ANNUAL AND SEASONAL TRENDS IN MORTALITY RATES FROM EXTERNAL CAUSES IN HUNGARY

PhD Thesis

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LIST OF PUBLICATIONS RELATED TO THE THESIS

Papers included in the thesis:

I. **Lantos T**, Nyári TA, McNally RJQ. Seasonal variation of mortality from external causes in Hungary between 1995 and 2014. *PLoS One*. 2019 Jun 6;14(6):e0217979. doi: 10.1371/journal.pone.0217979.
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II. **Lantos T**, McNally RJQ, Nyári TA. Patterns of suicide deaths in Hungary between 1995 and 2017. *SSM Population Health.* 2021 Nov 7;16:100788. doi: 10.1016/j.ssmph.2021.100788
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Other related publications:

III. **Lantos Tamás**, Nyári Tibor. Seasonal variation from suicides in Hungary between 1995 and 2014. [Öngyilkosság általi halálozások szezonális változása 1995 és 2014 között Magyarországon] *XXXI. Neumann Kollokvium*, Szeged, pp. 108-113. (In Hungarian)

GLOSSARY OF ABBREVIATIONS

ASMR	age-standardised mortality rate
ASSR	age-standardised suicide rate
CI	confidence interval
ESP	European Standard Population (1976)
EU	European Union
GLM	generalised linear model
GoF	goodness of fit
HCSO	Hungarian Central Statistical Office
ICD	International Classification of Diseases
IRR	incidence rate ratio
ISCED	International Standard Classification of Education
LB	lower bound
NB	negative binomial
NUTS	Nomenclature of territorial units for statistics (abbreviated from the French version)
RESP	Revised European Standard Population (2013)
SR	suicide rate
UB	upper bound

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1. INTRODUCTION

External causes of death include accidents (accidental falls, traffic accidents etc.) and acts of violence (suicide, assault/homicide etc.). In the mid-1990s, they used to be the third most common cause of death (behind circulatory diseases and neoplasms) in Hungary; at that time, our country had recorded one of the highest mortality rates from external causes throughout Europe. Over the next 20 years, external causes have slipped back to fourth place among the main causes of death (6.3%) – behind circulatory diseases (50.6%), neoplasms (24.9%) and digestive diseases (6.6%) –, still causing an average of approximately 7700 deaths a year. During these years, Hungary has recorded the fourth highest standardised death rates from external causes among the 28 members of the European Union (EU) [1].

For understandable reasons, these causes of death mainly affect younger age groups: among the under-45s, it is the leading cause of death both in the EU (the current member states meant by that) and in Hungary, resulting in substantial (disability-adjusted) years of life lost. On the other hand, among the over-65s, Hungary used to be the leading one among the countries with highest external-cause mortality in Europe (see *Figure 1*): overall (A), and both in view of accidents (B; including accidental falls – C) and suicides (D); however, unfortunately, it still belongs to the forefront in this respect.

Although external causes form a very heterogeneous group of deaths causes (numerous, less common death causes are included), three causes of death clearly stand out from the others in Hungary: suicides (nearly 2700 deaths/year on average during the period between 1995 and 2014 [2]), accidental falls (2550), and traffic accidents (1200); they are also the leading external causes of death in many European countries. Together, these causes account for about four-fifths of the total external-cause mortality; consequently, it is worth dealing with them separately, as they largely determine its pattern and trends.

Nonetheless, external causes of death deserve special attention not only because of their relatively high frequency, but also because they are very closely related to social and individual behaviour, which is highly dependent on the social order and its change. Despite all the above, except for suicides, they are still not the focus of investigations.

From 1960, the Hungarian suicide mortality rate had been consistently among the highest ones for decades [3]. During the period 1995–2017, Hungary recorded the third highest standardised suicide rate from among the 28 members of the EU (only behind Lithuania and Latvia, and narrowly followed by Estonia) and by far the highest among the Visegrad Group (V4) countries (the Czech Republic, Hungary, Poland, and Slovakia) [4].

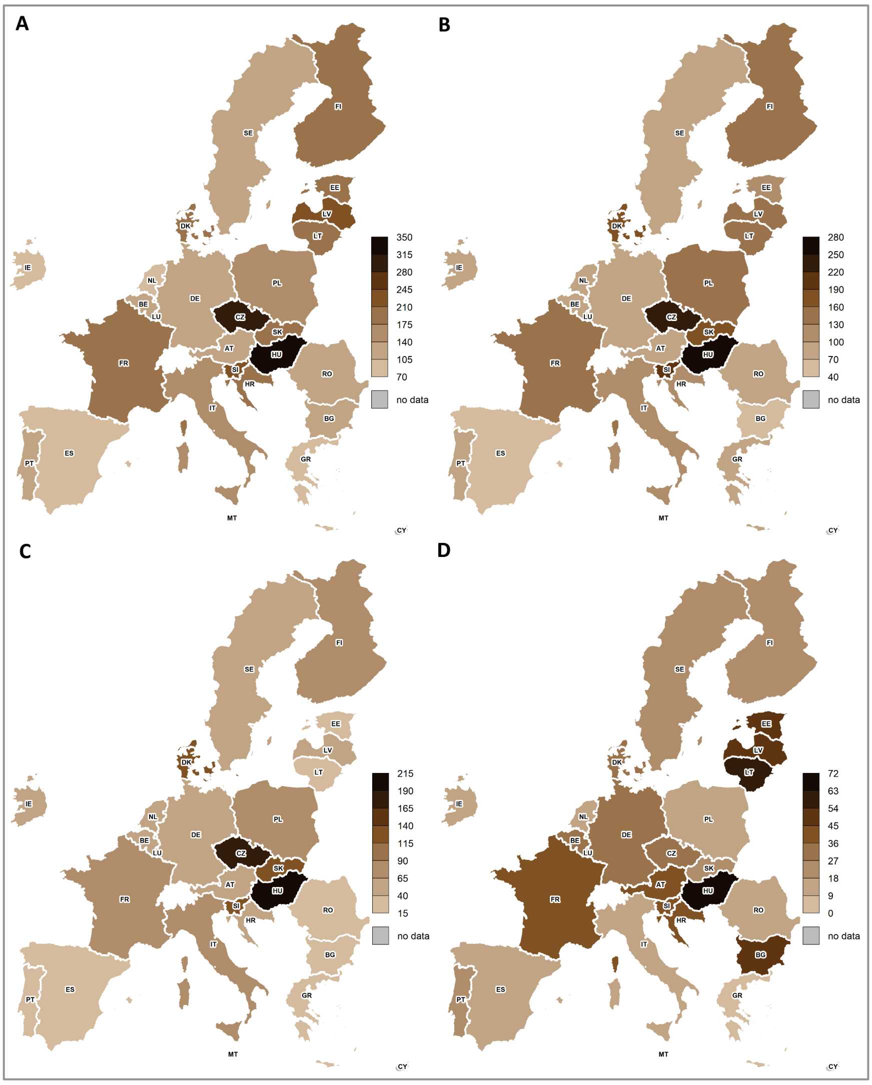

Figure 1. Member states of the EU coloured by standardised mortality rates (per 100,000 population) in 1995.

A. External causes of death B. Fatal accidents C. Accidental falls D. Suicides

Accordingly, suicide, as the leading external cause of death, has been investigated numerous times and in many ways. Rihmer et al. have investigated suicide from clinical-epidemiological perspectives [3]. They reported higher suicide rates in south-eastern Hungary compared with the suicide rates in the north-western parts of the country. Furthermore, a greater level of urbanicity is associated with a lower level of suicide rates. Males in all age groups are more at risk than females [5] and the risk of suicide increases with age [6].

Rihmer et al. also presented that completed suicides were decreasing from 1986 to 2006 but this was followed by a stagnant phase [3]. They assumed that the disappearance of the declining trend might be attributable to increasing unemployment and to the cutbacks that Hungarian psychiatry faced during those years [7].

Bálint et al. [8] have studied socio-epidemiological aspects and found that marriage is a protective factor against suicide [3, 9] and higher education levels are accompanied by a lower risk of suicide. According to Elo et al. [10], educational attainment shows one of the most consistent and strongest relationships with various indicators of health status, including those that might lead to suicidal ideation.

Fountalakis et al. investigated 29 European countries between 2000 and 2012 [11]. They found that both economic and climatic factors play a role in the development of suicides, but the impact of the latter is stronger. A significantly higher suicide rate was reported in the late spring – early summer peak in Hungary [12].

Investigating seasonality of suicide deaths is essential as its findings could be key elements in the prevention. According to an overview [13], "The seasonal variation is evident in Eastern European countries." In addition, despite the weakening seasonal link in Hungary [14], seasonality remained very strong compared to other countries [15]. Previous Hungarian studies [12, 16] have reported a seasonal peak in early summer (May–June). Similar peaks were detected in other Central European countries, such as Austria (for June) and the Czech Republic, Germany, and Switzerland (all for May) [17]. This can partly be explained by the "relative unhappiness" phenomenon (due to increased intensity of social life [18]) and the "broken-promise effect" proposed by Gabennesch [19] (with the beginning of summer, unfulfilled expectations lead to extreme forms of disappointment).

Consequently, several risk factors for suicide are already known, including sociodemographic factors, such as gender, age, marital status, and educational attainment. Furthermore, apart from these factors, the role of suicide method might also be important in a seasonal investigation of suicide mortality as seasonal peaks could vary by suicide method.

Although seasonal variation in mortality from suicide was studied in many countries in Europe and, specifically in Hungary [12, 14, 16], the general cyclic pattern and annual trends of mortality rates from external causes have not been investigated yet. These trends are important as they could lead to preventive measures and greater understanding of the underlying causes.

We hypothesise that cyclic trends could be also detected in other categories of deaths from external causes and that annual trends in mortality rates of external causes of deaths are decreasing. Previous studies showed that the pattern of mortality from external causes is different among males and females [20] and by age-groups [21]. Therefore, we applied a divided age-group structure and calculated mortality trends by gender.

2. AIMS OF THE THESIS

The aims of the thesis were:

- to investigate the annual and (monthly) seasonal trends in mortality rates from external causes in Hungary during the 20-year interval between 1 January 1995 and 31 December 2014 (Study I). That is,
    - to characterise mortality rates from external causes,
    - to calculate age-standardised mortality rates,
    - to fit annual and seasonal trends in mortality rates from external causes,
    - to carry out these analyses by gender.

- to describe detailed patterns of suicide deaths in Hungary between 1 January 1995 and 31 December 2017 (Study II). That is,
    - to confirm the findings of Study I for pattern of suicide,
    - to fit general annual and seasonal trends of suicide deaths,
    - to carry out risk estimation for detecting of socioeconomic factors of suicide (gender, age, region, marital status, and educational attainment, respectively),
    - to analyse the seasonal patterns for suicide rates (adjusted to one of the potential risk factors and by suicide method, respectively).

In the thesis, the sections 'Results' and 'Discussion' are presented for both Study I and Study II separately, according to the original papers.

3. MATERIALS AND METHODS

3.1. Statistical methods

Statistical analyses were conducted for all mortality causes and for men and women separately. *p*-values less than 0.05 were considered statistically significant. All analyses were performed using STATA Software Version 9.0 (Stata Corp LP, College Station, TX, USA).

External-cause mortality rates and suicide rates (SRs) were expressed per 100,000 population per year using the annual mid-year population estimates for the relevant year.

3.1.1. Standardisation

The aim of (direct) standardisation is to facilitate comparison of rates removing the effect of (age) composition. Accordingly, age-standardised mortality rates (ASMRs) and age-standardised suicide rates (ASSRs) were calculated to make the external-cause mortality rates and suicide rates more comparable in Hungary during the study period (1995-2014 [Study I] and 1995-2017 [Study II], respectively).

