column fractures (VCF), despite their relatively small proportion in the overall structure of human musculoskeletal injuries, represent a significant medical and social problem [1]. The indirect nature of injury, leading to over 90% of VCF, can be caused by the impact of both high-energy and low-energy traumatic effort [2, 3]. The most severe consequence of VCF

is traumatic damage to the spinal canal structures, resulting in partial or complete neurologic deficit. Even VCF, that are not accompanied by neurologic deficits, often lead to persistent impairments of the functional activity of the injured, significantly affecting both the quality of life and employability and social activity [4].

It has been established that VCF are closely related to progress and a significant change in the lifestyle of the population in the 20th-21st centuries. Thus, if at the beginning of the 20th century the share of VCF was about 0.33% of the total number of all traumatic injuries, then in the 1930s it was 5.0%, in the 1940s and 1950s it was over 6.0%. The increase in the frequency of traffic and industrial injuries, as well as cases of falls from a height, has caused an increase in the number of injured with vertebral column fractures of various degrees and nature [5, 6].

High-energy VCF, most characteristic of road traffic accidents (RTAs), falls from a significant height, or sports injuries, are predominantly observed in young population [7, 8], whereas low-energy traumatic impact, such as, falling from a height of one's own height, is the main cause of VCF in the elderly and senile individuals. Traumatic osteoporotic vertebral fractures account for a significant part of VCF [9]. In the elderly, vertebral fractures may initially present with minimal clinical symptoms, but later persistent pain develops, resulting in decreased physical activity [10, 11]. Moreover, it has been noted that the presence of one osteoporotic fracture of the vertebral column increases the risk of subsequent fractures by more than 5 times [12]. Population studies indicate an increased mortality rate in patients with low-energy osteoporotic VCF, which is statistically significantly correlate with the number of damaged vertebrae [13].

The epidemiology of VCF is incompletely studied. Due to obvious reasons, determining the actual frequency of VCF is challenging. Thus, specific behavioral patterns of the population, the availability of medical care, the principles of accounting and processing of primary medical documentation significantly complicate both the detection and systematization of pathology. Even in countries where national databases on population morbidity exist and are accessible, VCF are often concealed by more severe diagnoses, such as polytrauma.

The epidemiological data of VCF available in the literature, in most cases, are based on monocentric or multicentric studies and refer to the injured in a specific region [14, 15]. These studies primarily account for hospitalized patients, while a portion (in some cases, a significant one) of the injured who receive therapy at the primary healthcare level is not considered. One of the few databases available for analysis providing an insight into the actual scale of the problem under consideration is the Global Burden of Disease, the data from which have been used in this work.

Analysing the epidemiology of a particular disease or injury holds important economic value. Serving as the foundation for health care costs planning, epidemiological indicators also help identify certain age, gender, etc. groups of population at increased risk and develop the most effective preventive measures [16]. Furthermore, the analysis and comparison of data from geographically proximate regions facilitate the determination of social factors influencing the frequency of the pathology under consideration, the verification of which is impossible in a monocentric study [17].

Objective: to conduct a primary analysis of the epidemiological features of vertebral column traumas in the countries of Eastern Europe.

Materials and methods

The UN classification was used to compile the list of countries to be analysed, and only countries territorially located entirely within the European part of the Eurasian continent were considered.

The 30-year period before the 2019 (1990–2019) coronavirus disease pandemic was chosen as the optimal time interval reflecting the state of the problem, since the set of anti-epidemic measures (enforced self-isolation, quarantine, borders and industries closure), introduced since the beginning of 2020, has significantly influenced the injury pattern. Decrease in COVID-19 incidence and normalisation of social activity of the population in 2022 were accompanied by the beginning of active phase of armed aggression of the Russian Federation against Ukraine, which entailed significant migration processes affecting not only Ukraine, but also the whole Eastern Europe (EE), therefore, the collection of statistical data and their informativeness regarding the state of VCF problem is questionable.

To analyse the peculiarities of the epidemiology of VCF, statistical processing of the Global Burden of Disease database containing information on 369 diseases and types of injuries from 204 countries, in open access on the website of the Institute for Health Metrics and Evaluation (https://www.healthdata.org/), which operates on the basis of Washington State University, Seattle, USA. As of 2019, the database is the result of processing more than 280,000 sources of information, including reports of national health care structure agencies and other research institutions, medical records of health care facilities and emergency departments, insurance claims information, surveys, as well as scientific publications on specific aspects of the spread of disease or traumatic injury. Detailed information on the methods of collecting, analysing and statistically processing of primary information is provided in publications by the institute's research groups [18, 19].

The following sampling parameters were used in this study:
• measure:
- incidence - the number of diseases or injuries first reported in a calendar year among the population residing in a specific area;

This article contains some figures that are displayed in color online but in black and white in the print edition

- years lived with disability - this measure reflects the impact of the disease on the quality of life until it ends or leads to death;
- • metric:
- - number;
- • injuries by nature:
- - all fractures;
- - spinal fractures;
- • cause:
- - RTAs (injuries to driver, passenger, pedestrian, etc.);
- - unintentional impact (fall, external mechanical impact, occupational accidents, etc.)
- - intentional impact (suicide attempt, conflicts, terrorism, etc.);
- • location: Republic of Belarus (BY), Republic of Bulgaria (BG), Czech Republic (CZ), Hungary (HU), Republic of Moldova (MD), Republic of Poland (PL), Romania (RO), Slovak Republic (SK), Ukraine (UA);
- • age: age range from 0 to 95 years with 5-year interval (0–4, 5–9, etc.) or age groups;
- • sex: separately for males and females;
- • year: from 1990 to 2019.

Information on population structure in the countries for each year analysed was obtained from the UN Department of Economic and Social Affairs website (https://www.un.org/en/desa). Male and female population databases with five-year age groups, as well as a range of 1 year, were used.

Data on gross national income per capita were obtained from the World Bank website (https://www.worldbank.org).

Statistical analysis

Statistical data processing was performed using R (version 4.2.3) in the RStudio development environment (version 2023.03.0+386). Normalisation of data by sex and age was performed using the PHEindicatormethods package (version 2.0.1), which allows the calculation of directly standardised frequency characteristics of the trait with a confidence interval, using Bayar's method with correction according to the Dobson method [20, 21]. The inverse variance method (Meta package, version 6.5-0) was used to calculate the confidence interval of mean values [22].

Results and discussion
Brief countries characterisation

When assessing VCF as a health and social phenomenon within certain countries of Eastern Europe (EE), it is essential to consider that a large number of economic, social and geographical parameters potentially affect the analysed indicators. Basic indicators of EE countries are provided in **Table. 1.**

The above data show that, despite the objective geographical proximity and the predominance of the Slavic population, the countries under consideration have socio-economic and population peculiarities that should be taken into account in further analysis **(Fig. 1).**

Data of **Fig. 1** show that the widespread perception of a higher incidence of VCF in low-income countries in relation to the region under consideration does not correspond to reality. The dynamics of the indicator is provided in **Fig. 2.**

The analysis of the data revealed that, in general, there was a downward trend in the relative incidence of VCF. This is consistent with literature data. Thus, according to the UNICEF report on the of morbidity and mortality trends in Central and Eastern Europe, the collapse of the Soviet Union in the early 1990s had a negative impact on indicators of economic stability [23]. The crisis of social adaptation, associated with the breakdown of political, social and economic constants, was accompanied by a significant increase in the incidence of cardiovascular diseases, suicide, alcoholism, as well as an increase in crime rates, which indirectly or directly led to an increase in the number of injuries, in particular VCF. The implementation of reforms contributed to the stabilisation of the socio-economic situation, resulting in reduction in the population injury rate.

Significant and sharp growth in the analysed indicator was observed in Moldova in 1992 corresponding to the active phase of the war in Transnistria. That year, the average number of vertebral column trauma was 258.04 (192.24–364.41) per 100,000 population, whereas in 1990 it was 199.90 (155.61–259.01), or 11,508 (8 578–16,175) and 8,962 (6,982–11,637) cases, respectively.

