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## Observational Study

# Trends in suicide by hanging, strangulation, and suffocation in Serbia, 1991-2020: A joinpoint regression and age-period-cohort analysis

Milena Ilic, Irena Ilic

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## Abstract

### BACKGROUND

Hanging is one of the most commonly used methods for suicide in both sexes worldwide. In a number of countries, hanging mortality has increased over the last decades. Nevertheless, there is a scarcity of studies that have explored the patterns and trends for mortality of suicide by hanging on global, regional and national levels, as most evaluations are limited to certain populations.

### AIM

To assess the trends of suicide mortality by hanging, strangulation, and suffocation in Serbia, from 1991 to 2020.

### METHODS

This nationwide study, with epidemiological descriptive study design, was carried out based on official data. The age-standardized rates (ASRs, expressed *per* 100000 persons) were calculated by direct standardization, using the World Standard Population. Mortality trends from suicide by hanging were assessed using the joinpoint regression analysis: The average annual percent change (AAPC) with the corresponding 95% confidence interval (95%CI) was calculated. Age-period-cohort analysis was performed to address the possible underlying reasons for the observed suicide trends.

### RESULTS

Over the 30-year period studied, there were 24340 deaths by hanging (17750 males and 6590 females) in Serbia. In 2020, the ASR of deaths by hanging was 4.5 *per* 100000 persons in both sexes together (7.6 in males *vs* 1.7 in females). The trends of suicide mortality by hanging decreased significantly between 1991 and 2020 in

both males (AAPC = -1.7% *per year*; 95%CI: -2.0 to -1.4) and females (AAPC = - 3.5% *per year*; 95%CI: -3.9 to -3.1). Mortality rates of suicide by hanging had a continuously decreasing tendency in both sexes together in all age groups: The only exception was among males in 40-49 age group, with an increasing trend of suicide by hanging from 1991 to 2011 (by +0.3% *per year*).

### CONCLUSION

The trends in suicide mortality by hanging have been decreasing in Serbia in the last three decades in both sexes, but this was more pronounced in women than in men. Despite the decreasing trends observed in mortality of suicide by hanging, further research is needed for better clarification of trends and help in suicide prevention in the future.

**Key Words:** Suicide; Hanging; Mortality; Trends; Joinpoint analysis

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**Core Tip:** Although scarce, previous research showed disparities in mortality trends of suicide by hanging across the world. The mortality trends of suicide by hanging decreased significantly in Serbia in the last three decades in both sexes together, but it was more pronounced in women than in men. In 2020, the age-standardized rate of mortality by hanging was 4.5 *per 100000* persons in both sexes together (7.6 in males vs 1.7 in females), the male-to-female ratio was almost 5. Further research will allow a clarification of trends and help in a more effective suicide prevention.

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## INTRODUCTION

Suicide is a complex global public health issue[1-3]. According to the World Health Organization (WHO) 2000-2019 estimates, almost 800000 people die every year due to suicide across the world[4]. Previous research revealed that hanging was the predominant method of suicide in both sexes in most countries in the last decades[5,6]. Spicer and Miller[7] indicated that hanging, following firearms and drowning, was the most lethal method of suicide, while poisoning and cutting were the least lethal methods.

According to a systematic review and meta-analysis, the most common method of suicide in the Eastern Mediterranean Region of WHO was hanging (with a share of 39.7%, 95%CI: 26.8-52.7)[8]. Also, in almost all countries in Eastern Europe[4] and South Asia[9] hanging was the preferred method of suicide. During a 10-year period from 2004 to 2013 in India, poisoning as a method of suicide has declined in both genders aged 15-29 years, while hanging became the preferred method[10]. Based on the WHO mortality database, between 2000 and 2015 among 58 countries the age-standardized mortality rates of suicide by hanging among persons aged 15-64 were the highest both in males and females in Lithuania, while the highest rates among persons aged 65 years and older were both in males and females in Serbia[5]. The 20-year study (1997-2016) that examined suicides in South Africa, showed that mortality rates due to hanging increased by 3.9% *per year* in males and by 3.0% *per year* in females [11]. Similarly, over a period of 44 years (1969-2012) both sexes in Norway showed an upward trend for suicide by hanging, with a notably significant increase in men aged 15-24 years[12].