In Study II, male-to-female ratios were calculated as the ratio of the incidence rate for males relative to that for females.

3.1.2. Annual trends

The distribution of rare events is usually skewed and can be well approximated by the Poisson distribution. An important property of this distribution is that the mean is equal to the variance. In this case, the so-called 'dispersion parameter' (logarithm of its parameter lambda) is 1. However, in the case of population-level data (e.g. for cause-specific mortality), 'overdispersion' is a common phenomenon: the variance exceeds the mean; therefore, the assumptions of Poisson regression are not met. In such cases, negative binomial (NB) regression can be applied.

Since the likelihood-ratio test concerning overdispersion was significant, annual trends were investigated using NB regression models in analyses by gender and type of death from external causes (year of death was the only independent factor included in the model). Incidence rate ratios (IRRs) and 95% confidence intervals (CIs) were calculated (Study I).

Similarly, in Study II, our first approach to estimating IRRs and their 95% CIs was to employ Poisson regression models. However, the assumptions of this model were violated; therefore, the NB regression model was used for overdispersed count data [22] to investigate the effect of possible risk factors (gender, age group, region, marital status, and educational attainment) in relation to dying by suicide.

3.1.3. Seasonal trends

There are several methods for analysing cyclic trends [23]. We have used geometrical models for analysing cyclic variation which was introduced by Edwards [24]. However, Edwards' method used only the number of observations. Walter and Elwood [25] generalised Edwards' idea by including the population at risk. They described that seasonal fluctuation of an event which occurs on a fixed date every year might be described using cyclic patterns over time. The Walter-Elwood seasonality test has greater power for detecting seasonal trends, thus this test is robust for detecting seasonal effects.

Since the monthly population was estimated (Study I), Edwards' method was applied to confirm the findings of the Walter-Elwood method. Stolwijk et al. [26] described the application of generalised linear models (GLMs) for investigating seasonality which is an extension of the Walter-Elwood method and based on similar geometrical approaches. We have applied NB regression from GLMs' family [22] to investigate (also) the seasonal trends.

Additionally, we have used the Walter-Elwood (Study I) and – where the appropriate at-risk population could not be assigned to the suicide deaths – Edwards' methods (Study II) for analysing cyclic variation to confirm the findings. Note that the Edwards test is sensitive to occasional extreme values; however, both NB regression and the Walter-Elwood test are powerful methods in case of extreme values.

In Study II, seasonal variation in suicide deaths was investigated using NB regression in analyses overall, by gender and suicide method first: month of death was the only independent factor included in the model. Moreover, sine and cosine terms were included in the model to control for annual seasonality. Thereafter, one of the significant risk factors (obtained from the "initial" NB regression noted before) was added to the (fundamental) model as an explanatory variable.

Consequently, data on the month of the death were aggregated over the study period and cyclic trends in these monthly data were investigated using the methods mentioned above. Both NB regression and Walter-Elwood test adjust for the population at risk by grouping the data into months and were used to investigate single or double peaks of seasonality.

All these models mentioned above included the corresponding stratum-specific population (broken down by levels of a single given risk factor) as an exposure variable (Study II). In addition, quarters were also used to investigate cyclic trends of suicides, which were defined as Q1 (January, February, and March), Q2 (April, May, and June), Q3 (July, August, and September) and Q4 (October, November, and December).

3.2. Study population

Data on the (yearly) population were obtained from the published nationwide population register operated by of the *Hungarian Central Statistical Office* (HCSO [27]; Study I: 1995-2014, Study II: 1995-2017).

There were no monthly population data available, therefore we have used annual population data and the monthly birth and death data to estimate the numbers of population by months. The HCSO provided data on the number of births for each month over the study period but by gender only for each year. The number of births in each month for each gender was estimated assuming no monthly variation in the gender ratio within any year.

3.2.1. Seasonal variation of mortality from external causes in Hungary

The 20-year period between 1995 and 2014 was considered in this analysis. The data concerning the external cause of deaths have been published online (*Dissemination Database*) by the HCSO [2]. These data were classified according to the International Classification of Diseases, 10th Revision (ICD-10) codes. *Table 1* summarises the main categories.

Nº	Full name	ICD-10 codes	Abbreviated name
1	Railway accidents	V05, V15, V80.6, V81, V87.6, V88.6	Railway (as part of 'Traffic')
2	Motor vehicle accidents	V02-04, V09.0, V09.2, V12-14, V19.0-2, V19.4-6, V20-79, V80.3-5, V86, V87.0-5, V87.7-8, V88.0-5, V88.7	Motor vehicle (as part of 'Traffic')
3	Other transport accidents	V01, V06, V09.1, V09.3, V09.9, V10-11, V16-18, V19.3, V19.8-9, V80.0-2, V80.7-9, V82-85, V87.9, V88.9, V89.1, V89.3, V89.9, V98-99	Other transport (as part of 'Traffic')
4	Water transport accidents	V90-94	Water transport
5	Air transport accidents	V95-97	Air transport
6	Accidental falls	W00-19	Falls
7	Accidental drowning and submersion	W65-74	Drowning
8	Other accidents caused by submersion and obstruction	W75-84	Other drowning
9	Accidents caused by electric current	W85-87	Electric current
10	Accidents caused by smoke, fire, and flames	X00-09	Smoke-fire-flame (as part of 'Cold-heat')
11	Exposure to excessive cold	X31	Cold (as part of 'Cold-heat')
12	Lightning	X33	Lightning
13	Accidental poisoning and exposure to alcohol	X45	Alcohol
14	Other accidents	W00-X59 difference, Y40-Y84	Other accidents (as part of 'Other')
15	Suicide and self-harm	X60-84	Suicide
16	Assault	X85-Y09	Assault
17	Other external causes of morbidity and mortality	Y10-36, Y85-89	Other external (as part of 'Other')

Table 1. External causes of death (ICD-10 codes and groupings).

Due to similar characteristics, some of the causes of death were grouped together: *traffic accidents* (in the tables, abbreviated as *traffic*) include railway accidents (1), motor vehicle accidents (2) and other transport accidents (3); *cold/heating-related accidents* (abbreviated as *cold-heat*) include accidents caused by smoke, fire, and flames (10) and exposure to excessive cold (11); *other causes* (abbreviated as *other*) include other accidents (14) and other external causes of morbidity and mortality (17). Since the numbers of deaths from water transport accidents (4), air transport accidents (5) and lightning (12) were too small (<50), these death causes were added to the category *other causes*.

Data on both the population and numbers of deaths from external causes were classified by age groups as follows: 0-19 years (‘youth’), 20-34 years (‘young adult’), 35-59 years (‘middle-aged adult’) and over 60 years (‘older adults’).

Thus, age-specific death rates were calculated. Furthermore, the mortality rates of external causes were directly standardised [28] using the *European Standard Population* (ESP) published in 1976 [29] to make comparisons easier. The population distribution of ESP is the following: 0-19 years 29%, 20-34 years 21%, 35-59 years 34% and over 60 years 16% of the population.

3.2.2. Patterns of suicide deaths in Hungary

The 23-year period between 1995 and 2017 was considered in this analysis. The data on suicide deaths were also available on the online HCSO database [2]. Some cells contained protected data. We considered these ‘missing’ fields to be 1 (as in vast majority of cases, this must be the true value). This can cause some discrepancies in marginal numbers, but these differences are negligible.

The classification of suicide methods was based on the International Classification of Diseases (ICD; prior to 1996 [ICD-9]: E950-E959; since 1996 [ICD-10]: X60-X84, Y87). Based on these codes, the following *suicide methods* were distinguished: (1) “Hanging” (1995: E953 / 1996-2017: X70), (2) “Self-poisoning by drugs” (E950.0-E950.5 / X60–64), (3) “Self-poisoning by chemicals and other substances” (E950.6-E950.9 / X65–66, X68–69), (4) “Self-poisoning by gases” (E951-E952 / X67), (5) “Jumping from a height” (E957 / X80), (6) “Drowning” (E954 / X71), (7) “Firearm” (E955.0-E955.4 / X72–74) and (8) “Other/unspecified” (all remaining codes). These (specified) methods were grouped into two main categories: violent methods (subcategories 1, 5, 6 and 7) and non-violent ones (2, 3 and 4).

Territorial units were based on the second level of NUTS 2013 (*Nomenclature des unités territoriales statistiques* – Nomenclature of Territorial Units for Statistics, 2013 revision) classification [30]. These *statistical regions* (second level of the classification; NUTS2) were as follows (*Figure 2*): Central Hungary (HU10), Central Transdanubia (HU21), Western Transdanubia (HU22), Southern Transdanubia (HU23), Northern Hungary (HU31), Northern Great Plain (HU32) and Southern Great Plain (HU33).

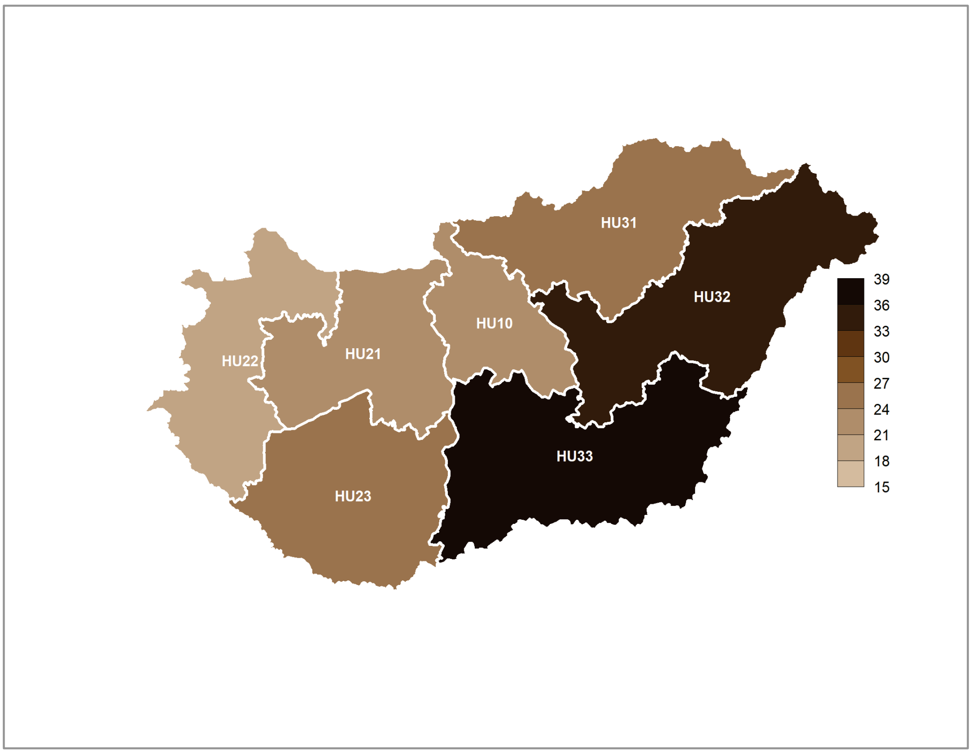

Figure 2. NUTS2 regions of Hungary coloured by crude suicide rates (number of deaths per 100,000 population) during 1995-2017.

