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Childhood injuries in the European Union: Can epidemiology contribute to their control?

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An average of 6000 children (0–14-y-old) died every year from injuries in the European Union during the last decade. Although the trends are overall favorable, injuries continue to represent the leading cause of death in this age group. The aim of this paper is to present childhood-injury-related public health issues and consider possible remedies of contemporary epidemiologic methods as applied to injury epidemiology and prevention. It has been estimated that half of the lives lost to childhood injuries could have been saved if all European Union countries matched the accomplishments of the country with the lowest mortality rate in each injury category. There is no specific pattern of association between Gross Domestic Product and incidence of motor-vehicle accidents by category of road user, whereas fatality from motor-vehicle accidents seems to be inversely, strongly and significantly related to Gross Domestic Product.

Conclusion: The ongoing development of large injury databases in the European Union is a prerequisite for understanding the complex interactions that lead to a childhood injury. Moreover, possible remedies for overcoming the genuine problems associated with the application of traditional epidemiologic methods to the investigation of the frequently transient in nature causes of injuries should be considered.

Key words: *Childhood injuries, epidemiology, preventive policies, research, routinely collected data, wealth*

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The epidemiology of childhood injuries in the European Union (EU) countries on the basis of available data has frequently been examined (1–3). An attempt is made in this article to trace the inherent weaknesses of routine sources of information and consider possible remedies of contemporary epidemiologic methods as applied to injury epidemiology and prevention.

Mortality trends

During the last decade, an average of over 6000 children (0–14-y-old) in the EU member states have died every year from injuries (2). The decreasing secular trends of injury mortality of variable size noted in each member state of the Union (Table 1) are striking (>5%) in the UK, Austria, Germany and Ireland. Just as noteworthy is the continuous decline in the Scandinavian countries, where very low mortality rates from childhood injuries had already been achieved in the early 1980s. Nevertheless, injuries continue to represent the leading cause of death in this age group, accounting for about one-third of the total.

Estimates of the preventability of diseases of environmental etiology are frequently based on the differences between—or the variability among—population groups with respect to the incidence and/or mortality rates of the corresponding diseases. Where childhood mortality from all types of injuries is concerned, in 1993 Sweden had the lowest mortality (4.95 deaths per 100 000 child-years). This value can be used as a semi-arbitrary baseline to calculate the percentage of preventable childhood injury mortality in EU member states. The results are shown by the gray columns in the Figure; thus, the preventable fraction of childhood mortality rate of Sweden equals O, whereas for any other country this fraction is given by the formula: (childhood injury mortality in country x – childhood injury mortality in Sweden): childhood injury mortality in country x.

In most EU countries, between 30% and 50% fewer childhood deaths from injuries could have been achieved with realistic policies and measures. Portugal,

Table 1. Age-adjusted childhood (0–14 y) mortality rate (MRadj, per 100 000 person-years) and regression derived percent annual decline (and 95% confidence interval) in EU member states during the decade 1984–93.

Country	1984 Deaths #	1984 Mradj	1993 Deaths #	1993 Mradj	Per cent annual decline of MRadj	95% CI		*p*-value
UK	1103	10.2	599	5.4	6.1	5.0	7.2	$<10^{-3}$
Austria	195	14.5	125	8.9	5.7	3.7	7.7	$<10^{-3}$
Germany	1233	13.8	970	7.6	5.3	4.3	6.3	$<10^{-3}$
Ireland	126	12.3	74*	8.3	5.1	3.8	6.5	$<10^{-3}$
France	1565	14.4	899	8.5	4.9	3.8	6.0	$<10^{-3}$
Portugal	556	24.9	255	15.1	4.7	3.1	6.3	$<10^{-3}$
Belgium	251	13.6	184**	10.5	4.6	3.2	6.0	$<10^{-2}$
Greece	262	13.2	156	9.1	4.3	3.0	5.6	$<10^{-3}$
Netherlands	279	10.1	174	6.3	3.5	2.1	5.0	10^{-3}
Sweden	97	6.4	81	5.0	3.4	0.7	6.0	0.04
Italy	935	8.4	586*	6.7	3.3	2.2	4.3	$<10^{-3}$
Denmark	89	9.8	61	6.8	2.4	−0.2	5.0	0.11
Spain	1028	12.2	692*	10.4	1.8	0.8	2.7	0.01
Finland	76	8.0	69	7.1	0.7	−1.7	3.0	0.58

* Latest available data 1992. ** Latest available data 1989.