Previous studies[13-16] indicated that suicide rates were the highest among males, elderly, single individuals, those with less schooling, family disintegration, unemployment, poverty, living in rural areas, with mental illness (especially alcohol misuse). Some authors indicated that males more frequently use highly lethal methods of suicide, such as hanging or firearms, in comparison to females [17]. In people with substance use disorders in Norway, the most common cause of death in males was hanging, while in females it was poisoning[18]. A study of the effects of Greece's economic crisis during the years 2011 and 2012 recorded the strengthened seasonality of suicides, while a noteworthy suicide risk was revealed for males, persons aged 45 years or more and for suicides by hanging[19].

The 2030 Agenda for Sustainable Development adopted by the United Nations in 2015 includes a target to reduce suicide mortality by one third by 2030, and to promote mental health and wellbeing [20]. The coronavirus disease 2019 (COVID-19) pandemic has drastically changed social and daily life: Lockdown, business restrictions, school closures, social distancing policies in order to prevent the spread of the coronavirus infection, and possible delays in diagnoses of mental and other illnesses led to

increased mental stress globally, but how it is affecting the burden of suicide is not yet clear[21,22]. Nevertheless, there is a scarcity of studies that have explored the trends for mortality of suicide by hanging on global, regional and national levels, as most evaluations are limited to some populations[3,5,6].

Serbia is a country in southeastern Europe where the previous three decades marked its socio-political landscape from the end of the last to the beginning of this century, representing a time-frame of civil wars and global crisis; in addition to 1991-1999 civil wars, the break-up of Yugoslavia, influx of arrivals of more than a million refugees, devastating impact of the United Nations-imposed economic sanctions (1992-1995), a 78-d NATO's bombing in 1999, political changes and transition to democracy in 2000, and global financial crisis in 2008. As the result of dramatic socio-economic changes, the population of Serbia has experienced significant health problems[23,24]. This study aimed to evaluate the direction and magnitude of the national trends in mortality of suicide by hanging in Serbia from 1991 to 2020, with special emphasis on age, period and cohort effects.

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## MATERIALS AND METHODS

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### Study design

For this nationwide research, with epidemiological descriptive study design, we used data of annual underlying mortality causes in Serbia to describe mortality trends of suicide by hanging for the period 1991-2020.

### Data sources

Official death certification data for suicide by hanging, strangulation and suffocation were obtained from the Statistical Office of the Republic of Serbia (unpublished data).

During the calendar period considered, different revisions of the international classification of diseases (ICD) were used in Serbia: From 1990 to 1996 data about the main cause of death were classified by 9<sup>th</sup> Revision (ICD-9), and since 1997 the data processing of mortality statistics is based on 10<sup>th</sup> Revision (ICD-10). Mortality data of suicide by hanging, strangulation and suffocation were covered by site code E953 by ICD-9[25] and code X70 based on ICD-10[26]. In this study, term "suicide by hanging" includes deaths from suicide by hanging, strangulation and suffocation. Besides this, "suicides" include deaths from self-inflicted injury or intentional self-harm, but not those that are of undetermined intent. In Serbia, according to the WHO guidelines, the definition of the underlying cause of death includes a disease or injury that has started a series of diseases or an injury that has triggered a series of disease states that directly led to death.

Death registration and certification of cause of death in Serbia is conducted by an authorized physician in a health care organization, a coroner, or a forensic physician. The procedure is consistent throughout the whole country and comprises several levels of control and verification by another trained medical doctor or specialist. The procedures of death certification and registration in Serbia are coordinated by the Ministry of Health and the Ministry of Internal Affairs. The standard practice with unnatural deaths is that the investigating judge orders an autopsy, including toxicological analyses. All data files are confidential. The completeness of the Serbian mortality database was 98% in 2000[27]. Also, the WHO evaluated national mortality data in Serbia as medium quality, based on criteria such as completeness reporting of > 90% and ill-defined causes and injury deaths with undetermined intent appear on < 10% of registrations[28].