Codes: HU10 Central Hungary, HU21 Central Transdanubia, HU22 Western Transdanubia, HU23 Southern Transdanubia, HU31 Northern Hungary, HU32 Northern Great Plain, HU33 Southern Great Plain

Marital status was used as a binary variable (married vs. non-married) in the analyses. The whole population was considered first, then, as a "more relevant" subgroup (in this respect), only the over-20-year-old age group was taken into consideration. It is worth mentioning that children under 16 may only marry with the permission of child protective services in Hungary (pursuant to Act V of 2013 on the Civil Code, Section 4(9) [Legal age for marriage]). Although the legal aspect of a relationship is not the only one to affects someone's life, other categorisation (e.g. single vs. non-single) were not possible as there are no such population-level data to investigate suicide deaths according to these categories.

Educational attainment was classified according to the ISCED-97 (International Standard Classification of Education, 1997 version) system [31, 32]: less than eight years of primary school (ISCED level 0–1A), eight years of primary school (2A), vocational qualification without secondary school-leaving certificate (vocational schools, 2C–3C), secondary school-leaving certificate (secondary vocational schools and grammar schools, 3A) and higher education degree (colleges and universities, 5A). In line with the above, population data were only available from 1998 (and only for the 15–74-year-old age group).

Data on both the population and number of deaths due to suicide were classified by *age group* as follows: 0–19 years ("youth"), 20–34 years ("young adults"), 35–49 years ("middle-aged adults"), 50-64 years ("older adults") and over 65 years ("elderly"/pensioners).

For the general population, age-specific death rates were calculated. The suicide mortality rates were directly standardised by age [28] using the *Revised European Standard Population* (RESP) published in 2013 [33] to make comparisons possible. The population distribution of RESP is the following: 0-19 years 21.5%, 20-34 years 18.5%, 35-49 years 21%, 50-64 years 19.5%, and over 65 years 19.5% of the population.

4. RESULTS

4.1. Seasonal variation of mortality from external causes in Hungary

Overall, 154,211 deaths from external causes (66.3% males and 33.7% females) were registered in Hungary during the period 1995-2014. Suicide/self-harm, accidental falls and traffic accidents were the most common causes with 53,769 (34.9%), 51,015 (33.1%) and 24,367 (15.8%) deaths, respectively (*Table 2*).

	Traffic	Falls	Drowning	Other drowning	Electric current	Cold-heat	Alcohol	Other	Suicide	Assault
OVERALL										
0-19	1362	0	306	62	0	6	0	41	606	48
20-34	5525	130	281	25	30	28	0	421	6135	117
35-59	10329	7076	1386	2176	188	3239	120	3197	27635	1668
60-	7151	43809	540	2685	13	3699	0	3976	19393	808
Total	24367	51015	2513	4948	231	6972	120	7635	53769	2641
Male										
0-19	1034	0	275	53	0	6	0	28	559	28
20-34	4947	130	281	25	30	25	0	409	5666	105
35-59	8475	6140	1310	1825	185	2772	114	2775	22232	1175
60-	4839	17310	450	1503	9	2123	0	2017	13074	382
Total	19295	23580	2316	3406	224	4926	114	5229	41531	1690
Female										
0-19	328	0	31	9	0	0	0	13	47	20
20-34	578	0	0	0	0	3	0	12	469	12
35-59	1854	936	76	351	3	467	6	422	5403	493
60-	2312	26499	90	1182	4	1576	0	1959	6319	426
Total	5072	27435	197	1542	7	2046	6	2406	12238	951

Table 2. Total numbers of deaths from external causes by gender and age group in Hungary during 1995-2014.

As was the case with the crude numbers and age-specific mortality rates, the highest age-standardised rate was also detected in the case of *suicide and self-harm* with an ASMR of 24.06 per 100,000 persons per year (95% CI: 23.86–24.26). The largest number of suicides (more than half of all cases) was found in the age group 35-59 years; however, the highest age-specific mortality rate with 45.07 per 100,000 persons per year was observed in the group aged over 60 years (*Table 3*).

	Traffic	Falls	Drown.	Other drown.	Electr. current	Cold-heat	Alcohol	Other	Suicide	Assault
OVERALL										
0-19	0.879	0.000	0.197	0.040	0.000	0.004	0.000	0.026	0.391	0.031
20-34	2.647	0.062	0.135	0.012	0.014	0.013	0.000	0.202	2.940	0.056
35-59	5.053	3.461	0.678	1.064	0.092	1.584	0.059	1.564	13.518	0.816
60-	2.659	16.292	0.201	0.999	0.005	1.376	0.000	1.479	7.212	0.300
ASMR	11.238	19.816	1.211	2.115	0.111	2.977	0.059	3.271	24.061	1.203
LB (95%CI)	11.097	19.644	1.164	2.056	0.097	2.907	0.048	3.197	23.857	1.158
UB (95%CI)	11.379	19.987	1.258	2.174	0.126	3.047	0.069	3.344	24.264	1.249
Male										
0-19	1.303	0.000	0.347	0.067	0.000	0.008	0.000	0.035	0.704	0.035
20-34	4.468	0.122	0.264	0.023	0.028	0.023	0.000	0.384	5.234	0.099
35-59	8.535	6.184	1.319	1.838	0.186	2.792	0.115	2.795	22.390	1.183
60-	4.640	16.598	0.431	1.441	0.009	2.036	0.000	1.934	12.536	0.366
ASMR	19.127	22.904	2.361	3.369	0.223	4.858	0.115	5.148	40.955	1.684
LB (95%CI)	18.857	22.612	2.265	3.256	0.194	4.723	0.094	5.009	40.561	1.603
UB (95%CI)	19.397	23.196	2.458	3.483	0.252	4.994	0.136	5.288	41.349	1.764
Female										
0-19	0.434	0.000	0.041	0.012	0.000	0.000	0.000	0.017	0.062	0.026
20-34	0.565	0.000	0.000	0.000	0.000	0.003	0.000	0.012	0.459	0.012
35-59	1.763	0.890	0.072	0.334	0.003	0.444	0.006	0.401	5.139	0.469
60-	1.405	16.098	0.055	0.718	0.002	0.957	0.000	1.190	3.839	0.259
ASMR	4.167	16.988	0.168	1.064	0.005	1.405	0.006	1.620	9.498	0.766
LB (95%CI)	4.052	16.787	0.145	1.011	0.001	1.344	0.001	1.556	9.330	0.717
UB (95%CI)	4.282	17.189	0.191	1.117	0.009	1.465	0.010	1.685	9.667	0.815

Table 3. Age-standardised mortality rates from external causes (per 100,000 population) in Hungary during 1995-2014.

Both in view of crude numbers and age-standardised mortality rates, the second most frequent death cause was *accidental falls* with an ASMR of 19.82 per 100,000 persons per year (95% CI: 19.64-19.99). In the age group below 20 years, there was no death from this cause at all.

This was the only death cause to have had more (even in crude numbers) female victims than male ones (53.8% and 46.2%, respectively). There were many more men among the victims of this external cause in the group aged 35-59 years (the age-specific mortality rates were 18.19 and 2.62 per 100,000 persons per year, respectively). In the age group 20-34 years, there were no female victims of this death cause at all.

However, the excess of deaths from this cause in the above-60 age group was enough for women to 'surpass' men even proportionately – even if this difference was not significant (25.12 versus 24.61 per 100,000 persons per year).

The third most prevailing death cause was *traffic accidents* with an ASMR of 11.24 per 100,000 persons per year (95% CI: 11.10-11.38). Although most cases of death due to traffic accidents were registered in the age group 35-59 years, the highest age-specific mortality rate was found in the group aged over 60 years (*Table 3*).

Nearly four-fifths (79.2%) of the traffic accident victims were men and there were (both in crude numbers and proportionately) more male victims in each of the age groups. The difference between males and females was most noticeable in the group aged 20-34 years (22.14 versus 2.69 per 100,000 persons per year).

The next most prevalent external cause (cold/heat-related accidents) was already nearly one order of magnitude smaller (in terms of mortality rates) than the leading one (suicide/self-harm). All the results concerning this death cause, together with the other ones not mentioned above were presented only in tabular form.

4.1.1. Annual trends in mortality

The NB regression model for annual age-standardised data revealed a declining trend in the yearly ASMRs for all types of death from external causes except for *other causes* (IRR: 1.014, 95% CI: 1.006–1.021; $p < 0.001$) during the study period (*Figure 3*). However, in the case of *drowning-related death causes* (7-8), the annual trend was significant ($p < 0.001$) only for males. Furthermore, the annual trend for *accidental poisoning and exposure to alcohol* (13) was also significant ($p = 0.038$); however, in the case of males – they accounted for the 95% of the victims – it was no longer significant ($p = 0.057$).

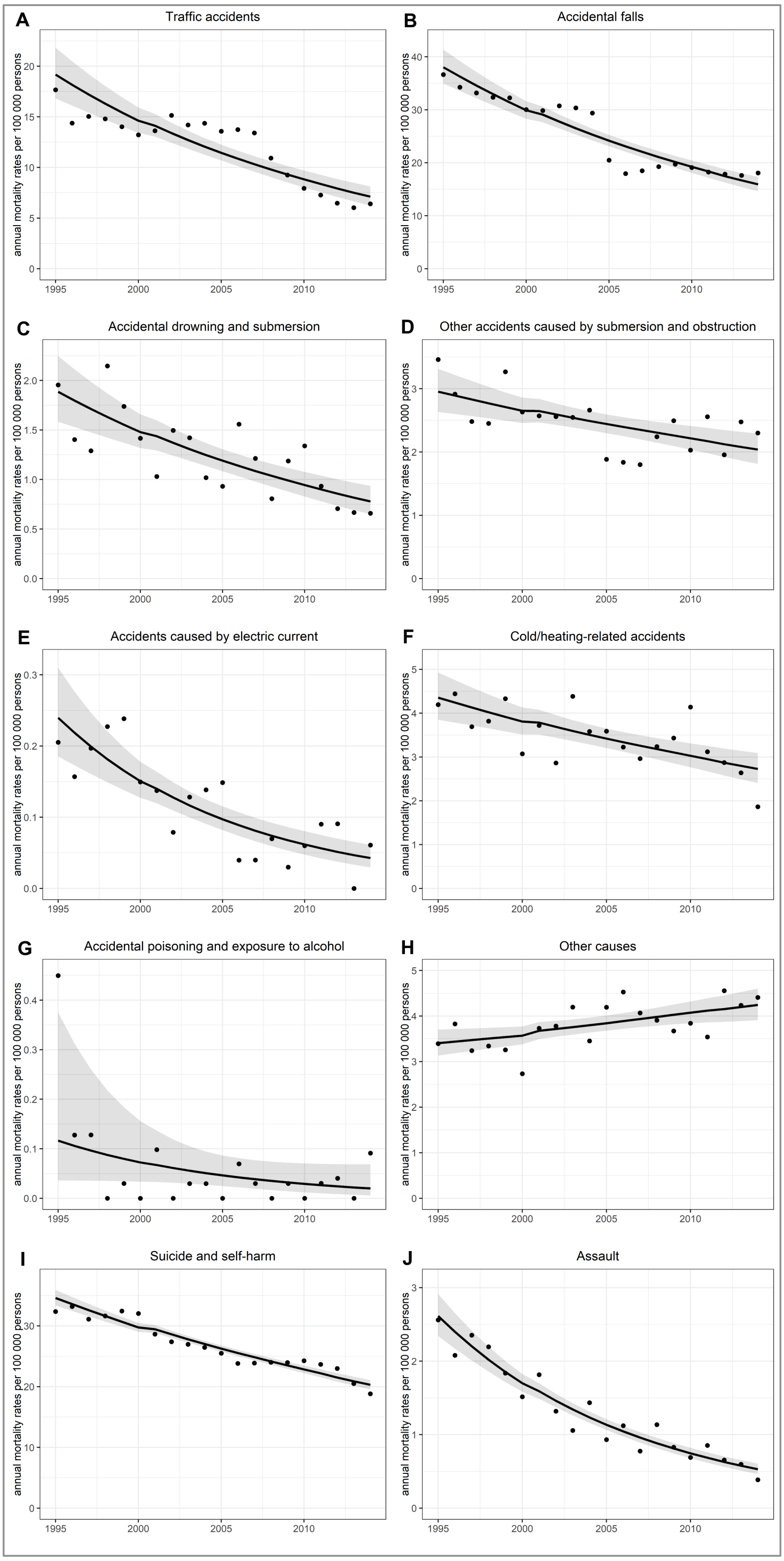

Figure 3. Annual trends of deaths from external causes in Hungary during 1995-2014.