Belgium, Spain and Greece have the highest injury mortality rates, but also the largest potential for reducing these rates through adoption and implementation of policies and measures of demonstrable effectiveness.

Injuries represent an etiological mixture and there is considerable variability among EU countries with respect to the proportion of childhood deaths caused by injuries of different broad categories, i.e. motor vehicle and other transport, falls, drowning, poisoning, machinery, fire and flames and firearms. Some countries have been more effective in combating mortality from certain categories of injuries, whereas others have been more successful with respect to other types of injuries. If an "ideal" country were envisaged, characterized by the lowest achievable childhood mortality in every single injury category (e.g. that of Austria in fire and flames, that of the UK in drownings and machinery, etc.,

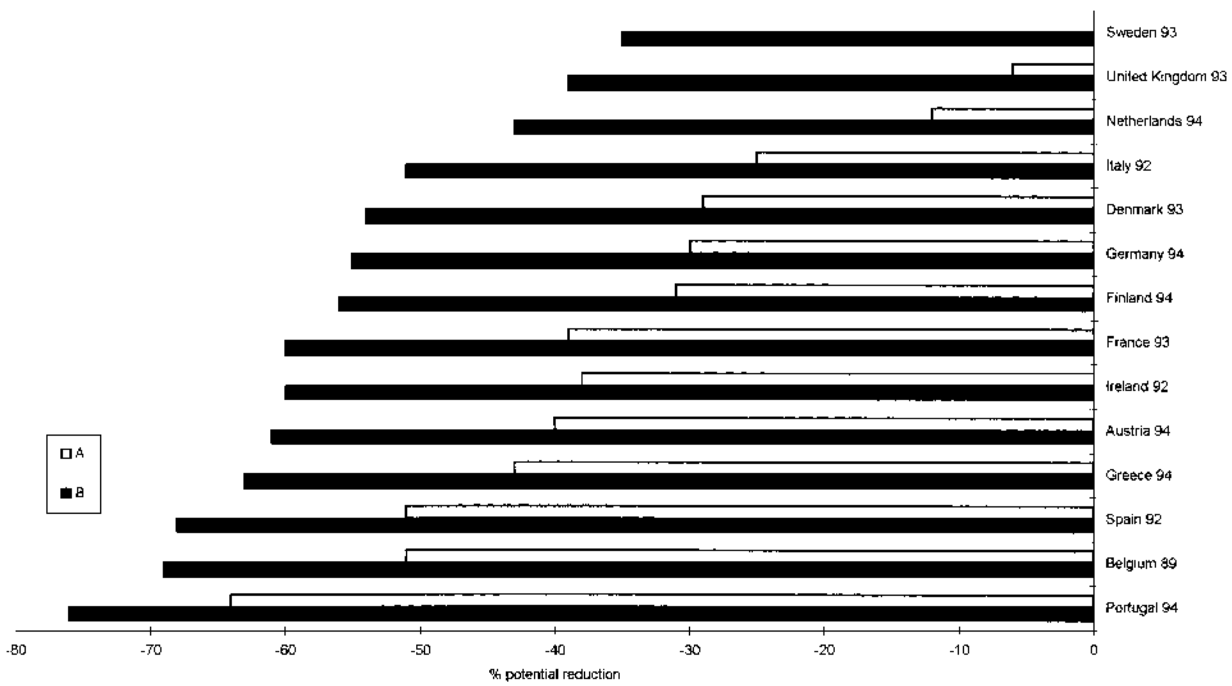

Fig. 1. Potential reduction (%) of childhood injury mortality in EU member states if every country were to achieve: A = the total injury mortality rate of Sweden (4.95×10^{-5}) and B = an "ideal" injury mortality rate equal to the sum of the lowest achieved category-specific rates in EU member states (3.20×10^{-5}).