Estimates of the resident population, based on the official censuses (1991, 2002 and 2011 censuses), were obtained from the same Serbian national statistical database. This study comprised the whole population of Serbia (approximately 7 million inhabitants). During the study period, as a consequence of wars in the former Yugoslavia during the 1990s, Serbia had the largest populations (nearly 1000000 persons) of refugees (from the former Socialist Federal Republic of Yugoslavia) and internally displaced persons (from Kosovo & Metohia), and ranked among the top countries in the world by the number of refugees[29]. During the following decades, after the wars in the former Yugoslavia, Serbia remained at the top of the list of European countries in terms of forced migration, as well as one of the five countries in the world facing a prolonged refugee crisis[30]. The last census in 2011 showed there are nearly 300000 forced migrants living in Serbia, equaling 3.9% of the total population. Data for refugees were included in the Serbian population in the present study and could not be set aside as a special contingent.

### Statistical analysis

In this study, two types of death rates (expressed *per* 100000 persons) of suicide by hanging in Serbia were calculated: Specific (age- and sex-specific) and age-standardized. The age-standardized rates (ASRs) were calculated by the direct standardization method, using the World standard population[31] as a reference population.

The temporal trends for mortality of suicide by hanging were assessed using the joinpoint regression analysis (Joinpoint regression software, Version 4.5.0.1–June 2017, available through the Surveillance Research Program of the United States National Cancer Institute), proposed by Kim *et al*[32]. Joinpoint regression analysis was used to identify point(s), the so-called “joinpoints”, where a significant change (increases or decreases) in the linear slope of the trend occurred, and to estimate annual percent change (APC) based on the trend within each segment[32]. Finally, the average annual percent change (AAPC) over the entire considered period was calculated; for each annual percent estimate, the corresponding 95% confidence interval (95%CI) was determined[33]. Due to difficulties in computing with small numbers (small number of cases reported in youngest age group), we restricted the analysis to the age group 10 years and over. Disparities in suicide mortality trends according to age and sex were tested by using a comparability test[34]. The objective of the comparability test was to designate whether the two regression mean functions were identical (test of coincidence) or parallel (test of parallelism). A *P* value of < 0.05 was considered statistically significant. In determining the direction of temporal trends, the terms “significant increase” or “significant decrease” were used, in order to signify that the slope of the trend was statistically significant ( $P < 0.05$ , on the basis of the statistical significance of the AAPC compared to zero). For non-statistically significant trends ( $P > 0.05$ , while AAPC with a 95%CI overlapping with zero), the terms “non-statistically significant increase” (for AAPC > 0.5%), and “non-statistically significant decrease” (for AAPC < -0.5%) were used, while the term “stable” was used for AAPC between -0.5% and 0.5%.

The age-period-cohort analysis was performed to examine the effects of age, period, and birth cohort on the observed temporal trends using the United States NCI web-based statistical tool, according to the method proposed by Rosenberg *et al*[35]. The parameters of the age-period-cohort analysis included longitudinal age curves (indicated the fitted longitudinal age-specific rates in the reference cohort, adjusted for period deviations), the period rate ratios (represent variations in mortality rates over time associated with all age groups simultaneously), the cohort rate ratios (associated with changes in mortality rates across groups of individuals with the same birth years, that is, for successive age groups in successive time periods), and local drifts (represent the annual percentage changes for each age group, generated from log-linear regressions) with net drift (represents the average annual percentage change in mortality *per* year of birth). Due to difficulties in computing due to unstable mortality rates, we omitted < 10 and 80+ age groups from the age-period-cohort analysis. The significance test used was a 1-df Wald test. Values of *P* less than 0.05 were considered statistically significant.

### Ethics statement

This study is approved by the Ethics Committee of the Faculty of Medical Sciences, University of Kragujevac (No. 01-14321).

## RESULTS

In the period 1991-2020, a total of 24340 (17750 males and 6590 females) deaths of suicide by hanging in Serbia were reported (Table 1). The overall average annual ASR was 7.0 *per* 100000 in both sexes together (ranging from 9.1 *per* 100000 in 1991 to 4.5 *per* 100000 in 2020). The average annual ASR was 11.1 *per* 100000 in men and 3.3 *per* 100000 in women. Suicide by hanging was about 3.7 times more common in males than females in Serbia.