Annual mortality rates per 100,000 persons: observed (points) and fitted rates (dashed lines) with confidence intervals (grey bands) obtained from negative binomial regression.

Referring to the leading external death causes, the annual trend was significant ($p < 0.001$) for each one of them. The annual suicide rate declined by 48.2% from the maximum of 30.5 per 100,000 persons in 1995 to the minimum of 15.8 per 100,000 persons in 2014. There was an IRR trend per annum of 0.974 (95% CI: 0.971–0.977). A similar decreasing trend was detected for the annual rate of deaths due to accidental falls (from 31.2 to 12.2, by 60.9%) and traffic accidents (from 17.2 to 5.4, by 68.6%) with an annual IRR of 0.957 (95% CI: 0.950–0.964) and 0.951 (95% CI: 0.939–0.963), respectively.

Annual trends were displayed by gender (in cases where the results were significant for both sexes) in *Figure 4*.

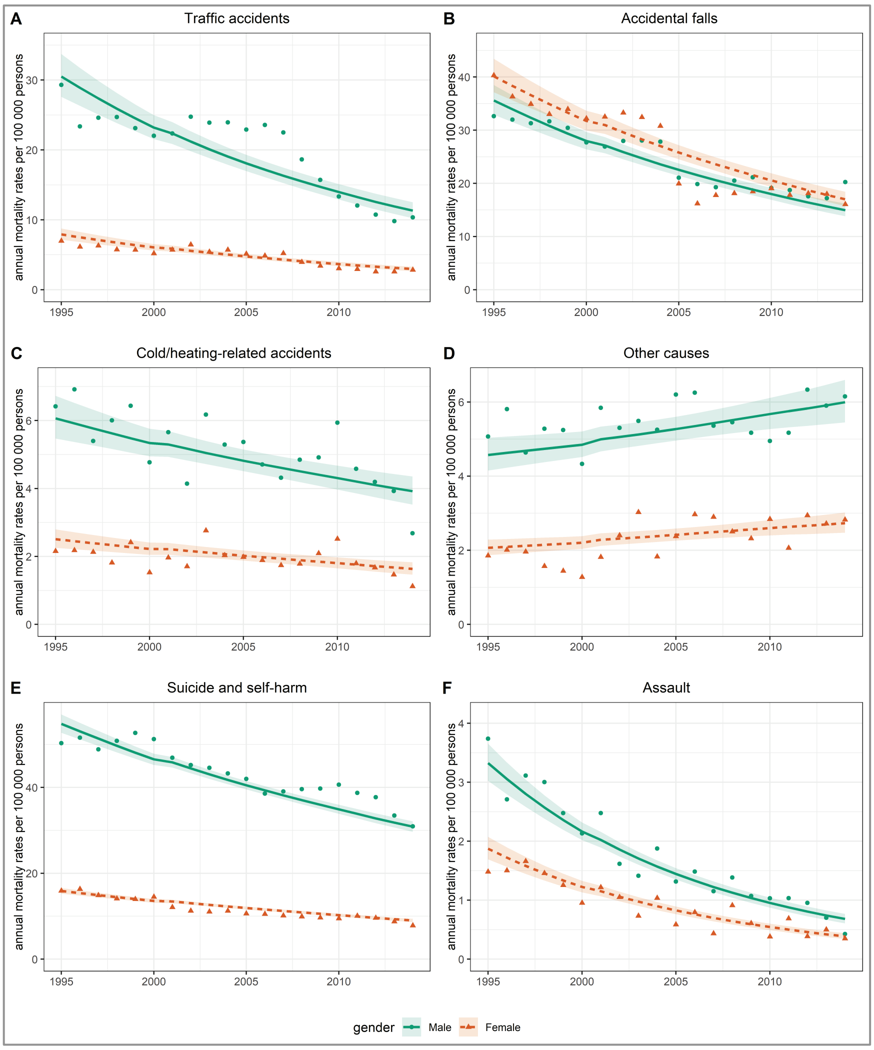

Figure 4. Annual trends of deaths from external causes by gender in Hungary during 1995-2014.

Annual mortality rates per 100,000 persons: observed (points) and fitted rates (dashed lines) with confidence intervals (bands) obtained from negative binomial regression.

4.1.2. Seasonal trends

The aggregated numbers of deaths are summarised in *Table 4*. The overall number of the deaths from *suicide and self-harm* was the highest among all deaths from external causes. Regarding the overall number of external-cause deaths December was the most frequent month of the year.

	Traffic	Falls	Drown.	Other drown.	Electr. current	Cold -heat	Alcohol	Other	Suicide	Assault	Overall
Jan.	1671	4691	75	448	0	1573	10	726	3838	226	13258
Feb.	1392	3999	97	404	3	1141	16	619	3647	188	11506
Mar.	1611	4340	160	484	0	727	8	633	4758	270	12991
Apr.	1736	4120	129	453	4	312	18	561	4875	223	12431
May	1870	4166	170	382	16	133	8	629	5139	211	12724
June	2077	4206	443	354	81	60	3	607	5010	215	13056
July	2230	4163	639	330	73	59	9	614	5182	215	13514
Aug.	2355	3975	462	328	42	86	6	553	4958	224	12989
Sept.	2328	3956	118	375	9	140	6	631	4581	192	12336
Oct.	2639	4612	54	463	0	382	3	698	4261	209	13321
Nov.	2234	4157	89	407	3	805	20	675	3845	230	12456
Dec.	2224	4630	77	520	0	1554	13	689	3675	238	13620
Total	24367	51015	2513	4948	231	6972	120	7635	53769	2641	154211

Table 4. The monthly numbers of deaths from external causes in Hungary during 1995-2014.

Using the Walter-Elwood method, a significant cyclic trend was found in the monthly deaths from each kind of external cause except for *accidental poisoning / exposure to alcohol* (*Table 5*).

	Traffic	Falls	Drown.	Other drown.	Electric current	Cold-heat	Alcohol	Other	Suicide	Assault
					OVERALL					
IRR	0.951	0.957	0.956	0.983	0.916	0.978	0.913	1.014	0.974	0.921
95% CI	0.939	0.950	0.941	0.973	0.894	0.966	0.838	1.006	0.971	0.911
	0.963	0.964	0.972	0.993	0.938	0.989	0.995	1.021	0.977	0.931
p for annual trend	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.038	<0.001	<0.001	<0.001
Dev. GoF	0.327	0.329	0.333	0.325	0.060	0.315	0.222	0.322	0.321	0.270
peak season	Sep	Dec	June/July	Jan	July	Jan	Jan/Feb	Dec	June	Feb
p for season.							NS			NS
Dev. GoF	0.209	0.214	0.204	0.227	0.003	0.308		0.203	0.210	
					Male					
IRR	0.952	0.965	0.955	0.974	0.921	0.975	0.914	1.007	0.977	0.918
95% CI	0.939	0.959	0.941	0.964	0.899	0.964	0.833	1.000	0.973	0.910
	0.964	0.971	0.969	0.984	0.943	0.985	1.003	1.014	0.980	0.926
p for annual trend	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.057	0.039	<0.001	<0.001
Dev. GoF	0.326	0.318	0.353	0.323	0.073	0.304		0.321	0.323	0.265
peak season	Sept	Oct/Nov	June/July	Jan	July	Jan	Jan/Feb	Nov	June	Apr/May
p for season.		NS					NS			NS
Dev. GoF	0.204		0.205	0.223	0.001	0.159		0.260	0.209	
					Female					
IRR	0.951	0.950	0.979	1.002		0.985		1.029	0.966	0.928
95% CI	0.941	0.948	0.901	0.986		0.972		1.014	0.962	0.918
	0.961	0.952	1.064	1.017		0.999		1.043	0.970	0.939
p for annual trend	<0.001	<0.001	0.621	0.837		0.032		<0.001	<0.001	<0.001
Dev. GoF	0.330	0.328				0.322		0.314	0.336	0.229
peak season	Sept/Oct	Jan	July	Feb		Jan		Dec/Jan	June/July	Jan
p for season.										NS
Dev. GoF	0.216	0.216	0.120	0.228		0.636		0.196	0.205	

Table 5. Annual and seasonal trends of deaths from external causes in Hungary during 1995-2014.

There was significant seasonality in the mortality rates from *accidental falls* (*Figure 5B*) with a winter peak (peak in December). A winter peak was also detected in the mortality rates from *other accidents caused by submersion/obstruction* (January) (*Figure 5D*) and cold/heat-related accidents (January/February) (*Figure 5F*). There was also a significant peak for *other causes* (in December) (*Figure 5G*); however, it is a heterogeneous group of external death causes and so needs to be treated with caution.

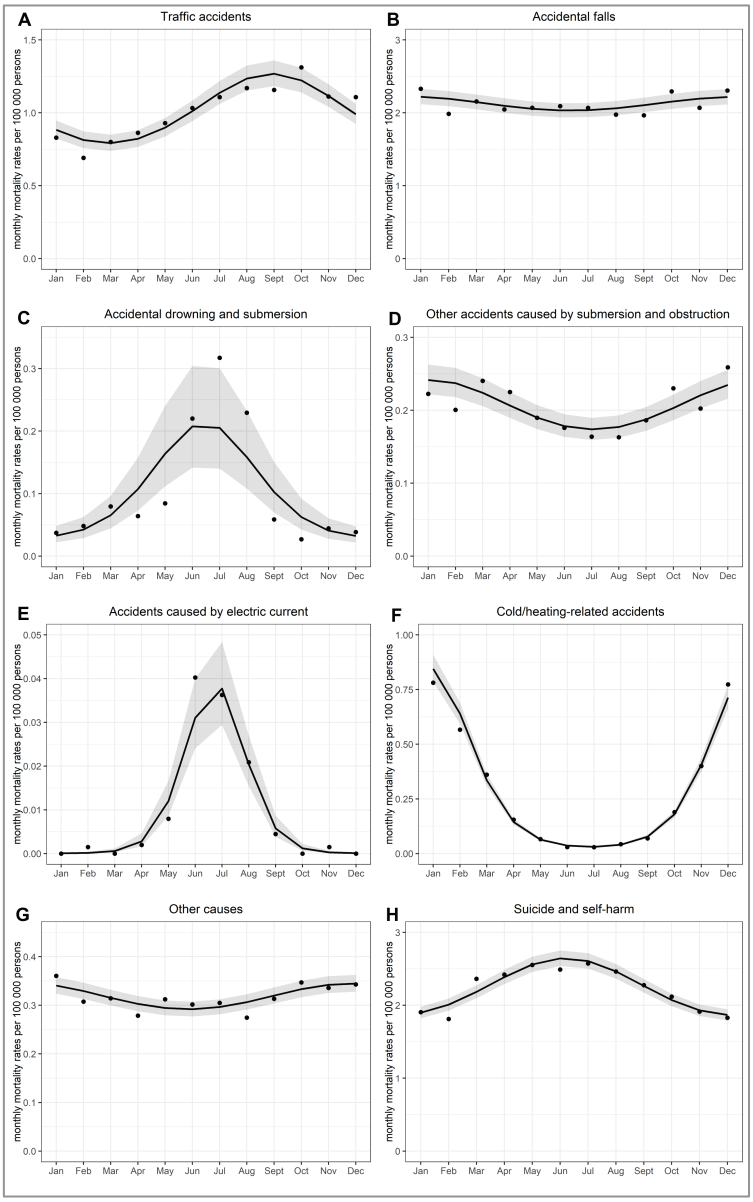

Figure 5. Seasonal trends of deaths from external causes in Hungary during 1995–2014.