Table 2. Principal external causes of accidental death (expressed as mortality rates per 100 000 child-years, MR) and percent of total injury mortality rate (%) due to childhood injury in selected EU countries during the last available 5-y.

Country	Motor vehicle		Other transport		Poisoning		Falls		Fire and flames		Drowning		Machinery		Firearms		Other		Total	
	MR	(%)	MR	(%)	MR	(%)	MR	(%)	MR	(%)	MR	(%)	MR	(%)	MR	(%)	MR	(%)	MR	(%)
Austria 89–93	3.8	(39.8)	0.5	(5.5)	0.1	(1.1)	0.8	(8.0)	0.2	(2.6)	1.6	(16.5)	0.5	(5.4)	0.0	(0.2)	2.0	(21.0)	9.5	(100.0)
Belgium 85–89	5.7	(51.2)	0.1	(1.0)	0.6	(5.2)	0.5	(4.7)	0.6	(5.7)	1.2	(10.7)	0.1	(0.8)	0.0	(0.3)	2.3	(20.3)	11.1	(100.0)
Denmark 89–93	4.5	(55.1)	0.2	(2.5)	0.1	(1.4)	0.3	(3.0)	0.5	(6.1)	1.0	(11.8)	0.2	(2.5)	0.0	(0.6)	1.4	(17.2)	8.3	(100.0)
Finland 89–93	3.8	(47.4)	1.0	(12.3)	0.1	(0.8)	0.3	(3.3)	0.4	(4.9)	1.4	(17.2)	0.0	(0.5)	0.0	(0.5)	1.1	(13.1)	8.1	(100.0)
France 89–93	4.0	(40.6)	0.2	(1.6)	0.1	(1.0)	0.4	(4.4)	0.6	(5.7)	0.9	(9.2)	0.1	(1.3)	0.0	(0.4)	3.5	(35.7)	9.9	(100.0)
Germany 89–93	3.5	(41.3)	0.3	(3.4)	0.1	(1.6)	0.4	(5.2)	0.7	(8.6)	1.4	(16.5)	0.1	(1.6)	0.0	(0.2)	1.8	(21.6)	8.5	(100.0)
Greece 89–93	5.0	(49.9)	0.1	(1.2)	0.1	(1.0)	0.4	(3.8)	0.3	(2.7)	0.8	(7.5)	0.1	(0.9)	0.1	(1.5)	3.2	(31.6)	10.1	(100.0)
Ireland 88–92	4.2	(46.9)	0.3	(3.0)	0.2	(2.3)	0.3	(3.5)	1.1	(12.5)	1.1	(12.1)	0.3	(3.7)	0.1	(0.9)	1.4	(15.1)	9.0	(100.0)
Italy 88–92	3.3	(50.2)	0.1	(1.6)	0.1	(2.1)	0.5	(7.6)	0.1	(2.2)	0.6	(8.5)	0.2	(2.4)	0.0	(0.4)	1.6	(24.9)	6.6	(100.0)
Netherlands 89–93	3.3	(46.0)	0.4	(6.1)	0.1	(1.5)	0.3	(4.3)	0.3	(3.9)	1.4	(18.6)	0.1	(1.2)	0.0	(0.0)	1.3	(18.4)	7.3	(100.0)
Portugal 89–93	8.1	(51.4)	0.4	(2.4)	0.5	(2.9)	0.8	(5.1)	0.7	(4.4)	1.5	(9.4)	0.3	(1.9)	0.1	(0.4)	3.5	(22.2)	15.8	(100.0)
Spain 88–92	4.7	(45.0)	0.1	(1.1)	0.2	(1.9)	0.4	(3.8)	0.3	(3.1)	1.3	(12.6)	0.1	(0.8)	0.1	(0.5)	3.3	(31.2)	10.4	(100.0)
Sweden 89–93	2.5	(49.6)	0.4	(7.0)	0.0	(0.5)	0.2	(3.5)	0.3	(6.0)	0.9	(17.2)	0.1	(2.0)	0.0	(0.7)	0.7	(13.6)	5.1	(100.0)
UK 89–93	3.2	(48.9)	0.2	(2.7)	0.2	(2.3)	0.3	(5.1)	0.9	(13.5)	0.5	(8.1)	0.0	(0.7)	0.0	(0.1)	1.2	(18.7)	6.6	(100.0)