Trend for mortality of suicide by hanging was decreasing significantly in both sexes together by -2.1% yearly (95%CI: -2.4 to -1.8), from 1991 to onwards (Figure 1A and Table 2). Overall mortality of suicide by hanging peaked at 9.2 *per* 100000 in 1993, and declined thereafter to 4.5 *per* 100000 in 2020. Joinpoint regression analysis identified one joinpoint (in 2012), with consequent two trends: Both periods showed significantly decreasing trends, firstly with APC of -1.6% (95%CI: -1.9 to -1.2) and then with APC of -4.1% (95%CI: -5.6 to -2.6).

Suicide death rates by hanging increased with age both in males and females (Tables 2 and 3). In both sexes, suicide mortality rates were almost four times higher in people aged 70 or older than in people under 70. Age-specific suicide mortality rates in males were two times higher than rates in females in people under 70 and almost three times higher in people aged 70 or older. Suicide mortality rates were decreasing significantly in all age groups in both sexes from 1991 to 2020: The only exception was for males in age group 40-49, with an unfavorable trend of suicide mortality by hanging in 1991-2011 period, with APC = +0.3% *per* year (95%CI: -0.9 to +1.4). According to comparability test, mortality trends of suicide by hanging by age were parallel ( $P > 0.05$ ) both in males and females.

Suicide mortality rates by hanging in males decreased from 14.1 *per* 100000 in 1991 to 7.6 *per* 100000 in the last year observed; AAPC = -1.7%, 95%CI: -2.0 to -1.4 (Figure 1B and Table 3). Joinpoint analyses of suicide mortality by hanging in males identified one joinpoint in the year 2012, with two trends: Both trends were decreasing significantly, with APC of -1.2% (95%CI: -1.6 to -0.9) and -3.7% (95%CI: -5.2 to -2.3). In females, suicide mortality rates by hanging decreased from 5.4 *per* 100000 in 1993 to 1.7 *per* 100000 in the last year observed. Trend of suicide mortality by hanging in females decreased significantly from 1991 to 2020 (AAPC = -3.5%, 95%CI: -3.9 to -3.1). According to the comparability test,

**Table 1 Suicide mortality by hanging/strangulation/suffocation in Serbia, 1991-2020; number of cases and age standardized rate per 100000 (using World standard population)**

Year	All		Males		Females	
	Number	ASR	Number	ASR	Number	ASR
1991	978	9.1	690	14.1	288	4.7
1992	1010	9.1	697	13.7	313	5.0
1993	1033	9.2	690	13.6	343	5.4
1994	948	8.5	679	13.3	269	4.3
1995	830	7.4	588	11.4	242	4.0
1996	909	8.3	638	12.6	271	4.5
1997	907	8.1	649	12.6	258	4.0
1998	857	7.6	594	11.6	263	4.2
1999	947	8.2	661	12.7	286	4.3
2000	919	7.7	646	12.1	273	3.9
2001	860	7.4	605	11.4	255	3.9
2002	876	7.4	644	12.0	232	3.3
2003	807	6.9	600	11.5	207	2.9
2004	836	7.1	623	11.6	213	3.2
2005	856	6.9	609	11.0	247	3.2
2006	881	7.3	640	11.7	241	3.3
2007	841	7.0	609	11.1	232	3.3
2008	804	6.9	572	10.6	232	3.4
2009	836	7.1	630	11.6	206	3.1
2010	745	5.9	562	9.7	183	2.4
2011	818	6.8	603	10.9	215	3.1
2012	807	6.7	616	11.1	191	2.7
2013	734	6.1	562	10.1	172	2.5
2014	720	5.9	558	9.9	162	2.2
2015	646	5.4	501	9.0	145	2.1
2016	603	5.2	451	8.4	152	2.2
2017	614	5.1	481	8.7	133	1.9
2018	586	4.8	466	8.2	120	1.7
2019	586	5.1	453	8.5	133	1.9
2020	546	4.5	433	7.6	113	1.7
Overall	24340	7.0	17750	11.1	6590	3.3

ASR: Age-standardized rate.

trends of suicide mortality by hanging in men and women were not parallel and not coincident ( $P < 0.05$ ).