Monthly mortality rates per 100,000 persons: observed (points) and fitted rates (dashed lines) with confidence intervals (grey bands) obtained from negative binomial regression.

The Water-Elwood method revealed significant seasonality in the mortality rates from *suicide/self-harm* (*Figure 5H*) with a summer peak (June). A summer peak was also observed in the mortality rates from *accidental drowning/submersion* (June/July) (*Figure 5C*) and *accidents caused by electric current* (July) (*Figure 5E*). The mortality rates from traffic accidents peaked significantly in September (*Figure 5A*). However, no more cyclical variation was discovered in the mortality rates either from any other kind of external-cause deaths or from all external causes combined.

It is worth noting that, in the case of accidental falls, the seasonality was significant only for females; for the other types of external death causes, there was no such difference between men and women (*Table 5*).

Seasonal trends were displayed by gender (in cases where the results were significant for both sexes) in *Figure 6*.

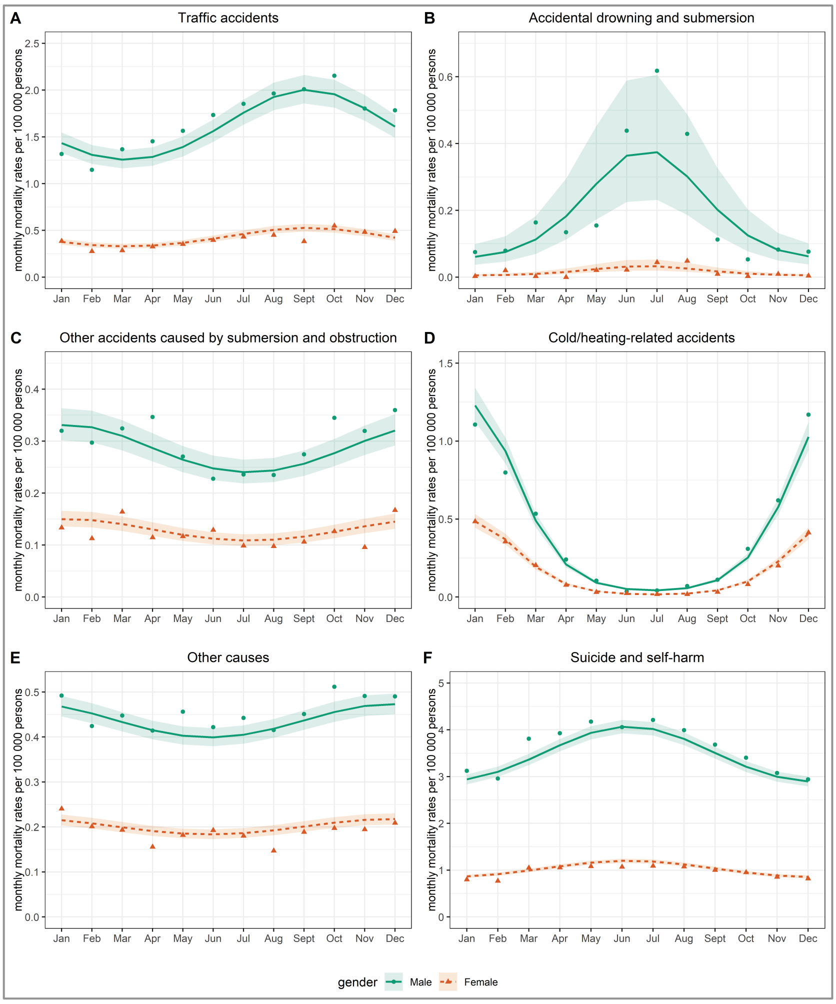

Figure 6. Seasonal trends of deaths from external causes by gender in Hungary during 1995-2014.

Monthly mortality rates per 100,000 persons: observed (points) and fitted rates (dashed lines) with confidence intervals (bands) obtained from negative binomial regression.

NB regression models confirmed the findings obtained by the Walter-Elwood method. There was no significant double peak model of seasonality.

4.2. Patterns of suicide deaths in Hungary

In total, 60,210 suicide deaths (45,753 males and 14,457 females; 76% and 24%, respectively) were registered in Hungary during the 1995–2017 period. The over 35s (the groups aged 35–49, 50-64 and over 65 years, combined) accounted for more than six-sevenths of all victims (51,793 cases, 86%).

Hanging, self-poisoning by drugs and jumping from a height were the most common (specified) methods of suicide, with 37,594 (62.4%), 7,133 (11.8%) and 3,864 (6.4%) deaths, respectively.

4.2.1. The pattern of suicide by sociodemographic factor

Table 6 displays summary statistics for suicide cases and suicide rates (expressed as deaths per 100,000 people at risk) in Hungary during the study period by sociodemographic subgroup.

Subgroup	Population	Number of deaths	SR (95%CI)	1995-2017 SR change	Male-to-Female ratio (95%CI)
GENDER					
Male	110,006,527	45,753	41.6 (41.2-42)	-47%	3.48 (3.42-3.55)
Female	121,048,933	14,457	12 (11.8-12.2)	-54%	
AGE GROUP					
0-19 years	51,144,509	1,075	2.1 (2-2.2)	-47%	3.49 (3.01-4.06)
20-34 years	49,422,180	7,342	14.9 (14.5-15.2)	-48%	5.25 (4.92-5.59)
35-49 years	49,339,387	17,234	34.9 (34.4-35.5)	-67%	4.33 (4.18-4.48)
50-64 years	44,316,074	17,467	39.4 (38.8-40)	-46%	3.87 (3.75-4)
above-65 years	36,833,310	17,092	46.1 (45.4-46.8)	-55%	3.33 (3.23-3.44)
STATISTICAL (NUTS2) REGION					
Central Hungary	66,711,903	14,378	21.6 (21.2-21.9)	-48%	2.55 (2.47-2.65)
Central Transdanubia	25,277,988	5,720	22.6 (22-23.2)	-41%	3.86 (3.63-4.12)
Western Transdanubia	22,864,409	4,186	18.3 (17.8-18.9)	-35%	4.3 (3.98-4.64)
Southern Transdanubia	22,086,841	5,392	24.4 (23.8-25.1)	-51%	3.66 (3.43-3.9)
Northern Hungary	28,566,295	7,258	25.4 (24.8-26)	-57%	4 (3.78-4.24)
Northern Great Plain	34,926,322	11,553	33.1 (32.5-33.7)	-52%	3.84 (3.68-4.02)
Southern Great Plain	30,621,702	11,225	36.7 (36-37.3)	-50%	3.72 (3.56-3.89)
MARITAL STATUS (WHOLE POPULATION)					
Married	94,759,906	24,791	26.2 (25.8-26.5)	-56%	4.34 (4.2-4.48)
Not married	136,295,554	35,375	26 (25.7-26.2)	-46%	3.06 (2.99-3.14)
MARITAL STATUS (ABOVE-20 AGE GROUP)					
Married	94,634,867	24,783	26.2 (25.8-26.5)	-56%	4.34 (4.2-4.48)
Not married	85,276,084	34,274	40.2 (39.8-40.7)	-60%	3.44 (3.36-3.52)
EDUCATIONAL ATTAINMENT					
0-7 grades	5,581,765	2,757	49.4 (47.6-51.2)	-38%	3.98 (3.66-4.32)
Primary School	42,641,140	16,697	39.2 (38.6-39.8)	-32%	4.51 (4.35-4.68)
Vocational School	35,930,581	11,399	31.7 (31.1-32.3)	-62%	4.82 (4.54-5.13)
Secondary Education	45,724,284	7,723	16.9 (16.5-17.3)	-37%	3.38 (3.22-3.56)
Higher Education	23,638,192	2,691	11.4 (11-11.8)	-41%	2.91 (2.68-3.17)

Table 6. Descriptive statistics of suicide cases and crude suicide rates by sociodemographic factor in Hungary during 1995-2017.

4.2.1.1. Gender

The crude numbers and rates are displayed in *Table 6*. The suicide rate (SR) is about three-and-a-half times higher among men than among women (41.6 versus 12 per 100,000 persons per year).

4.2.1.2. Age group

The male-to-female ratio was the highest in the group aged 20–34 years (5.25), then this ratio declined progressively towards the older age groups, reaching a minimum of 3.33 in the group aged over 65 years.

Age group	1995		2017		1995-2017	
	Number of deaths	Age-spec. mort. rate	Number of deaths	Age-spec. mort. rate	Number of deaths	Age-spec. mort. rate
OVERALL						
0-19	82	3.05	31	1.62	1075	2.12
20-34	414	19.89	189	10.39	7342	14.89
35-49	1065	46.66	355	15.53	17234	34.93
50-64	821	46.98	493	25.4	17467	39.41
65-	984	68.18	565	30.70	17092	46.14
Total	3366	32.91	1633	16.68	60210	26.09
ASSR (95% CI)	36.69 (35.45-37.93)		16.5 (15.7-17.2)		27.27 (27.05-27.49)	
MALE						
0-19	73	5.31	21	2.14	844	3.25
20-34	338	31.90	170	18.19	6206	24.67
35-49	859	76.21	277	24.05	13971	56.94
50-64	591	74.38	363	39.79	13413	65.68
65-	614	112.83	409	58.90	11319	82.50
Total	2475	50.57	1240	26.53	45753	41.64
ASSR (95% CI)	59.69 (57.34-62.04)		28.2 (26.63-29.77)		46.2 (45.77-46.62)	
FEMALE						
0-19	9	0.69	10	1.07	231	0.93
20-34	76	7.44	19	2.15	1136	4.70
35-49	206	17.83	78	6.88	3263	13.16
50-64	230	24.13	130	12.64	4054	16.97
65-	370	41.16	156	13.62	5773	24.75
Total	891	16.70	393	7.68	14457	11.95
ASSR (95% CI)	18.06 (16.87-19.24)		7.21 (6.49-7.92)		11.99 (11.8-12.19)	

Table 7. Numbers of suicide deaths and suicide rates (per 100,000 population) in 1995, 2017, and during 1995-2017.

4.2.1.3. Age-specific rates

The age group with the largest number of suicides was different: the group aged between 50 and 64 years (29% of all cases) overall, the 35-49-year-old age group (30.5%) for males and the group aged over 65 years (39.9%) for females, respectively. However, the highest age-specific suicide rates were observed in the latter age group both overall and by gender. Both in the whole population and by gender, growing rates were detected across age groups.

During the 1995–2017 period, all these age-specific rates fell (by slightly different extent: 47–67%). Similar drops can be observed gender-wise, with one exception: the rate for women aged under 20 years rose (from 0.69 to 1.07 per 100,000 persons, meaning an increase of 57%). In view of crude numbers, this represents only one additional victim in 2017 compared to nine suicide cases in 1995 (the corresponding population at risk declined by about 30%).

However, it is worth noting that the number of suicide deaths for men in the same age group fell from 73 to 21 over the course of these 23 years. As a result, while there were eight times as many male victims as female ones in the age group below 20 years in 1995, there were barely more than twice as many in 2017.