Table 1. Brief overview of Eastern European countries 2009 est.

Location	BY	BG	CZ	HU	PL	MD	RO	SK	UA
Area, thousand km²	207,6	111,0	78,9	93,0	323,8	33,8	238,4	49,0	603,7* (560,3)
Population density, persons per km²	45,4	62,8	135,3	105,0	121,4	78,7	81,3	111,3	69,3
Share of female population, %	69,2	71,6	76,4	73,1	74,1	66,8	71,9	74,3	66,9
Share of urban population, %	75,0	75,0	74,0	72,0	60,0	43,0	54,0	54,0	69,0
Life expectancy, years	74,0	75,0	79,0	76,0	78,0	71,0	76,0	78,0	72,0
GDP per capita, US Dollars	6 837,8	9 878,8	23 664,8	16 786,2	15 700	4 405	12 959	19 381,6	3 661,5

Note. * including and excluding (in brackets) temporarily occupied territories.
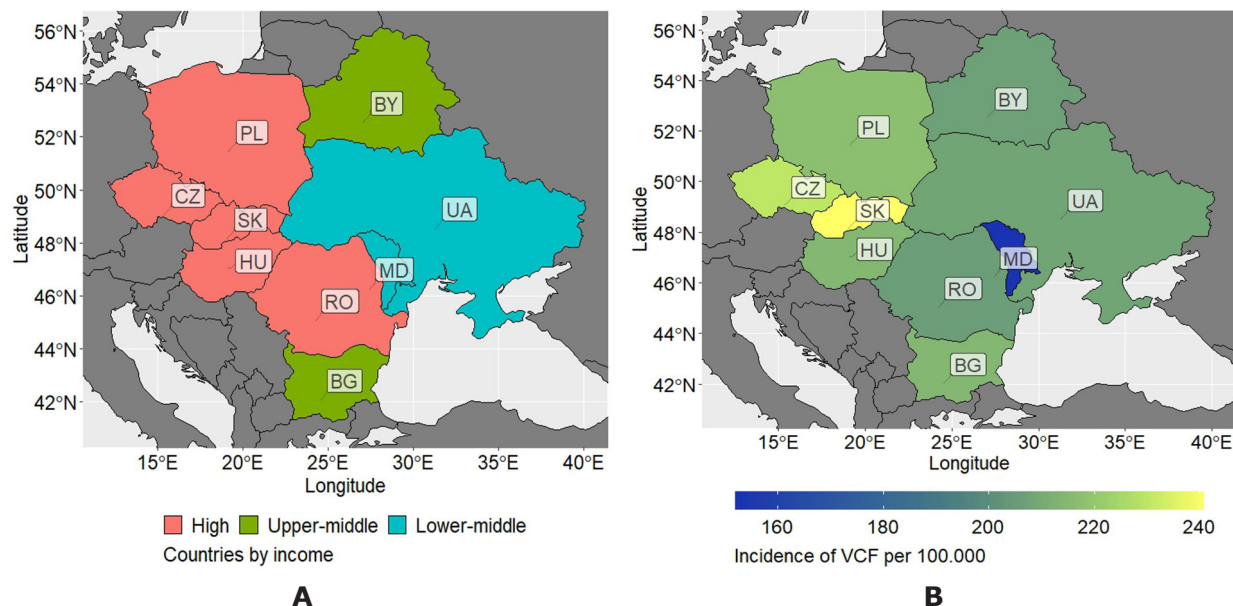
Fig. 1. The income level of the population of Eastern European countries according to the World Bank classification as of 2019 (A) and the relative incidence of cases of VCF in these countries in 2019 (B)
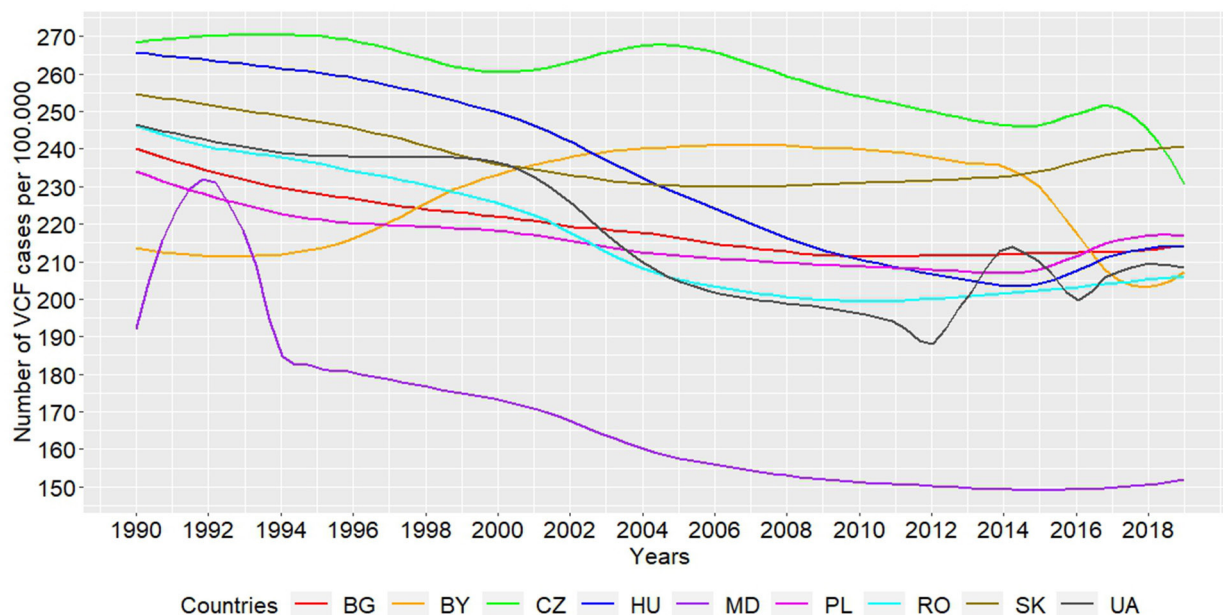
Fig. 2. Comparative characteristics of the relative incidence of VCF in Eastern European countries in 1990–2019 (the indicator is standardized by sex and age)

A similar situation was observed in Ukraine. Since 1990, a steady downward trend in the incidence of vertebral column injuries has been recorded reaching a minimum in 2012. Thus, in 1990, the average incidence, standardised by sex and age, was 246.44 (184.17–334.76) per 100,000 population, or 130,155 (97,205–176,251) cases, in 2012 – 191.38 (144.93–257.35) per 100,000, or 91,021 (68,721–122,220) cases, that is, an average decrease by 30%. In 2013, the Revolution of Dignity and the invasion of the Russian Federation in Donbas in 2014 caused a significant increase in the number of injuries among the population, in particular

vertebral column injuries. In 2014, compared to 2012, an average of 13.1 thousand more VCF (228.75 (174.6–304.18) per 100 thousand population) were registered. Thereafter, the indicator varies, but does not decrease below 200 cases per 100,000 per year.