as shown in Table 2), the preventable fraction, namely the proportion deaths due to injuries that could have been prevented, would be clearly higher in every country. This fraction would be non-zero either in Sweden or the UK because not even Sweden has yet achieved the lowest childhood mortality rate in every single type of injury among the EU countries under comparison, and can benefit from the experience of countries that have already achieved lower injury mortality rates in the respective type of injury (black columns in the Figure). It is estimated that these two leading countries in childhood injury prevention have the potential to further reduce the respective childhood injury mortality rates (preventable fraction 35–40%) provided they could achieve the "ideal" rates, that is, the sum of the lowest injury category-specific mortality rates already reached in some other EU member states. This approach slightly overestimates the potential for injury prevention, because it takes no account of inflexible constraints that may exist in some countries and incorporates an overoptimistic element of chance. On the other hand, the estimates were made for a single calendar year (1993, for most countries), and neither of the indicated approaches takes into account the pattern of declining trends in every country and every category of injury, which would underestimate the preventable fraction. In any case, the Figure illustrates the enormous waste of youthful lives from injuries of various types. It is estimated that of the total of 5000 lives lost due to childhood injuries during 1993, at least half could have been saved if all countries had matched the accomplishments of the leading country in each injury category.

External causes

Table 2 shows proportional (%) distributions of childhood injury deaths in EU countries by category of injury. Proportional indicators have well-known weaknesses, but they do contribute to the rational prioritization of corrective measures (4). There is considerable variation by external cause, but motor-vehicle accidents dominate the pattern in every single country. Drowning, burns, falls and poisoning are quantitatively less important, but deserve separate consideration because they provide unique preventive opportunities. Interpretation of the evidence concerning external causes of injury deaths is, however, hindered by the fact that a large and variable fraction of injury deaths are recorded unclassified as to the external cause. Nevertheless, it is evident that motor-vehicle accidents represent a particularly acute problem for Portugal, whereas "other transport" injuries seem to deserve special consideration, mainly in Finland. Falls are surprisingly more common, as a proportional cause of death, in Austria and Italy, whereas drowning is, again in proportional terms, an important problem for affluent societies with

Table 3. Incidence rates (IR = cases per 10^6 child-years) and fatality ratios (FR = deaths as per thousand of injured) of motor-vehicle injuries by road-user category in EU member states (circa 1990), with the corresponding Gross Domestic Products (GPD, in USD/capita).

		Occupants[1]		Cyclists[1]		Pedestrians[1]	
Country	GDP[2]	IR	FR	IR	FR	IR	FR
Austria	17690	1302	12	938	8	1014	14
Belgium	17510	1746	8	1088	11	719	11
Denmark	17880	256	18	398	51	199	45
Finland	16130	271	46	313	36	193	37
France	18430	624	31	264	19	544	17
Germany	19770	1231	11	1384	7	1126	9
Greece	7680	353	39	156	35	330	42
Ireland	11430	485	26	194	38	394	46
Italy	17040	606	16	323	14	202	29
Netherlands	16820	253	40	1089	14	415	18
Portugal	9450	1152	18	510	19	1569	25
Spain	12670	548	35	131	32	346	39
Sweden	17490	421	22	315	6	151	25
UK	16340	1181	6	615	5	1555	9

Sources: 1. Economic Commission for Europe. Statistics of Road Traffic Accidents in Europe and North America, vol. XL. United Nations. Geneva. 1995. 2. World Health Organization. Tobacco or Health: a Global Status Report. WHO. Geneva. 1997

an otherwise good record in the prevention of childhood injury, notably Sweden, The Netherlands and Finland. Death injuries from machinery appear unusually common in Austria and Ireland. Poisoning rates are proportionally higher in Belgium and Portugal, whereas fire and flames cause more than 10% of childhood injury deaths in the UK and Ireland. Lastly, firearms remain a minor childhood injury problem in the EU overall, with two-thirds of the countries having rates approaching zero.