4.2.1.4. Age-standardised rates

In the total population, the ASSR between 1995 and 2017 was 27.27 per 100,000 persons per year (95% CI: 27.05–27.49). In the male and female subpopulations, the ASSRs during the same period were 46.2 (45.77–46.62) and 11.99 (11.8–12.19), respectively.

In 1995, the annual suicide rate was 36.69 per 100,000 persons (95% CI: 35.45–37.93); in 2017, the same rate was less than half of that: 16.5 (15.7–17.3). During the 23 years of the study, these rates were similarly halved for both genders: there was a decrease for males from 59.69 (57.34–62.04) to 28.2 (26.63–29.77) and for females from 18.06 (16.87–19.24) to 7.21 (6.49–7.92).

4.2.1.5. Region

Western Transdanubia had the lowest suicide rates, both in 1995 and 2017, as well as in the whole period (also by gender); similarly, the Southern Great Plain had the highest rates in every respect.

However, there were also major changes in the order of rates: while Central Hungary fell from second place in 1995 to fifth place in 2017, Northern Hungary rose from fifth place to second place in the same period.

The male-to-female ratio was the lowest in Central Hungary (2.55) and the highest in Western Transdanubia (4.3).

4.2.1.6. Marital status

In the whole population, the suicide rate was nearly the same for married persons and non-married ones. This apparent contradiction is resolved by the fact that there are few married persons in the age group below 20 years (and very few of them die of suicide).

If only the subpopulation over the age of 20 was considered, the mortality rate for unmarried persons was more than 1.5 times higher (40.2 versus 26.2 per 100,000 persons per year). These rates decreased to a similar extent (by 56–60%) between 1995 and 2017 in the two groups. The male-to-female ratio was about 25% higher in the married subpopulation (4.34 versus 3.44).

4.2.1.7. Educational attainment

During the 20-year period under examination, 1998–2017, suicide rates gradually decreased with higher levels of education. This was also the case for 2017; however, in 1998, primary school non-completers were not far behind vocational school graduates in this respect. In 19 years, the suicide rate for the latter group dropped to nearly one-third (which was by far the biggest drop among the groups).

The largest male-to-female ratio was also observed in this group (4.82); after that, this ratio fell progressively towards those with higher educational attainment, reaching its minimum (2.91) in the most educated group (people with a college/university degree).

4.2.2. Risk factors

Table 8 shows incidence rates for groups within categories (compared to the group with the lowest risk of suicide in the category i.e. the *reference group*) obtained from the NB regression.

Subgroup	OVERALL		MALE		FEMALE	
	IRR (95% CI)	p-value	IRR (95% CI)	p-value	IRR (95% CI)	p-value
AGE GROUP						
0-19 years	1	p<0.001	1	p<0.001	1	p<0.001
20-34 years	7.56 (6.94-8.23)		8.31 (7.54-9.16)		4.97 (4.24-5.82)	
35-49 years	18.27 (16.74-19.94)		19.34 (17.52-21.36)		15.8 (13.62-18.34)	
50-64 years	20.7 (19.09-22.45)		22.32 (20.33-24.5)		20.9 (18.09-24.19)	
above-65 years	23.71 (21.76-25.83)		27.87 (25.32-30.68)		30 (25.81-34.89)	
STATISTICAL (NUTS2) REGION						
West. Transdan.	1	p<0.001	1	p<0.001	1	p<0.001
Central Hungary	1.18 (1.12-1.24)		1.05 (1-1.11)		1.93 (1.76-2.12)	
Central Transdan.	1.24 (1.18-1.3)		1.21 (1.14-1.27)		1.43 (1.29-1.59)	
South. Transdan.	1.33 (1.26-1.4)		1.3 (1.22-1.38)		1.63 (1.47-1.81)	
North. Hungary	1.39 (1.32-1.46)		1.38 (1.3-1.46)		1.6 (1.45-1.77)	
North. Gr. Plain	1.81 (1.72-1.9)		1.77 (1.67-1.87)		2.16 (1.96-2.38)	
South. Gr. Plain	2 (1.91-2.11)		1.96 (1.85-2.07)		2.46 (2.24-2.71)	
MARITAL STATUS (WHOLE POPULATION)						
Not married	1	p=0.702	1	p=0.042	1.35 (1.28-1.43)	p<0.001
Married	1.01 (0.97-1.05)		1.05 (1-1.09)		1	
MARITAL STATUS (ABOVE-20 AGE GROUP)						
Married	1	p<0.001	1	p<0.001	1	p<0.001
Not married	1.54 (1.47-1.62)		1.59 (1.51-1.67)		2 (1.88-2.12)	
EDUCATIONAL ATTAINMENT						
Higher Educ.	1	p<0.001	1	p<0.001	1	p<0.001
Secondary Educ.	1.55 (1.47-1.64)		1.7 (1.6-1.81)		1.49 (1.36-1.63)	
Vocational School	2.97 (2.81-3.13)		2.7 (2.54-2.87)		1.59 (1.43-1.76)	
Primary School	3.67 (3.47-3.88)		4.27 (4-4.55)		2.75 (2.51-3.01)	
0-7 grades	4.29 (3.96-4.65)		5.12 (4.66-5.62)		4.03 (3.58-4.54)	

Table 8. Incidence rate ratios for suicide in Hungary during 1995-2017 by single risk factor (using NB regression).

The risk of suicide was significantly ($p < 0.001$) higher in men than in women: a nearly three-and-a-half times larger incidence rate was detected during the study period (IRR = 3.48).

An increasing suicide risk was observed across age groups: the incidence rate (compared to the age group below 20 years) for groups aged 20–34 years, 35–49 years, 50–64 years and over 65 years was 7.56 (95% CI: 6.94–8.23), 18.27 (16.74–19.94), 20.7 (19.09–22.45) and 23.71 (21.76–25.83), respectively.

Western Transdanubia had the lowest risk of suicide among the regions. The incidence rate ratios (incidence rate compared to that region) in the next four regions (in this respect) were between 1.18 and 1.39; however, the suicide risk in the two worst regions was about twice as high (the Northern and Southern Great Plain: IRR = 1.81 and IRR=2).

In the whole population, there was no significant difference ($p = 0.714$) between incidence rates for married persons and non-married ones; however, for the subpopulation aged over 20 years only, the suicide risk was significantly ($p < 0.001$) higher for married persons than for non-married ones (IRR = 1.54). We also examined the suicide risk for unmarried persons in the subpopulation aged over 15 years, which showed a slight decrease (IRR: 1.35, 95% CI: 1.29–1.41; $p < 0.001$).

A significant growing trend in suicide risk was detected among those with lower educational attainment: the incidence rate (compared to the most educated group i.e. people with a college/university degree) for people completing secondary, vocational and primary school, and primary school drop-outs was 1.55 (95% CI: 1.47–1.64), 2.97 (2.81–3.13), 3.67 (3.47–3.88) and 4.29 (3.96–4.65), respectively.

4.2.3. General trends

The NB regression model for annual data (*Figure 7*) revealed a declining trend in the yearly suicide rates (IRR: 0.972, 95% CI: 0.969–0.975; $p < 0.001$). A similar significant ($p < 0.001$) decreasing trend was detected both for males (IRR: 0.972, 95% CI: 0.969–0.976) and females (IRR: 0.969, 95% CI: 0.966–0.972).

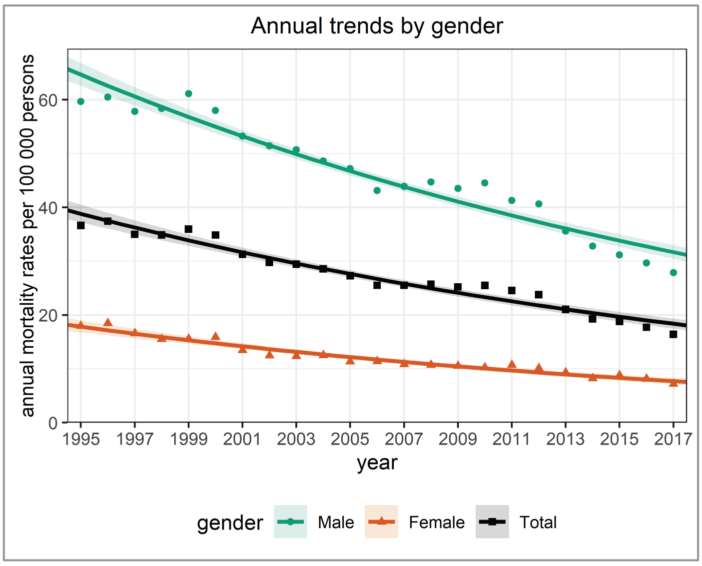

Figure 7. Annual trends of suicides by gender in Hungary during 1995-2017.

Annual suicide rates per 100,000 persons: observed (points) and fitted rates (solid lines) with confidence intervals (bands) obtained from negative binomial regression.

Using the Edwards test, a significant ($p < 0.001$) cyclical trend was found in monthly suicide deaths with a peak at the end of June. There was a similar significant ($p < 0.001$) seasonal pattern in suicide rates with a peak in June for both sexes, and there was essentially no gender difference in the peak (the difference was only a week). Seasonal investigations on a quarterly basis led to similar results: a significant ($p < 0.001$) peak at the end of Q2 (both overall and by gender).

4.2.4. *Seasonality by risk factor*

Table 9 displays seasonal trends in Hungary by subgroup during the 23 years of the study.

Subgroup	Seasonal peak	Angle	p-value	Amplitude	Goodness of Fit
GENDER					
Female	late-June	177.1	<0.001	0.149	0.424
Male	mid-June	169.8	<0.001	0.169	0.4
AGE GROUP					
0-19 years	-	-	0.202	-	-
20-34 years	late-June	173.6	<0.001	0.087	0.305
35-49 years	early-June	157.7	<0.001	0.149	0.355
50-64 years	late-June	171.4	<0.001	0.167	0.371
above-65 years	early-July	180.1	<0.001	0.226	0.429
STATISTICAL (NUTS2) REGION					
Western Transdanubia	late-June	173.5	<0.001	0.182	0.285
Central Hungary	mid-June	162.2	<0.001	0.107	0.433
Central Transdanubia	late-June	179.4	<0.001	0.163	0.339
Southern Transdanubia	early-June	155.4	<0.001	0.158	0.409
Northern Hungary	late-June	179	<0.001	0.178	0.308
Northern Great Plain	late-June	172.3	<0.001	0.205	0.38
Southern Great Plain	late-June	173.5	<0.001	0.191	0.39
MARITAL STATUS (WHOLE POPULATION)					
Not married	late-June	175.1	<0.001	0.155	0.42
Married	mid-June	166.9	<0.001	0.178	0.368
MARITAL STATUS (ABOVE-20 AGE GROUP)					
Married	mid-June	166.9	<0.001	0.178	0.368
Not married	late-June	175.2	<0.001	0.158	0.389
EDUCATIONAL ATTAINMENT					
Higher Education	late-June	171	0.002	0.098	0.317
Secondary Education	mid-June	163.5	<0.001	0.115	0.427
Vocational School	mid-June	164.7	<0.001	0.146	0.377
Primary School	late-June	172.6	<0.001	0.172	0.343
0-7 grades	mid-June	168.6	<0.001	0.289	0.458

Table 9. Seasonal (monthly) trends of suicides by levels of a single factor in Hungary during 1995-2017.

Adding one of the significant risk factors to sine and cosine terms in the NB model, both the seasonal pattern and the factor remained significant. At each level of each factor, the number of suicide deaths reached its peak between early June and early July. Generally, no more than a half-month difference was detected in peaks in suicides within the levels of a given factor, except the region, for which the difference in peaks was almost a month. Goodness-of-fit (GoF) statistics for all models were tabulated.