To simplify the analysis and eliminate annual fluctuations of the indicator, the study period was divided into groups with a 5-year interval *(Table 2).*

The above data demonstrate that the downward trend in the number of traumatic injuries is observed in almost all countries under consideration, except Belarus (indicators in 1990–1994 and 2015–2019 are almost the

Table 2. Incidence rates of vertebral column fractures in Eastern European countries per 100,000 population per year

Country	Years					
	1990–1994	1995–1999	2000–2004	2005–2009	2010–2014	2015–2019
BG	234,46 (225,2–243,73)	225,38 (216,29–234,48)	219,8 (210,58–229,02)	213,79 (204,4–223,18)	211,53 (202,02–221,04)	212,92 (203,43–222,41)
BY	212,17 (203,29–221,05)	220,78 (211,48–230,09)	237,1 (227,23–246,97)	240,78 (230,74–250,82)	237,55 (227,45–247,65)	212,37 (202,76–221,98)
CZ	269,73 (259,31–280,15)	266,22 (255,93–276,52)	263,53 (253,5–273,56)	262,34 (252,28–272,41)	250,15 (240,02–260,27)	244,32 (234,10–254,54)
HU	263,63 (252,99–274,27)	256,67 (246,05–267,29)	241,25 (230,8–251,7)	220,21 (210,21–230,21)	206,98 (197,29–216,67)	210,02 (200,16–219,88)
MD	202,65 (194,31–211)	178,71 (171,02–186,40)	167,02 (159,52–174,52)	154,56 (147,35–161,77)	150,27 (143,04–157,5)	150,08 (142,53–157,64)
PL	227,95 (218,46–237,45)	219,9 (210,51–229,29)	215,47 (205,92–225,01)	210,29 (200,74–219,84)	207,87 (198,33–217,41)	213,55 (203,83–223,26)
RO	241,4 (231,56–251,25)	232,18 (222,54–241,82)	217,16 (207,69–226,63)	202,16 (193,03–211,29)	200,26 (191,13–209,39)	204,11 (194,76–213,46)
SK	251,68 (241,51–261,86)	243,06 (233,14–252,97)	233,22 (223,54–242,89)	230,11 (220,39–239,84)	231,69 (221,71–241,67)	237,85 (227,46–248,24)
UA	242,53 (231,93–253,14)	237,91 (227,28–248,53)	223,91 (213,54–234,28)	200,64 (191,11–210,18)	198,57 (189,24–207,91)	205,36 (196,13–214,58)

Note. Mean values of sex- and age-standardised frequencies. The 95% confidence interval is given in brackets*.*

same). The maximum decrease within the analysed time ranges was observed in Moldova (by 25.9%) and Hungary (by 20.3%), the minimum – in Slovakia (by 5.5%) and Poland (by 6.3%). In the last 5 years before the pandemic, the minimum incidence of vertebral column fractures was recorded in Moldova and Romania, the maximum in Slovakia, the Czech Republic and Poland. We did not find an explanation in the available literature. The population density may probably play a leading role in this, since the maximum values of this parameter in the EE are typical for Slovakia, the Czech Republic, and Poland, while Moldova and Romania are characterized by a relatively small share of the urban population compared to other countries leading to a more evenly distributed population.

The results we obtained estimating the frequency of vertebral column fractures in the overall structure of traumatic injuries of the musculoskeletal system are consistent with the literature data - 3.5–4.5%. In contrast to the prevalence of VCF injuries in the EE countries, the share of these injuries tended to increase slightly *(Fig. 3)*, with the exception of Hungary (average values decreased from 4.0% in 1990–1994 to 3.94% in 2015–2019). The maximum increase of this indicator was recorded in Poland (from 3.8% in 1990–1994 to 4.0% in 2015–2019). In addition, a growth in the share of vertebral column fractures was observed in Belarus, Slovakia and Romania.

The mentioned armed conflicts in Moldova and Ukraine were accompanied by a sharp increase in the share of vertebral column fractures in the overall structure of musculoskeletal system injuries. Thus, if

in 1990 in Moldova this indicator was 3.82%, in 1992 it increased to 4.37%. In Ukraine, the figures for 2012 and 2014 were 4.12 and 4.46%, respectively. In 2019, the highest values were registered in Belarus and Ukraine (4.13 and 4.12%, respectively), the lowest – in Bulgaria and the Czech Republic (3.87 and 3.91%).

The data analysis revealed significant variability in the gender structure of the injured, to some extent correlates with the average income per capita in EE countries. Thus, the smallest differences in the frequency of injuries between men and women were recorded in Hungary – with their ratio averaging 5:4. A slight downward trend in the share of male victims was found, from 56.88% in 1990–1994 to 55.41% in 2015–2019 *(Fig. 4)*. Similar figures (average male-to-female ratio of 3:2) were recorded in the Czech Republic, but unlike Hungary, starting from the 1990s, the share of males among vertebral column injuries patients tended to increase until 2006 (60.77%) followed by a gradual decrease until 2019 (58.5%). The highest proportion of men (male to female ratio of about 7:3) at the beginning of the analysed period, was registered in Romania (70.32%) and Bulgaria (69.53%), in 2015–2019 this indicator decreased to 66.46 and 65.97% respectively. In Slovakia, Belarus, and Poland, throughout the study period, the ratio of men to women was relatively stable (2:1 on average), and the progressive increase in the share of women was insignificant (1.5%). It is noteworthy that the curves for the Czech Republic and Slovakia are almost identical, with Slovakia having a 10% higher figure. This correlation can be explained both by territorial proximity and similar behavioral

patterns. In Moldova in 1992, the share of men in the structure of vertebral column injury victims increased significantly (71.69%), which is probably related to the military conflict. For comparison: in 1990, the share of men did not exceed 64.95%. In Ukraine, a significant change in the gender structure in 2014 and later compared to previous years was not recorded against the background of an increase in the total number of injuries *(*see *Fig. 2*). This can be explained by a significantly higher traumatization among civilians of both sexes compared to the war in Transnistria, as well as active female involvement in armed formations to counter armed aggression.

Analysis of the causes of vertebral column injuries in the population of EE countries *(Fig. 5)* revealed similar patterns. Thus, the frequency of vertebral column injuries caused by RTAs for the entire analysed period was about 16% of the total number of vertebral column injuries, intentional injuries - 3%, unintentional injuries - 81%. The maximum share of the injured with vertebral column fractures as a result of RTAs was registered in Belarus in 1990–1994 (21.7%), the minimum - in Hungary in 2015–2019 (11.3%). In general, in most countries, a decrease in the role of RTAs as a cause of vertebral column fractures was noted *(Table 3)*.
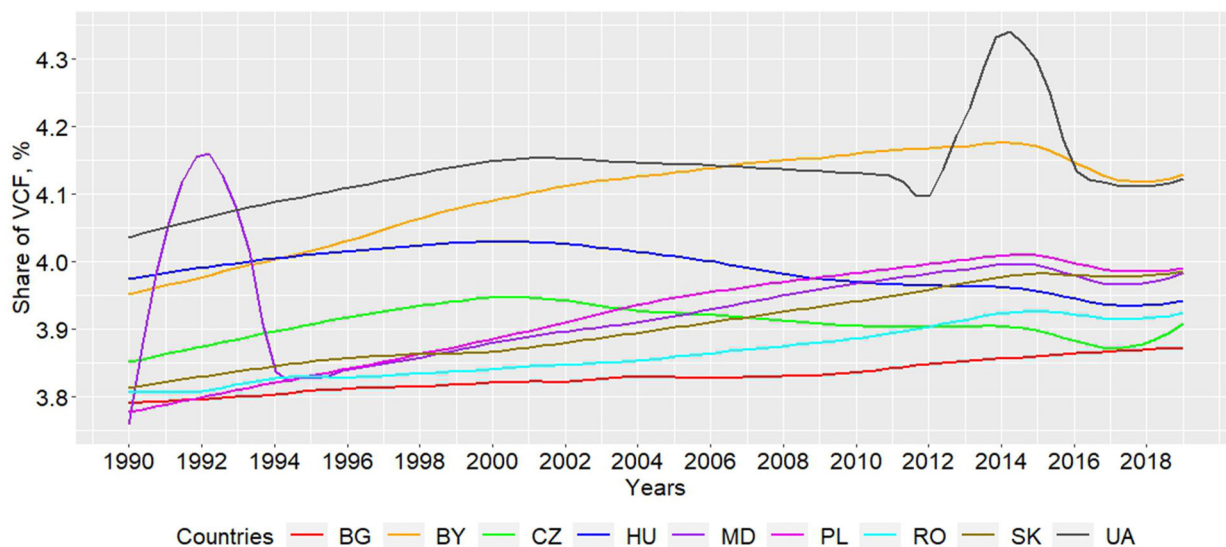