Injuries dominate the spectrum of childhood morbidity and mortality. Most public health workers recognize that epidemiology has been the basic science providing the foundations for the control of most diseases that turn out to be amenable to such control—be these infections, smoking-related or nutrition-related. Thus, it is natural to ask whether epidemiology has failed in this particular field.

It is more likely, however, that epidemiology should evolve to accommodate the special problems surrounding that study of infectious diseases, that of chronic diseases, following the emergence of the latter as the principal causes of morbidity and mortality after World War II. As Susan Baker has pointed out, injury epidemiology should shift in emphasis from personal risk factors to the circumstances surrounding the causation of accident, that is, a shift from underlying to proximal causes (5). Some of the changes that are likely to emerge in injury epidemiology are outlined in the following sections.

Does socio-technological development matter?

Ever since the transatlantic luxury liner "Titanic" sank and fatalities among third-class passengers were several times higher than those among first-class passengers, it has become apparent that injury rates have a strong socioeconomic gradient (3), as higher socioeconomic strata are more apt to identify, and derive benefit from, new technological developments. With few exceptions (6–8), recent papers have confirmed that the pattern is both strong and persistent (9–11) especially with regard to some types of injuries (12), and concerns both incidence and outcome of injuries (13).

There are two general components in mortality: incidence and fatality (4). The three measures are linked by the equation: Mortality Rate = Incidence Rate * Fatality Ratio. Data on incidence rates and fatality ratios from motor-vehicle accidents by road user category (circa 1990) are assembled by the Economic Commission of the United Nations (14). Comparable data for other types of injuries are not available. Motor-vehicle data for EU countries and gross domestic product (GDP) in USD/capita in each of the listed countries during the corresponding period (15) are given in Table 3. No pattern of association emerges between GDP on the one hand and incidence of motor-vehicle accidents by category of road user on the other. Fatality from motor-vehicle accidents for every category of road user, however, is overall inversely, strongly and significantly related to GDP (correlation coefficients were -0.52 for motor-vehicle occupants, -0.45 for cyclists and -0.45 for pedestrians). These findings should be interpreted with caution because they are derived from routinely collected data. There has been no attempt to formally evaluate the comparability of this information and how it is affected by social attitudes, registration patterns and inter-country variability in the fraction of injury cases and deaths from unknown causes. A possible explanation could be that healthcare effectiveness is higher in the economically more developed countries of the EU (16).

With respect to incidence, which, as indicated, is a crucial determinant of mortality, variation across European countries reflects cultural differences and lifestyle, as well as socioeconomic differentials, variation in the quality of infrastructure and, to a considerable extent, differences in the completeness of registration. The underlying critical factors need to be determined, so that measures can be rationally formulated (9).

Has injury epidemiology been successful?

Epidemiology has been the basic science of public health and has contributed more than any other field in the development of preventive measures and policies for infectious and cardiovascular diseases and several forms of cancer (17, 18). The contributions and the potential of injury epidemiology, however, appear to be more limited (19). Progress in injury prevention has been dependent mostly on principles of physics, technological improvements, legal measures, or just common sense. Is this because epidemiological methods are inherently inappropriate for the investigation of injury causation or is it because the necessary data have been difficult to assemble? There are elements of truth in both arguments.

There are important differences between the causation of human diseases and that of injuries. Most causes of cardiovascular, neoplastic or infectious diseases are clearly identifiable entities, whereas the factors that contribute to injuries are frequently behavioral and poorly defined. Moreover, most human diseases have natural histories with identifiable stages, whereas injuries may have risk factors but are rarely, if ever, characterized by latent stages.