4.2.5. *Seasonality by suicide method*

There were large differences in peaks by suicide method, as shown in *Figure 8*.

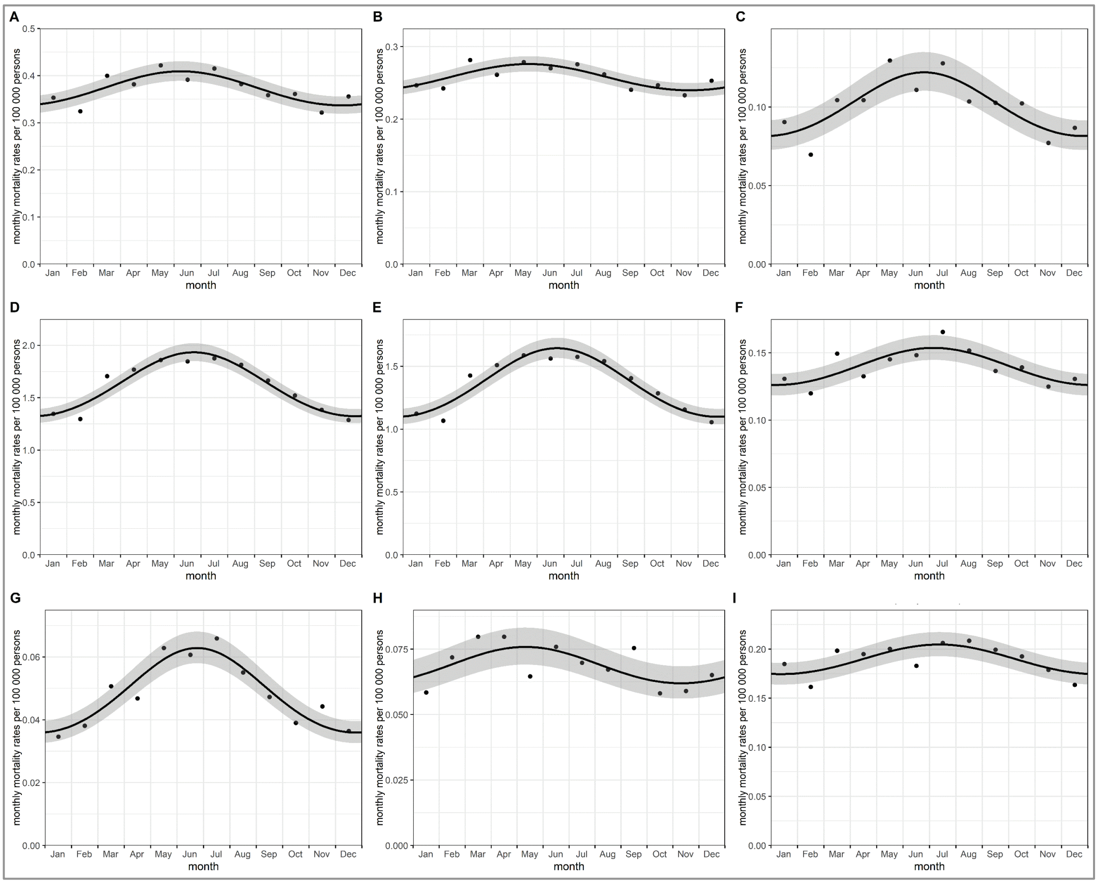

Figure 8. Seasonal (monthly) trends of suicides by suicide method in Hungary during 1995-2017.

A. NON-VIOLENT methods (combined): p<0.001 B. Self-poisoning by drugs: p<0.001 C. Self-poisoning by chemicals and other substances: p<0.001 D. VIOLENT methods (combined): p<0.001 E. Hanging: p<0.001 F. Jumping from a height: p<0.001 G. Drowning: p<0.001 H. Firearm: p=0.007 I. OTHER (unspecified) methods: p<0.001. Monthly suicide rates per 100,000 persons: observed (points) and fitted rates (solid lines) with confidence intervals (bands) obtained from negative binomial regression.

The peak of non-violent suicides was in early June; suicides committed by violent methods peaked half a month later, in late June. However, within violent and non-violent methods, there were differences of more than one month (for firearm and jumping from a height) and almost two months (for drug overdose and chemical poisoning), respectively. Furthermore, as regards all the suicide methods, a difference of more than two months was also detected. Quarterly peaks were nearly the same as those observed in a monthly breakdown.

5. Discussion

5.1. Seasonal variation of mortality from external causes in Hungary

5.1.1. Main findings

The leading external causes of death were suicide, unintentional falls and traffic accidents, accounting for more than five-sixths (83.8%) of the mortality from all external causes combined. The number of deaths due to external causes was higher (both in crude numbers and proportionately) for males in all four age groups; the smallest difference (in crude numbers) was found in the above-60 age group, which can be explained by the characteristics of the age pyramid (more females than males in this age group). Overall, this age group accounted for more than half (53.2%) of the external-cause mortality, which was attributable to the large number of fall-related (female) victims aged over 60. However, for males only, the leading age group was the one between 35 and 59 years (due to the large number of deaths from suicide and traffic accidents). Nonetheless, the highest age-specific rate for males was also observed in the group aged over 60.

Either significant seasonal variation peaking in winter or significant summer-peak seasonality was observed in most of the external-cause mortality rates. However, a significant cyclical variation with a peak in September was discovered in the death rates from traffic accidents. Nevertheless, no seasonal trend was found in the combined mortality from external causes.

Decreasing annual trends in the ASMRs for almost all kinds of death from external causes were found during the study period. Consequently, an improving tendency can be observed in Hungary relating to the mortality due to external causes. The annual rate declined by 55.9% from the maximum of 94.4 per 100,000 persons in 1995 to the minimum of 41.6 per 100,000 persons in 2014. This decrease is particularly important since the mortality from external causes is traditionally high in the Central and Eastern European Countries (CEECs).

However, Hungary is still far from the EU-15 average in respect to mortality rates due to external causes (nearly twice higher than the ones in EU-15). Furthermore, the decrease in deaths due to external causes is primarily attributable to the spectacular fall observed in accidental mortality. This is linked to the EU accession in 2004 and the directive that was introduced at this time, which makes it compulsory to install safety belt systems in all types of vehicles that are placed on the market. Nevertheless, we cannot fail to mention that Hungary had switched from manual coding of death causes to machine coding in the same year.

5.1.2. Strengths and limitations

The data were obtained from vital registers, which could have been influenced by a certain simplification of categorisation during the 20-year interval of the study. Additionally, the official Hungarian population estimates did not account for international migration in the period 1995-2001, which caused a sudden increase in population between 1999 and 2000. Although the vital statistics performance index of Hungary is one of the best in the world [34] and the percentage of garbage coded deaths is also quite low in Hungary [35], there can be cause-of-death biases (e. g. youth suicides registered as fatal traffic accidents or fatal falls/accidents due to circulatory diseases). However, we are confident that our results do reflect real trends.

Overdispersion did not influence our results as the NB regression method was employed in the investigation of annual mortality trend. One of the additional advantages of the present study is the analysis by gender.

The description of incidence rates in terms of seasonal variation or cyclic trends is important in many epidemiological studies since the population-level investigation can be utilised in the prevention. As far as we are aware, this is the first epidemiological study reporting the effect of seasonality for deaths from external causes in Hungary.

Environmental effects are involved in the aetiology of mortality. The available Hungarian monthly mean temperature [36] and precipitation [37] data generally supported these hypotheses for external-cause mortality. Unfortunately, there were no monthly (detailed) environmental data available to investigate causality more precisely. Despite daily temperature data being unavailable, heat-related seasonal effects were found in mortality from suicide, accidental drowning/submersion, and traffic accidents.

In the seasonality, monthly cyclic trend analyses, we applied the Walter-Elwood method, which is a generalisation of Edwards' test, specifically designed to investigate the seasonality of events with a variable population at risk. The Walter-Elwood test avoids difficulties relating to the former method: Edwards' test ignored any possibility of variation in the population at risk which might be responsible for the cyclic variation of the disease incidence, the test was sensitive to occasional extreme values [38], it suffered from lack of power for small sample sizes [39] and its assumption of equally spaced time intervals might not be fulfilled in practice. Additionally, the Walter-Elwood seasonality test has greater power for detecting seasonal trends following a sinusoidal pattern than the Pearson's χ^2 test [40].

5.1.3. Comparison with other studies

Several studies investigated annual trends in suicide [41-43]. In concordance with the results of Scandinavian studies, there was a significant decrease in the annual trend during the 20 years of investigation. In Hungary, despite the higher rate of decline, age-standardised suicide rate is still about 1.5 times higher than in the EU overall. Nevertheless, although Eastern Europe (Hungary, Lithuania) has become one of the leading geographical regions based on suicide mortality rates, there is now evidence of an increasing trend in Asia (particularly South Korea) [44].

Rihmer et al. investigated suicides from epidemiological and clinical aspects in Hungary, giving recommendations for prevention [3, 45]. Their studies highlighted the role of general practitioners (and health care workers, in general) in prevention: since most of the suicides associated with depression can be prevented, then further training in this area would be important.

In 2012, Hungary had started a major restructuring of its healthcare system; in the next two years, there was a decrease in suicide rates (*Figure 3I*). On the other hand, raising the standard of living, reducing unemployment, improving the quality of health and social care and the proper media communication on depression and suicide go beyond health care. Prevention programs focusing specifically on men would also be needed as they are generally more exposed to and susceptible to social and psychological stress [20]. As far as suicide prevention (especially) for the elderly is concerned, the education for the grieving process would be of high importance.

In a study published in 2015 [46], Majdan and Mauritz conducted research that studied the mortality from accidental falls among the elderly (>65 years) in two countries with a similar population pyramid to Hungary (Slovakia, Austria) between 2003 and 2010. A growing trend was found in Slovakia; however, a declining standardised annual trend was detected in Austria, as we did in Hungary. The difference was explained (at least partially) by the better health system.

In Hungary, a sharp drop in the number of fatal falls was observed in a certain year: from 2004 to 2005 (*Figure 3B*). We might assume that some regulations had a role in this decrease: a new decree on the professional rules for managing local public roads was adopted in 2004, which obliges municipalities to develop winter road management plans [Decree 5/2004 (I. 28.) of the Ministry of Economy and Transport (GKM) on the Professional Rules for the Management of Local Roads].

Hungary used to be the leading one among the countries with highest fall-induced mortality rates in the EU; in 2012, its place was taken by Slovakia in this respect. Consequently, the creation of appropriate regulatory background and its enforcement are important in the prevention of accidental falls.

Both death rates from suicide and falls were higher among the elderly; therefore, the development of a social and health care system that supports older people can be an important element of prevention.

Consistent with the results of other studies [47, 48], there was also a declining trend (especially since 2007; *Figure 3A*) in the mortality from traffic accidents in Hungary. This is likely to be the result of a restriction of the traffic law, with substantial changes in May 2008. One of the main elements of this regulation is that drunk driving is (even in international terms) strictly punishable ("zero tolerance"), and a high fine on the spot can be imposed even in the case of low alcohol consumption.

It is important to note that the 2007 amendment to the law had earned impressive media coverage; thereby, citizens were properly informed about the changes, which could also have contributed to a large decrease in accidents. We speculate that further limitations on speed in the Highway Code would have similar (positive) consequences.