Fig. 3. Dynamics of the share of vertebral column injuries in the overall structure of musculoskeletal system injuries in Eastern European countries in 1990–2019 (the indicator is standardized by sex and age)
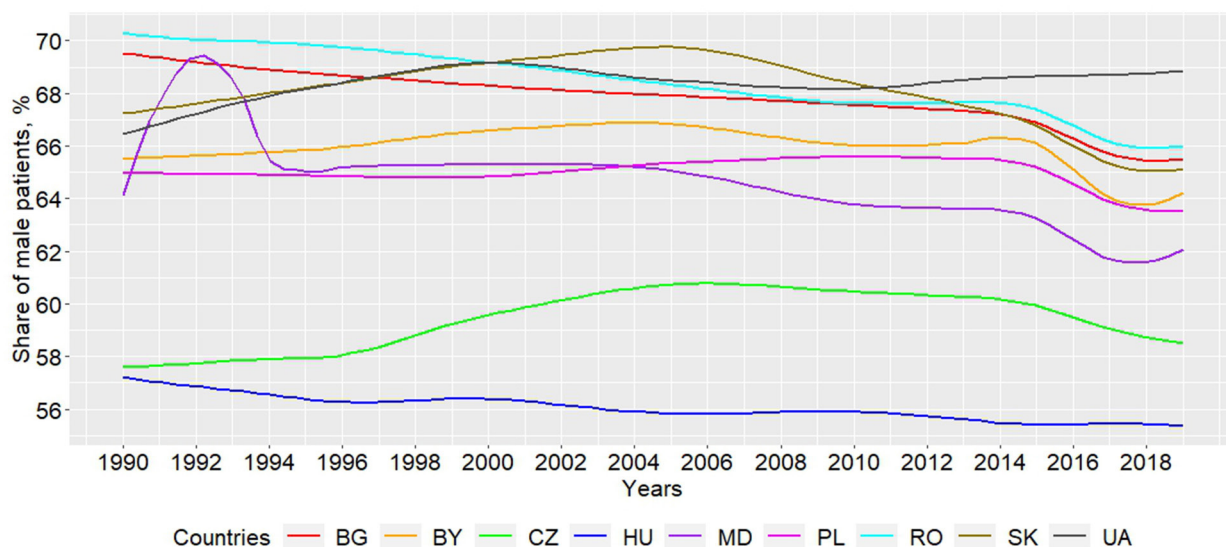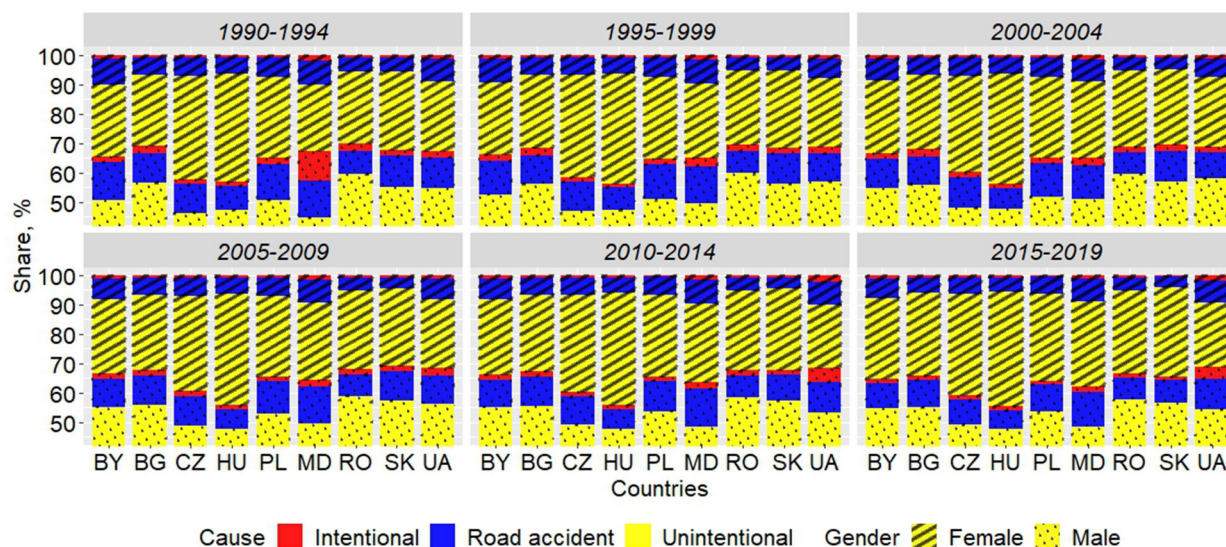

Fig. 4. Dynamics of the share of male patients among the injured with VCF in Eastern European countries in 1990–2019 (the indicator is standardized by age)

Fig. 5. Frequency of causes of vertebral column injuries in Eastern European countries in 1990–2019 (indicator standardized by age)

Table 3. The share of victims with vertebral column fractures sustained as a result of road traffic accidents from the total number of patients with vertebral column fractures in the countries of Eastern Europe, %

Country	Years					
	1990–1994	**1995–1999**	**2000–2004**	**2005–2009**	**2010–2014**	**2015–2019**
BG	15,62 (62,68)	15,5 (62,19)	15,53 (61,94)	16,04 (62,59)	16,11 (63,25)	14,82 (62,69)
BY	21,72 (59,25)	19,73 (58,84)	17,48 (57,78)	16,77 (57,07)	16,1 (56,58)	15,07 (55,01)
CZ	16,19 (61,03)	16,05 (61,62)	16,81 (61,93)	16,66 (61,64)	15,58 (60,78)	14,12 (59,63)
HU	13,89 (58,6)	13,24 (58,08)	12,73 (55,77)	12,56 (55,1)	12,2 (55,74)	11,35 (55,59)
MD	20,67 (61,49)	20,82 (60,95)	19,27 (60,3)	20,68 (60,98)	21,25 (61,46)	19,5 (61,49)
PL	19,1 (63,98)	18,78 (63,31)	18,27 (62,56)	17,61 (62,63)	16,49 (62,64)	15,11 (61,68)
RO	12,78 (61,89)	12,28 (61,32)	11,89 (60,64)	11,88 (60,69)	12,31 (61,66)	12,07 (61,23)
SK	15,51 (68,86)	15,07 (70,07)	14,76 (71,88)	14,22 (71,94)	12,82 (69,97)	11,36 (67,69)
UA	18,03 (57,07)	16,25 (58,28)	15,1 (58,87)	16,97 (58,22)	18,06 (57,92)	18,05 (58,39)

Note. The proportion of men is given in brackets.

In Belarus, by the end of the analysed period, the incidence of vertebral column injuries as a result of road traffic accidents decreased by almost a quarter (about 15%). In addition, a decrease in this indicator was registered in Poland (from 19.1% in 1990–1994 to 15.1% in 2015–2019) and Slovakia (from 15.5 to 11.3%). In Bulgaria, the Czech Republic, Hungary, Moldova and Romania, the role of RTAs as a cause of VCF decreased slightly. Ukraine was the only one of the EE countries where the rate in 2010–2014 and 2015–2019 corresponded to that in 1990–1994 (about 18%). The period from 1990 to 2004 was characterized by a decrease in the share of victims of RTAs, but since 2005, an increase has been recorded, with a maximum in 2019 - 16,200 cases, or about 36.9 episodes per 100,000 population. This value is the highest among the EE countries, and the lowest registered in Romania with 23.6 cases per 100,000 population.

Analysis of the gender structure of individuals injured in RTAs did not reveal any significant dynamics. Men predominated among the injured, but their share did not exceed 62% in most countries, except for Slovakia, where this indicator was the highest in 2000–2009 - 72%.