The unpredictable sequence of events and conditions that increase the likelihood of occurrence of an injury creates some unusual problems in the application of traditional epidemiologic methods in the study of injury causation and prevention (19). Large-scale randomized trials are very difficult to undertake and the design of cohort studies is hindered by our inability to specify in advance an adequate range of the relevant proximal exposures of behavioral or environmental nature. Thus, it is very difficult to contemplate in advance the variable constellation of circumstances that may trigger an accident. The proper design of case control studies is, if anything, more complicated, because instantaneous death or serious injury may create selection bias, whereas post-traumatic shock or denial of responsibility regularly introduce information bias. In addition, there is poor correspondence between clinical and etiological homogeneity of injuries, which introduces considerable non-differential misclassification in most of the generally used investigative designs. Lastly, procedures for selection of controls are more challenging in injury epidemiology than in other fields of epidemiologic research: for example, to what extent does a past accident represent an exclusion criterion from the control series?

Injury epidemiology is important, but different

In contrast to other fields of etiological research, which is undertaken as a prerequisite for primary prevention, injury epidemiology and control cannot rely on animal studies. Almost by default, injury epidemiology is bound to represent the mainstream research tool. Informal epidemiological approaches, including case studies, case series and critical incident analyses, have made important contributions and will continue to contribute but their usefulness is limited to identification of hazardous products and processes, to the formulation of safety standards and to the establishment of principles for ergonomic designs. Traditional analytical epidemiological designs, including ecological, case-control and cohort studies, are still valuable, but they may have entered the “diminishing” returns phase of their trajectory. In order to address human factors that increase the long-term likelihood of an accident, however, or perhaps more important, trigger it, new epidemiological designs need to be contemplated and new resources must be developed.

The case-crossover design introduced by Maclure (20) allows the investigation of factors of transient nature in the triggering of acute events. The method was successfully used in the investigation of cardiovascular events (21), but has also been employed in the identification and even quantification of events and conditions that facilitate the occurrence of accidents (22–24). Because transient and instantaneous phenomena are frequently critical in the causation of injuries, the case-crossover design has the potential to become an extraordinarily valuable instrument in the investigation of proximal causes of injuries.

No method, however, can be used in the absence of suitable databases. Although childhood mortality and years of life lost as a result of injuries are of unacceptable magnitude, fatality rates are in general so low as to make mortality a very poor substitute for incidence. The development in the EU of large databases of incident childhood injuries in which comparable methodologies and coding systems have been used may turn out to be a turning point in our understanding of the complex interactions that lead to an injury. There are already examples of successful utilization of such databases worldwide (25–29), but prospects are likely to be better when experience accumulates and methodologies are customized to accommodate the strength and limitations of these databases and assess new opportunities for measuring exposure to injury risk (30).

The long road to injury prevention

Deaths from childhood and early adulthood (0–24 y) injuries reduce life expectancy by just as much as half the cancer deaths do throughout life. In the USA during the early 1990s, deaths from injuries were four times as many as those from AIDS and several times as many as those from environmental pollution of any type (31). Therefore, it is irrational that research efforts, resources and community mobilization towards injury prevention cannot even be compared to those dedicated to other contemporary health threats.

Childhood injury prevention has never achieved and probably will never receive adequate academic recognition and research support (31). Injury epidemiology itself is not an active part of mainstream epidemiology. Yet, there are already some signs of positive changes. The proportion of childhood injury papers in major pediatric journals, including *Pediatrics*, *Archives of Diseases in Childhood* and *Acta Pediatrica*, has more than doubled in the period 1983 to 1997. The EU is launching a program focusing on the prevention of injuries. Legislation mandating the use of childhood car restraint systems is welcomed even in countries with a poor injury prevention record, such as Greece, and the ethos of injury prevention is spreading throughout Academia, the media and the community at large. Those working on injury prevention have traded the excitement of scientific discovery for the quiet satisfaction that their efforts may improve quality of life at population level much more than any other health intervention.

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