The risk of death from suicide by hanging increased continuously with age in both sexes together (Figure 2). The net drift was -1.8% (95%CI: -2.3 to -1.3) *per year*, and the curves of local drift values were under 0 in all age groups, with a few non-significant exceptions in the youngest age groups. Period rate ratios were significantly declining over the whole period studied, particularly after 2013. Cohort rate ratios showed significantly downward patterns, but these tendencies slowed down in recent cohorts, particularly for those born in 1951-1980 birth cohorts and after 1996. Results of Wald tests showed that the relative risk for suicide by hanging in Serbia had statistically significant ( $P < 0.05$ ) cohort and period

**Table 2** Joinpoint regression analysis<sup>1</sup> of suicide mortality by hanging/strangulation/suffocation in both sexes in Serbia, by age, 1991-2020

Age <sup>2</sup>	Year 1991		Year 2020		Number of joinpoints	AAPC	Lower 95%CI	Upper 95%CI
	No of cases	rates	No of cases	rates				
Age-specific rates <sup>3</sup>								
10-19	9	0.9	4	0.6	0	-2.7 <sup>1</sup>	-4.4	-1.1
20-29	56	5.8	20	2.5	0	-1.5 <sup>1</sup>	-2.4	-0.6
30-39	101	8.4	45	4.7	0	-1.2 <sup>1</sup>	-1.8	-0.6
40-49	133	14.1	69	7.1	0	-1.5 <sup>1</sup>	-2.2	-0.8
50-59	190	17.5	100	10.8	0	-1.4 <sup>1</sup>	-1.8	-1.1
60-69	219	23.7	123	12.4	0	-2.8 <sup>1</sup>	-3.1	-2.4
70-79	161	48.6	107	18.5	0	-3.5 <sup>1</sup>	-4.1	-2.9
80+	109	76.5	78	24.5	0	-3.4 <sup>1</sup>	-3.9	-3.0
Age-standardized rates <sup>3</sup>								
All ages	978	9.1	546	4.5	1	-2.1 <sup>1</sup>	-2.4	-1.8

<sup>1</sup>Statistically significant trend.

<sup>2</sup>Joinpoint results are not shown for the subgroups aged < 10 yr, because during the observed period, a total of 2 cases of suicide by hanging/strangulation/suffocation deaths occurred in both sexes.

<sup>3</sup>Per 100000 people.

AAPC: Average annual percentage change; CI: Confidence interval.

effects, as well as the net drift and local drifts.

In Serbia in both males and females, the risk of death from suicide by hanging increased by age (Table 4). The period effects have showed a downward pattern since 2013 in males, while continuously decreasing in females. The risk of deaths by hanging decreased, in general, with birth cohort in both sexes in Serbia, with stable cohort effects for men and women born between 1946 and 1966. The local drift values were under zero in all age groups in both genders, while an insignificant value was observed in age groups < 50 in males and < 30 in females (data not shown). The net drift was -1.4% (95%CI: -1.9 to -0.9) in males, and in females it was -3.7% (95%CI: -5.1 to -2.2). The Wald test showed statistically significant period and cohort effects for both genders, as well as net drift, but the local drifts were not statistically significant ( $P > 0.05$ ).

## DISCUSSION

This study described mortality trends of suicide by hanging in Serbia over a 30-year period from 1991 to 2020. Male predominance in suicide rates by hanging was showed. Trends of suicide mortality by hanging have been decreasing in both sexes and all age groups, but it was more pronounced in women than in men. Furthermore, this population-based analysis revealed significant period and birth-cohort effects in mortality of suicide by hanging.