The share of VCF resulting from intentional violent acts was relatively small. Excluding episodes of armed conflicts, the average rate in EE countries from 1990 to 2019 was 2.75% of all vertebral column fractures. There was a general trend of a decrease in the share of these injuries during the study period. In 1990, the lowest rates were observed in Hungary, the Czech Republic, and Slovakia (2.21, 2.39, and 2.50%, respectively), while the highest rates were recorded in Romania and Moldova (3.48% and 4.29%, respectively). The average indicator in EE countries is 3.06%. In 2019, the minimum share was registered in Poland, Hungary and Slovakia (1.83, 1.86 and 1.9%), the maximum - in Moldova (3.05%). The average indicator in the EE countries, except for Ukraine, was 2.2%. A correlation was found between the frequency of VCF resulting from intentional violent acts and the level of the population's income. For example, in Poland, against the background of significant economic growth, the analysed indicator decreased from 1990 to 2019 by 0.83%. Armed conflicts play an important role in the occurrence of VCF. Thus, in 1991 and 1992 in Moldova, the incidence of VCF, resulting from violent actions, was 28.67 and 11.63%, respectively. In Ukraine, a peak was registered in 2014 (19.36%) and a gradual decline from 9.9% in 2015 to 4.28% in 2019, without reaching the value of the early 1990s - 3.27% in average for the first five-year period under review.

The share of men who sustained VCF resulting from violent acts in EE countries, even outside the period of military conflicts, is expectedly higher than the average rates of injuries from all causes. Thus, the average value for the period in the EE is 70.32%. In the early 1990s, the maximum rates were recorded in Slovakia, Bulgaria and Romania (respectively 74.80, 79.64 and 80.17%), the minimum - in Belarus and Ukraine (60.76 and 62.39%), in 2019 – in Slovakia and Bulgaria (72.11 and 73.15%) and Moldova and Belarus (61.31 and 62.98%), respectively. In general, the gender structure of individuals who sustained VCF as a result of violent acts has changed insignificantly in the EE countries: the share of men in 1990 was 70.61%, in 2019 - 68.28%. In Moldova, the rate peaked at 88.3% in 1992-1993, 20.0% higher than in the pre-war and post-war years. In Ukraine, the share of men remained stable both before and during the armed aggression of the Russian Federation.

Unintentional injuries prevailed in the structure of VCF in EE countries (about 81.12%). This indicator was 79.42%, in the early 1990s, in 2019 it was 83.26% with a tendency to increase, which is natural against the background of a decrease in the share of other causes of injury. The gender structure of the injured generally corresponded to that of other VCF. In 2019, the lowest share of men was registered in Hungary and the Czech Republic (55.11 and 58.06%), and the highest in Romania and Ukraine (66.67 and 71.3%).

The analysis of the age structure of the injured with VCF, as well as the dynamics of its changes, are presented in *Fig. 6*.

The data presented indicate that each of the countries under study exhibited a time-stable pattern. Thus, neonatal vertebral column injuries (age up to 28 days) is extremely rare (0.034% of all vertebral column injuries cases). The indicator is relatively stable during the study period, with the exception of Bulgaria, where

maximum values of 0.06% were registered from 2005 to 2014. The incidence of injuries in children under 1 year of age in all EE countries was insignificant. There was a further decreasing trend in the share of this age category in the overall structure of victims: in 1990–1994, the average value for all countries was 0.486%, in 2014–2019 - 0.39%. In 2005–2014, the maximum indicators were recorded in Bulgaria (0.6%), as well as in Moldova (0.52%). The share of patients aged 1 to 9 years in EE countries was about 5.676%. The dynamics of this indicator were similar in all countries, with a maximum share in the early 1990s (on average about 5.96%), a decrease in 2000–2009 (to 4.99%) and a rise until 2019 (to 5.9%). At the end of the analysed period, the minimum indicators of the share of children aged 1–9 years in the structure of patients with vertebral column fractures were recorded in Ukraine (4.29%), the maximum in the Czech Republic (7.46%). The share of adolescents (10–19 years) decreased from 15.98% in the early 1990s to 11.09% in 2019. The dynamics of this indicator were similar in all countries. In 2019, the minimum indicators were registered in Belarus and Ukraine (8.88 and 9.92%, respectively), the maximum in Bulgaria and Romania (12.09 and 13.12%). Patients aged 20–44 made up the largest group of victims of VCF. The general trend was a slight decrease in their share, probably due to the general aging of the population. In the EE countries, in 1990–1994, about 45.8% of vertebral column injuries occurred in persons aged 20–44 years, in 2015–2019, – 41.98%, with the exception of Ukraine, where there was an increase to 53.67% for obvious reasons. The minimum indicators were registered in Hungary and the Czech Republic (31.37 and 35.77%, respectively). Analysis of age groups older than 45 revealed a general tendency towards a slight increase in their share in the total structure of victims. Thus, patients aged 45–59 years registered 15.97% in 1990–1994, in 2014–2019 - 20.38%, patients aged 60–74 years – 9.5 and 13.16%, patients aged >75 years – 5.12 and 7.0%. Significant differences between countries in the incidence of injuries in the elderly population are stable and due to the specifics of the gender-sex composition, the influence of which is discussed below.

The analysis of the incidence of VCF within selected age groups per 100,000 population showed a more even distribution, which is caused by the specificity of the population pyramids of the countries under consideration. Thus, in Ukraine in 2014–2019, the incidence of VCF in children under 1 year of age was only 0.28% of the total number of registered vertebral column injuries, or 64.15 cases per 100,000 *(Fig. 7)*. To facilitate visualisation of the dynamics, marginal time periods are given: 1990–1994 and 2015–2019.

An overall decrease in the frequency of VCF in all EE countries was found, which is consistent with the indicators mentioned earlier *(see *Fig. 2*)*. In some cases, the decline in the indicator in age groups is higher than would be expected given the significance for the total population of individual countries. In addition, a comparison of the periods 1990–1994 and 2015–2019 revealed a certain levelling of differences between age groups. The frequency of VCF among the population of EE countries has the following features:

• the age category "under 1 year" in 1990–1994 was characterised by the average frequency of VCF in the EE countries - 101.54 (89.47–113.6) cases per 100,000 population of the corresponding age, and it decreased until 2015–2019 up to 86.13 (71.93–100.33) cases per 100,000 population of the corresponding age. In most countries, the dynamics of the decrease of this indicator was quite uniform, except Bulgaria, where in 2000–2004, a rise to 138.15 cases per 100,000 population of the corresponding age was registered, with a further decrease to 123.02 cases per 100,000 population of the relevant age in 2014–2019, although this value is the maximum among EE countries. In addition, an increase in the injury rate by 11.32% from 2010–2014 to 2015–2019 was recorded in the Czech Republic (107.39 cases per 100,000 population of the corresponding age). The minimum value was registered in Ukraine - 64.15 cases per 100,000 population of the relevant age;

• a slightly different picture was observed when analysing the age group "1–9 years". In Bulgaria, the Czech Republic, Hungary, Poland and Romania, an increase in the level of injury was registered. In 2015–2019, the maximum value was recorded in the Czech Republic (189.8 cases per 100,000 population of the corresponding age), the minimum value was recorded in Ukraine (90.66 cases per 100,000 population of the corresponding age compared to the average rate in the EE countries of 133, 2 (107.05–159.34) cases per 100,000 population of the corresponding age), in Belarus, Moldova and Romania - a decrease in the injury rate;

• the adolescent period (10–19 years) was naturally characterised by an increased rate of both general trauma and VCF, compared to earlier age groups, in all EE countries *(*see ***Fig. 7)***. Thus, at the beginning of the analysed period (1990–1994), the average incidence of VCF in EE countries was 246.21 (225.77–266.66) cases per 100,000 population. The maximum values were registered in the Czech Republic (269.41 cases per 100,000 population of the corresponding age), Romania (278.51 cases per 100,000 population of the

corresponding age) and Bulgaria (285.7 cases per 100,000 population of the corresponding age), the minimum values were in Belarus and Moldova. In Poland, throughout the entire study period, the prevalence of injuries was 232 cases per 100,000 population of the corresponding age without any significant dynamics. In 2015–2019, the average indicator in the EE countries was 239.13 (211.7–266.56) cases per 100,000 population of the corresponding age;