The seasonality of suicide attempts (parasuicide) and completed suicide has been investigated in many countries earlier [41, 43, 49-53]. We focused on the latter, but the attempts can be also authoritative for suicide in this respect (approximately every tenth attempt is "successful"). The results of the studies mentioned above were the same as ours: late spring – early summer seasonality with a peak in May-June. The previous Hungarian studies [12, 16] came to similar conclusions. This result can be explained by the temperature and mood fluctuations (typical for the elderly) and by the phenomenon "relative unhappiness" caused by the increasing intensity of social activity [13, 18]. Christodoulou et al. stated in their overview that "the seasonal variation is evident in Eastern European countries"; however, they also mentioned that the seasonal association was weakening in Hungary [14, 51].

It would be important for general practitioners to know when suicide peaks: although the summer climax is no longer surprising for researchers in this area, it is much less known among GPs. Of course, not only health professionals are responsible for prevention; raising public awareness on suicide is also essential: since it is still a general misconception that winter holidays are the most depressive period of the year, depressed people get less attention in the summer when they would really need it.

Having investigated the seasonal variation in fall-induced fractures [54] and deaths [55] among the elderly (>65 years), previous studies identified cooler seasons and colder states as risk factors, respectively. This is consistent with the winter peak seasonality (peak in December) we obtained, which can also be explained by the slippery sidewalks and roads due to snow and ice [56].

Several studies on seasonality of injuries and deaths from traffic accidents reported late summer and early autumn seasonality [47, 57, 58]. The September peak obtained in our study is consistent with their results, which can be attributable to the drowsiness (dozing at the wheel, driving mistakes) due to the scorching sun and humidity.

5.2. Patterns of suicide deaths in Hungary

5.2.1. Strengths and limitations

The data were obtained from vital registers; although Hungary's vital statistics performance index is one of the best in the world [34], there may be cause-of-death biases (e.g. youth suicides registered as fatal traffic accidents). Additionally, the official Hungarian population estimates did not account for international migration in the period 1995-2001, which caused a sudden increase in population between 1999 and 2000. Despite the limitations of the published data, the trends and risk factors for suicide were calculated to present population-level processes as we believe that these are "negligible" at a population level for such a long period.

This epidemiological study on nationwide data relates to the risk of suicide by sociodemographic characteristic, such as gender, age group, region, marital status, and educational attainment. Instead of only reporting suicide mortality rates (or ASSRs), we used regression models to estimate trends in suicide deaths in Hungary between 1995 and 2017. Overdispersion did not influence our results, as the NB regression method was employed in both risk estimation and investigation of the annual mortality trend. We also used the Edwards test in the monthly cyclical trend analyses, which confirmed the findings of the NB regression model, as both yielded similar results. Furthermore, the longest study period available (from a public database) was used in these seasonality analyses. A description of incidence rates in terms of seasonal variation is important in many epidemiological studies, as it could lead to preventive measures. As far as we are aware, this is the first epidemiological study to investigate the seasonal variation of suicide deaths by NUTS2 region in such a detailed way in Hungary.

5.2.2. Main findings

Risk estimates of suicide rates were calculated by gender, age group, region, marital status, and educational attainment, highlighting a nearly three-and-a-half times greater risk in males than in females overall. The risk of suicide in males was more than threefold in all age groups. A significantly increased risk of suicide mortality was observed for non-married persons compared with married ones; moreover, greater age and lower education also raised the risk of suicide.

Significantly decreasing annual trends in suicide rates were found during the study period: the yearly suicide mortality rates halved in Hungary between 1995 and 2017. Similar trends were observed in both genders. The greatest percentage drop among all subgroups was seen in the group with middle educational attainment (people graduating from vocational school).

Significant seasonality was detected in monthly suicide mortality rates (both overall and by gender), with a peak in late June. The pattern of seasonal effect remained almost unchanged after adjusting the (sociodemographic) factors noted above for seasonality in NB regression models.

Seasonal trends with a peak from late June to mid-July were observed in mortality rates for all suicide methods except for firearm and drug overdose (mid- and late May, respectively). However, there was no significant seasonal variation in monthly suicide rates from gas poisoning, mostly due to the low number of cases.

In summary, our study describes the risk factors and pattern of trends in mortality rates for suicide in Hungary during the 1995–2017 period.

5.2.3. Comparison with other studies

Seasonal trends in suicide mortality rates were investigated in several studies. A similar peak in June was reported by Zonda et al. [16]. In our study, risk factors were included in the models that investigated seasonal variation in suicide deaths; each of these factors remained significant (and, conversely, seasonality remained significant in the presence of each factor). Consequently, our study only proves that seasonal effects have been independently increasing the risk of suicide in early summer.

Environmental effects are involved in the aetiology of mortality. The available Hungarian monthly mean temperature [36], precipitation [37] and sunshine duration [59] data generally supported these hypotheses for suicide mortality. Unfortunately, there were no monthly (detailed) environmental data available to investigate causality more precisely. It is assumed that sunlight triggers suicidality via melatonin [17] and serotonin transmission [60]. As regards seasonal rhythms, the duration of sunshine still shows a significant correlation with the frequency of suicide, but the extent of this effect is low [61]. Müller et al. concluded that higher environmental temperature and global radiation correlate with increased suicidality [62].

In Hungary, Törő et al. [63] found that the number of suicides increased during warm weather with low relative humidity [64]. A recent Hungarian study demonstrated that daily sunshine duration had a significant, immediate positive relationship with daily suicide rates [65].

Gender as a risk factor for suicide was investigated by various regression methods in several countries [49, 66, 67], including Hungary [8]; there was a 2.5- to fivefold suicide risk for males. In line with these studies, we also found a high (approximately 3.5-fold) suicide risk for men.

In agreement with studies conducted in different countries [68-70], we also observed a significant seasonal pattern in suicide deaths with a peak in June for both genders. Similar results were reported by Zonda et al. [16] for a three-decade study period (1970–2000) in Hungary and by Sebestyén et al. [12] for a shorter, subsequent one in that country (1998–2006). There was no autumn rise in suicide deaths for women in Hungary, as indicated by some researchers [71-73] in the literature. Some authors found different seasonal peaks in other countries [74, 75].

Several studies [6, 76, 77] that investigated the suicide risk of age came to the conclusion also reflected by our findings: the risk of suicide increases with age. By contrast, in England and Wales the male suicide rate was the highest in the 25–34-year-old age group [78].

Many studies have reported a relationship between age and seasonal pattern in suicide [70, 71, 79, 80]; however, their findings (in terms of peaks) were quite different. According to Woo et al. [81], the inconsistency between these studies might reflect methodological and environmental differences. We observed that seasonal variation was more pronounced among older age groups, a finding which is in agreement with some of the studies referenced above [71, 80, 82].

Rihmer et al. presented higher suicide rates in south-eastern Hungary compared with those in the north-western parts of the country [3]. Another Hungarian research group found an elevated suicide risk for both men and women living on the Great Plain (in the east and south-east) and stated that this effect cannot be explained by education, marital status, or other demographic factors [83].

In agreement with the studies mentioned above, we observed a significant (almost twofold) suicide risk for the regions on the Great Plain (compared to Western Transdanubia, the region with the lowest risk of suicide).

The seasonal variation of suicide deaths by NUTS2 region was similar. We found that even the maximum distance of these peaks was less than a month (early vs. late June).

Like other studies [8, 84-86], we also found that marriage was a protective factor against suicide, although the suicide risk for non-married persons was slightly lower (about 1.5-fold) than those reported in the studies noted above.

The seasonal variation in suicides was investigated by marital status (single, married, widowed or divorced) in Finland [87]. This study by Näyhä found a seasonal peak in spring or early summer for all categories of marital status (in the case of both genders), but also a second peak in autumn for married and widowed females.

By contrast, we considered marital status as a binary variable (married or non-married); the difference between the peaks (both in June) was less than half a month.

As regards education, we concluded that higher levels of educational attainment are accompanied by a lower risk of suicide; these are consistent with the findings of several previous studies [8, 86, 88]. However, the relationship between educational attainment and suicide risk is less obvious for women [8, 89].

As far as we are aware, there is no study to date that has published the seasonal pattern of suicides by educational attainment; however, our study revealed that there was almost no difference between the peaks (mid- or late June) in Hungary.

It is already known that there is a seasonal variation in suicide deaths committed by violent methods [63, 68, 69, 71, 79, 80, 82, 90-92]. All these studies reported a seasonal peak in spring or early summer, which is consistent with the general pattern of suicide mortality. As compared with our study, some of them [68, 80, 90] revealed a peak in June. As elsewhere, hanging was the main violent method in Hungary; like other studies [80, 82, 90], we noted a seasonal peak in June for these suicide deaths.

In contrast to certain studies [69, 79, 80, 91], we found a seasonal pattern for non-violent suicide methods with a peak in June. However, we also observed that violent methods of suicide had a more marked seasonal variation compared with non-violent ones.

As far as we know, this is the first study in Hungary to investigate the seasonality of suicide by method at a population level.

6. CONCLUSIONS

As far as we are aware, our research (Study I) has been the first epidemiological study reporting the effect of seasonality for deaths from external causes in Hungary. We found seasonal effects related to – among others – suicide, accidental falls, and traffic accidents with peaks in June, December, and September, respectively. These death causes account for overwhelming majority of the all-external-cause mortality. Environmental effects are involved in the aetiology of these external causes of death in Hungary.

We also studied suicide deaths separately and more extensively (Study II): several sociodemographic risk factors (gender, age group, marital status etc.) for suicide and seasonal patterns of suicidal deaths were investigated using well-established statistical methods. To our knowledge, this has been the first study in Hungary to analyse the seasonal pattern of suicide deaths in several respects: by educational attainment, NUTS2 region (in such a detailed way) and suicide method (at a population level), respectively.

In line with the general seasonal peak in late June, similar peaks (between early June and early July) were observed within the levels of each risk factor and the seasonality remained significant even in the presence of any of the factors; this has confirmed the significant role of environmental effects in the aetiology of suicide mortality.

Moreover, we also examined the annual pattern of external-cause mortality. Decreasing annual trends for almost all kinds of death from external causes (including suicide) were found during the study period. The creation of appropriate regulatory background (decree on managing local public roads, directive on safety belt systems, restriction of the traffic law) and its enforcement were important in the prevention of deaths due to external causes (especially accidental falls and traffic accidents). However, Hungary is still far from the front line of EU in respect to both external-cause and suicide mortality rates.

To reduce the overall mortality rate from external causes (especially those that are associated with seasonal differences such as traffic accidents and suicides) and to prolong life expectancy, preventive measures must be taken (e.g. increased police presence on the roads at the opening of the academic year, cultural education programs on suicide and its seasonal pattern conducted with the involvement of the media – targeting both the civilian population and health professionals – to pay more attention to men, the elderly and patients with depressive disorder, especially in summer); however, further cohort studies should be carried out to investigate this hypothesis using detailed individual data.

7. KEY NOTES

- Annual and seasonal trends in mortality rates from external causes and suicides (in detailed) were investigated in Hungary during 1995-2014 and 1995-2017, respectively.
- Suicide, unintentional falls, and traffic accidents mortality declined significantly. The declining annual trend was significant both for males and females.
- Significant declining trends in annual mortality were also found for assault, cold/heating-related accidents and accidents caused by electric current.
- Suicide risk was significantly higher in men than in women, and it increased with age and decreased with education level. Marriage was a protective factor against suicide.
- Significant winter-peak seasonality was found in the mortality rates from accidental falls, cold/heat-related accidents and other accidents caused by submersion/obstruction.
- Significant seasonal trends with a peak from June to July were observed in death rates from suicide, accidental drowning/submersion and accidents caused by electric current.
- Seasonal pattern of suicide mortality (peak in late-June) remained almost unchanged after adjusting sociodemographic factors.
- There were differences in seasonal peaks by suicide method.
- Environmental effects are involved in the aetiology of suicide and accidents.

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* * *

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