• the most active and able-bodied population (20–44 years old) in a number of EE countries was characterized by the highest rates of VCF among age groups (Bulgaria, Belarus, Moldova, Romania, Ukraine in 1990–1994, Belarus, Moldova and Ukraine in 2015–2019). In 1990–1994, the average indicator in the EE countries was 306.23 (286.37–326.09) cases per 100,000 population of the corresponding age. The highest values were registered in Ukraine – 360.15 cases per 100,000 people of the corresponding age. Subsequently, a gradual decrease in the indicator was observed in all countries. In Belarus, the dynamics differed: in 1990–1994, the number of cases per 100,000 population of the corresponding age was 304.09 cases, in 2005–2009 – 350.65 cases per 100,000 population of the corresponding age, subsequent changes corresponded to those in other countries of EE. In 2015–2019, the highest values of the frequency of VCF were recorded in Ukraine - 301.61 cases per 100,000 population of the corresponding age, while the average indicator in the EE countries was 250.58 (225.73–275.43) cases per 100,000 population of the corresponding age;

• the average incidence of VCF among the population aged 45–59 years in 1990–1994 was 235.05 (213.67–256.43) cases per 100,000 population of the corresponding age with a slight decrease in 2015–2019 to 214, 29 (195.26–233.32) cases per 100,000 population of the corresponding age. The studied indicator was characterized by a wide range. Thus, in 1990–1994, the maximum values were registered in Ukraine and Hungary (264.34 and 278.23 cases per 100,000 population of the corresponding age), the minimum values were registered
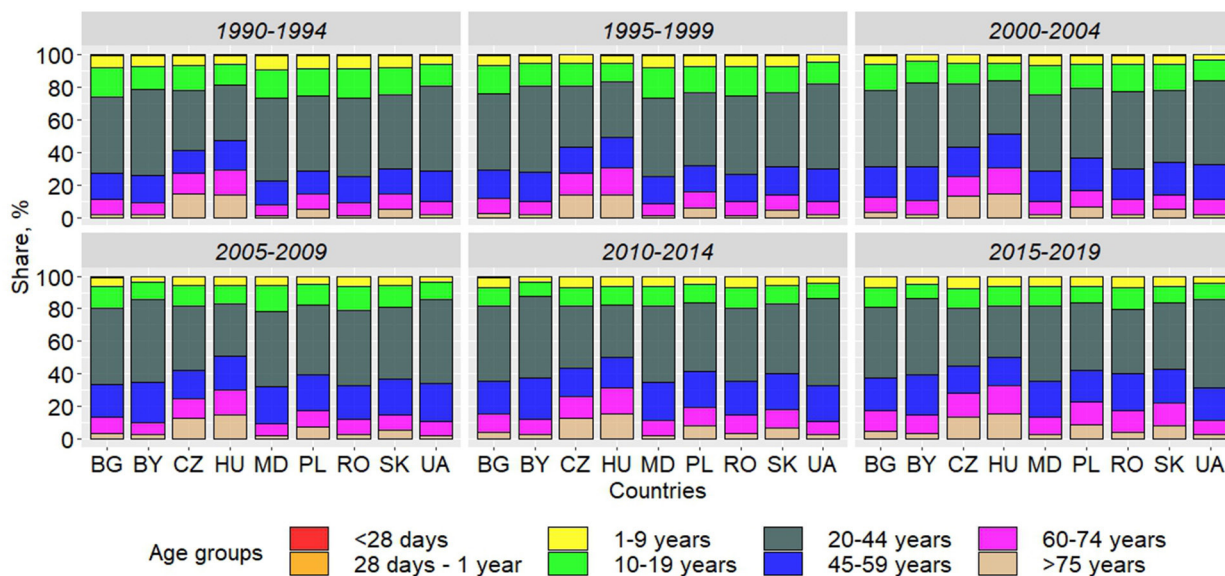

Fig. 6. Frequency of vertebral column fractures in different age groups of the population of Eastern European countries in 1990–2019

Fig. 7. Frequency of vertebral column injuries (per 100,000 population) in different age groups of the population of Eastern European countries in 1990–1994 and 2015–2019.

in Bulgaria and Moldova (197.47 and 209.32 cases per 100 thousand population of the corresponding age). In 2015–2019, Bulgaria and Hungary recorded the lowest rates - 187.7 and 191.68 cases per 100,000 population of the corresponding age, the highest were in Belarus and Slovakia (252.09 and 254.01 cases per 100,000 population respectively);

• age groups "60–74 years" and "≥75 years" showed similar dynamics. These age groups in the Czech Republic and Hungary were characterized by maximum values with a decreasing trend, in Poland and Slovakia – by moderate frequency with a slight increase in dynamics, in Ukraine, Moldova, Bulgaria, Romania and Belarus – by minimum values compared to other age groups, and showed minimal changes during the analysed period.

Data on changes in the frequency of vertebral column fractures in age groups from 1990–1994 to 2015–2019 are shown in ***Table. 4***.

The analysis conducted revealed that in upper- and lower- middle-income countries according to the World Bank classification, the highest incidence of VCF was found among the most working-age population (20–44 years), whereas in countries with a high level of gross domestic product (GDP) per capita it was found in the age group of 60–74 and ≥75 years. It is controversial to claim that high indicators, e.g. 836.65 cases per 100,000 population of corresponding age among persons aged ≥75 years in the Czech Republic in 1990-1994, are indeed associated with increased injury rates. The explanation for this phenomenon is likely the high level of health care, which allows for the detection and registration of even minor traumatic changes, that often occur in the elderly and senile individuals under the influence of a traumatic force of insignificant intensity. It is in these countries that a decrease in the frequency of the dynamics has been recorded due to the implementation of measures to combat osteoporosis and trauma among individuals of the specified age categories. In countries

with upper-middle-income, an increase in the incidence of VCF among persons aged ≥75 years was noted, which is likely to be related to the optimisation of methods of providing medical care with the increase in the well-being of the population.

One of the basic criteria that characterises the socio-economic significance of VCF is the number of years lived with disability, which determines both the actual loss of working capacity and the need for budget expenditures to support the injured with disabilities. Given that the analysed indicator is determined only by VCF, and the role of spinal cord injury, which often accompanies vertebral trauma, is not taken into account, the value of the indicator "years lived with disability" is closely correlated with the overall frequency of VCF. ***Table 5*** shows the average indicators without population size consideration, which more effectively demonstrates the significance of the analysed issue.

The above data indicate a high socio-economic significance of the considered pathology in all EE countries. In Ukraine, a significant decrease in the "years lived with disability" indicator was registered compared to other countries, which can be attributed to a reduction in both the frequency of injuries and the number of population. In EE countries with upper income levels per capita, this indicator remains stable, in a number of cases its growth has been recorded, which is likely due to the improvement of the quality of medical care, especially diagnostics, especially in the elderly and senile individuals, and an increase in life expectancy of patients who have experienced vertebral column injuries.

Consequently, gender and age-specific patterns of vertebral column injury have a stable pattern specific to each of the countries considered. As an example ***Fig. 8*** demonstrates charts of the actual frequency of VCF depending on the causes of injury among individuals of different age groups of male and female gender in 1990 and 2019 in Ukraine and Poland.

Table 4. Change in the incidence (%) of vertebral column fractures (per 100,000 population) in different age groups of the Eastern European population from 1990–1994 to 2015–2019

Country	Age, years						
	<1	1–9	10–19	20–44	45–59	60–74	≥75
BG	↓ 4,08	↑ 0,96	↓ 9,41	↓ 20,23	↓ 5,21	↓ 3,30	↑ 21,81
BY	↓ 26,15	↓ 4,59	↓ 7,57	↓ 5,78	↑ 10,73	↑ 21,72	↑ 18,95
CZ	↓ 1,12	↑ 21,09	↑ 11,68	↓ 15,20	↓ 10,97	↓ 38,55	↓ 89,58
HU	↓ 33,81	↑ 9,95	↑ 6,88	↓ 40,10	↓ 45,15	↓ 48,67	↓ 74,01
MD	↓ 10,13	↓ 19,36	↓ 15,38	↓ 31,41	↓ 6,43	↑ 10,62	↑ 21,44
PL	↓ 33,13	↑ 0,47	↓ 0,3	↓ 15,94	↑ 5,32	↑ 1,81	↓ 21,93
RO	↓ 13,03	↓ 10,02	↓ 15,3	↓ 44,46	↓ 9,93	↑ 7,83	↑ 15,39
SK	↓ 11,90	↑ 5,95	↑ 3,11	↓ 17,37	↓ 3,19	↓ 1,54	↓ 7,27
UA	↓ 43,71	↓ 21,26	↓ 8,46	↓ 19,41	↓ 32,37	↓ 20,37	↓ 21,70

Table 5. Total number of years lived with disability in Eastern European countries in different periods

Country	Years					
	1990–1994	1995–1999	2000–2004	2005–2009	2010–2014	2015–2019
BG	1045,8 (1017,0–1074,7)	984,5 (957,0–1012,1)	948,3 (921,3–975,3)	920,8 (894,7–947,0)	897,0 (871,5–922,4)	887,8 (862,8–912,8)
BY	1238,2 (1207,2–1269,3)	1319,6 (1287,8–1351,5)	1430,6 (1397,5–1463,6)	1461,7 (1428,8–1494,5)	1454,1 (1421,3–1487,0)	1300,6 (1269,9–1331,3)
CZ	1719,9 (1684,7–1755,0)	1750,3 (1714,6–1786,0)	1745,6 (1710,7–1780,5)	1742,3 (1707,1–1777,5)	1706,6 (1672,1–1741,1)	1710,0 (1675,7–1744,3)
HU	1794,1 (1758,6–1829,6)	1793,7 (1758,4–1828,9)	1704,2 (1669,7–1738,8)	1548,4 (1515,1–1581,8)	1451,6 (1419,7–1483,5)	1457,7 (1425,4–1490,1)
MD	452,0 (432,8–471,1)	409,0 (391,0–427,0)	382,5 (365,3–399,7)	357,8 (341,4–374,2)	352,6 (336,6–368,5)	346,9 (330,9–363,0)
PL	4686,0 (4625,5–4746,6)	4728,9 (4668,1–4789,8)	4867,6 (4807,5–4927,7)	4997,3 (4937,3–5057,2)	5162,9 (5102,6–5223,1)	5451,9 (5390,9–5512,8)
RO	2828,7 (2780,5–2876,9)	2742,3 (2695,3–2789,4)	2584,7 (2539,1–2630,3)	2402,4 (2359,0–2445,9)	2386,3 (2343,9–2428,6)	2414,5 (2372,7–2456,4)
SK	710,7 (686,8–734,6)	707,7 (684,1–731,4)	700,0 (676,4–723,7)	716,9 (693,3–740,4)	755,4 (731,7–779,0)	812,4 (788,2–836,7)
UA	7270,6 (7196,5–7344,6)	7096,7 (7023,5–7169,9)	6694,8 (6623,9–6765,6)	5939,7 (5873,8–6005,6)	5683,6 (5619,8–5747,3)	5737,3 (5674,7–5799,9)

Note. The 95% confidence interval is given in brackets.
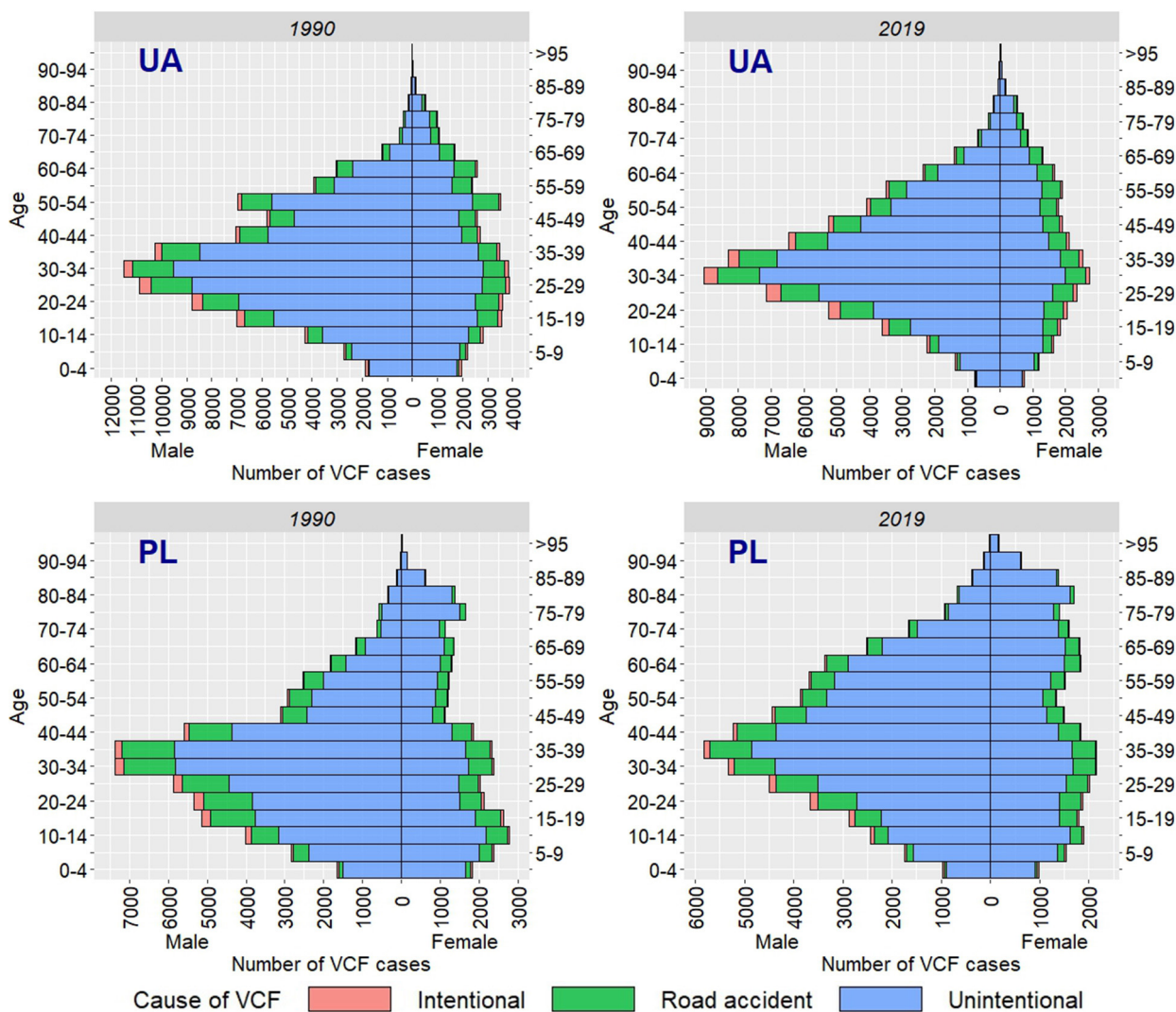
Fig. 8. Distribution of vertebral column fractures (actual number of cases) in Ukraine and Poland depending on sex, age and cause in 1990 and 2019.

It has been established that many socio-economic and behavioral features of the population have a certain influence on the epidemiology of VCF. The significance of some of them (population income level, average age, population size and density, share of urban residents) is highlighted in this article, but determining the degree of influence of each of the factors on the frequency indicators of VCF requires a more detailed statistical analysis.

Conclusions

The analysis made it possible to identify the peculiarities of the epidemiology of VCF in the EE countries:

1) contrary to common belief, the relative incidence of VCF is higher in countries with a higher level of GDP;

2) during the analysed period, a downward trend in the relative frequency of VCF was registered in all EE countries;

3) armed conflicts in Moldova (in 1992) and Ukraine (since 2014) are characterised by a statistically significant increase in VCF incidence;

4) in the overall structure of traumatic injuries of the musculoskeletal system, the share of VCF in the EE countries accounts for 3.5–4.5%, and this indicator is progressively increasing;

5) the share of men among VCF individuals is relatively stable and specific for each of the countries under consideration. Unlike the war in Transnistria, the armed conflict in the east of Ukraine was not accompanied by a significant change in the gender structure of patients with VCF, which suggests a large share of the civilian population among the injured;

6) analysis of the causes of vertebral column fractures revealed that on average in the EE countries the incidence of unintentional injuries is about 81%, road traffic accidents - 16%, intentional injuries - about 3%, while the share of the latter two is gradually decreasing;

7) in countries with a high level of GDP, a significantly higher frequency of traumatization of the elderly and senile population has been recorded, which is probably related to more effective diagnostic methods;

8) sex and age characteristics of vertebral column fractures have a fairly stable pattern specific to each

of the considered countries. A large number of socio-economic and behavioral features of the population affect the incidence of VCF, but the significance of these parameters requires further research.

Disclosure

Conflict of interest

The authors declare no conflict of interest.

Ethical standards

This article does not contain any studies involving humans or animals.

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References

1. Oner C, Rajasekaran S, Chapman JR, Fehlings MG, Vaccaro AR, Schroeder GD, Sadiqi S, Harrop J. Spine Trauma-What Are the Current Controversies? J Orthop Trauma. 2017 Sep;31 Suppl 4:S1-S6. doi: 10.1097/BOT.0000000000000950

2. Martin BW, Dykes E, Lecky FE. Patterns and risks in spinal trauma. Arch Dis Child. 2004 Sep;89(9):860-5. doi: 10.1136/adc.2003.029223

3. Láinez Ramos-Bossini AJ, Ruiz Santiago F, Moraleda Cabrera B, López Zúñiga D, Ariza Sánchez A. Imaging of low-energy vertebral fractures. Radiologia (Engl Ed). 2023 May-Jun;65(3):239-250. doi: 10.1016/j.rxeng.2023.01.006

4. Prior JA, Crawford-Manning F, Whittle R, Abdul-Sultan A, Chew-Graham CA, Muller S, Shepherd TA, Sumathipala A, Mallen CD, Paskins Z. Vertebral fracture as a risk factor for self-harm: a retrospective cohort study. BMC Musculoskelet Disord. 2021 Sep 4;22(1):757. doi: 10.1186/s12891-021-04631-9

5. Hu R, Mustard CA, Burns C. Epidemiology of incident spinal fracture in a complete population. Spine (Phila Pa 1976). 1996 Feb 15;21(4):492-9. doi: 10.1097/00007632-199602150-00016

6. Leucht P, Fischer K, Muhr G, Mueller EJ. Epidemiology of traumatic spine fractures. Injury. 2009 Feb;40(2):166-72. doi: 10.1016/j.injury.2008.06.040

7. Saul D, Dresing K. Epidemiology of vertebral fractures in pediatric and adolescent patients. Pediatr Rep. 2018 Mar 29;10(1):7232. doi: 10.4081/pr.2018.7232

8. Axibal DP, Mitchell JJ, Mayo MH, Chahla J, Dean CS, Palmer CE, Campbell K, Vidal AF, Rhodes JT. Epidemiology of Anterior Tibial Spine Fractures in Young Patients: A Retrospective Cohort Study of 122 Cases. J Pediatr Orthop. 2019 Feb;39(2):e87-e90. doi: 10.1097/BPO.0000000000001080

9. Schousboe JT. Vertebral Fracture Identification as Part of a Comprehensive Risk Assessment in Patients with Osteoporosis. Curr Osteoporos Rep. 2018 Oct;16(5):573-583. doi: 10.1007/s11914-018-0472-6

10. Nevitt MC, Ettinger B, Black DM, Stone K, Jamal SA, Ensrud K, Segal M, Genant HK, Cummings SR. The association of radiographically detected vertebral fractures with back pain and function: a prospective study. Ann Intern Med. 1998 May 15;128(10):793-800. doi: 10.7326/0003-4819-128-10-199805150-00001

11. Hallberg I, Bachrach-Lindström M, Hammerby S, Toss G, Ek AC. Health-related quality of life after vertebral or hip fracture: a seven-year follow-up study. BMC Musculoskelet Disord. 2009 Nov 3;10:135. doi: 10.1186/1471-2474-10-135

12. Klotzbuecher CM, Ross PD, Landsman PB, Abbott TA 3rd, Berger M. Patients with prior fractures have an increased risk of future fractures: a summary of the literature and statistical synthesis. J Bone Miner Res. 2000 Apr;15(4):721-39. doi: 10.1359/jbmr.2000.15.4.721

13. Cooper C, Atkinson EJ, O'Fallon WM, Melton LJ 3rd. Incidence of clinically diagnosed vertebral fractures: a population-based study in Rochester, Minnesota, 1985-1989. J Bone Miner Res. 1992 Feb;7(2):221-7. doi: 10.1002/jbmr.5650070214

14. Park SM, Ahn SH, Kim HY, Jang S, Ha YC, Lee YK, Chung HY. Incidence and mortality of subsequent vertebral fractures: analysis of claims data of the Korea National Health Insurance Service from 2007 to 2016. Spine J. 2020 Feb;20(2):225-233. doi: 10.1016/j.spinee.2019.09.025

15. Yu F, Xia W. The epidemiology of osteoporosis, associated fragility fractures, and management gap in China. Arch Osteoporos. 2019 Mar 8;14(1):32. doi: 10.1007/s11657-018-0549-y

16. Zvekic-Svorcan J, Aleksic J, Jankovic T, Filipovic K, Cvetkovic M, Vuksanovic M, Filipov P. Capture the vertebral fracture: Risk factors as a prediction. J Back Musculoskelet Rehabil. 2019;32(2):269-276. doi: 10.3233/BMR-170898

17. Leslie WD, Lix LM, Binkley N. Targeted vertebral fracture assessment for optimizing fracture prevention in Canada. Arch Osteoporos. 2020 May 3;15(1):65. doi: 10.1007/s11657-020-00735-2

18. Vos T, Lim SS, Abbafati C, Abbas KM, Abbasi M, Abbasifard M, et al. Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. The Lancet. 2020 Oct;396(10258):1204–22. doi: 10.1016/S0140-6736(20)30925-9

19. James SL, Abate D, Abate KH, Abay SM, Abbafati C, Abbasi N, et al. Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. The Lancet. 2018 Nov;392(10159):1789–858. doi: 10.1016/S0140-6736(18)32279-7

20. Breslow NE, Day NE. Statistical methods in cancer research. Volume II--The design and analysis of cohort studies. IARC Sci Publ. 1987;(82):1-406.

21. Dobson AJ, Kuulasmaa K, Eberle E, Scherer J. Confidence intervals for weighted sums of Poisson parameters. Stat Med. 1991 Mar;10(3):457-62. doi: 10.1002/sim.4780100317

22. Balduzzi S, Rücker G, Schwarzer G. How to perform a meta-analysis with R: a practical tutorial. Evid Based Ment Health. 2019 Nov;22(4):153-160. doi: 10.1136/ebmental-2019-300117

23. Crisis in mortality, health and nutrition. Florence, Italy: UNICEF International Child Development Centre; 1994. https://www.unicef-irc.org/publications/52-crisis-in-mortality-health-and-nutrition.html.