Unfortunately, national-level data on the suicide by hanging are quite limited[36]. In the WHO mortality database, only about one third of the WHO Member States reported data on methods of suicide, and that was mostly highly developed countries[5,36]. The data on global suicides mortality by hanging are much clearer for high-income countries, which account for 50% of all suicides by hanging in the world. Hanging was a common method of suicide in Europe between 1970 and 2009: Its prevalence in Poland was the highest, comprising 90% of all suicides, with the very high (7:1) male-to-female rate ratio[37], while lower prevalence of suicides by hanging with sex differentials was reported in Estonia [38], Germany[39], Austria[40], and Finland[41]. The earlier study on suicide-related mortality in Serbia indicated that hanging accounted for 61.2% of all suicides in the 1991-2014 period, with a 3:1 male-to-female rate ratio[24]. However, data on mortality rates of suicide by hanging at the national level are still very sparse.

This manuscript indicates an annual ASR of suicide by hanging of 4.5 per 100000 population in Serbia in 2020 (7.6 for males and 1.7 for females). In Canada in 2018 an ASR of hanging of 9.6 was recorded in males and 3.0 in females[42]. In Australia, from 1986 to 2005, ASR of hanging was 7.33 in males and 1.47 in females, with increasing trends[43]. In India in 2014, ASR of suicide by hanging was 6.1 among males and 2.6 among females[44]. Based on the WHO mortality database, among 58 countries in 2015, ASR of

**Table 3** Joinpoint analysis: Trends<sup>1</sup> in age-specific suicide mortality rates (*per 100000*) by hanging/strangulation/suffocation in Serbia, by sexes, 1991-2020

Age <sup>2</sup>	Males		Females	
	Period	APC (95%CI)	Period	APC (95%CI)
10-19	1991-2020	-2.8 <sup>1</sup> (-4.4 to -1.0)	<sup>3</sup>	
20-29	1991-2020	-1.2 <sup>1</sup> (-2.1 to -0.3)	<sup>3</sup>	
30-39	1991-2014	-0.1 (-1.0 to +0.7)	1991-2020	-2.2 <sup>1</sup> (-3.3 to -1.1)
	2014-2020	-7.7 <sup>1</sup> (-13.5 to -1.5)		
	Full period <sup>4</sup>	-1.1 <sup>1</sup> (-1.7 to -0.4)		
40-49	1991-2011	+0.3 (-0.9 to +1.4)	1991-2020	-3.2 <sup>1</sup> (-4.4 to -2.1)
	2011-2020	-4.9 <sup>1</sup> (-8.5 to -1.1)		
	Full period	-1.0 <sup>1</sup> (-1.7 to -0.2)		
50-59	1991-2020	-0.8 <sup>1</sup> (-1.3 to -0.4)	1991-2020	-3.2 <sup>1</sup> (-4.0 to -2.5)
60-69	1991-2020	-2.3 <sup>1</sup> (-2.8 to -1.8)	1991-2008	-2.2 <sup>1</sup> (-3.8 to -0.6)
			2008-2020	-7.6 <sup>1</sup> (-10.1 to -5.0)
			Full period	-4.3 <sup>1</sup> (-5.1 to -3.5)
70-79	1991-2020	-3.1 <sup>1</sup> (-3.6 to -2.5)	1991-2020	-4.7 <sup>1</sup> (-5.5 to -3.9)
80+	1991-2020	-3.2 <sup>1</sup> (-3.7 to -2.7)	1991-2020	-3.8 <sup>1</sup> (-4.9 to -2.8)
All ages	1991-2012	-1.2 <sup>1</sup> (-1.6 to -0.9)	1991-2020	-3.5 <sup>1</sup> (-3.9 to -3.1)
	2012-2020	-3.7 <sup>1</sup> (-5.2 to -2.3)		
	Full period	-1.7 <sup>1</sup> (-2.0 to -1.4)		

<sup>1</sup>Statistically significant trend.

<sup>2</sup>Joinpoint results are not shown for the subgroups aged < 10 yr, because during the observed period, a total of 1 case of suicide by hanging/strangulation/suffocation deaths occurred in men and 1 case in women.

<sup>3</sup>Incalculable: Joinpoint results are not shown because fewer than 10 cases of suicide by hanging/strangulation/suffocation occurred in each of the decennium in any year.

<sup>4</sup>For full period presented average annual percent change.

APC: Annual percent change; CI: Confidence interval.

suicide by hanging among persons aged 15-44 was the highest both in males and females in Guyana (73.4 and 24.4, respectively), among persons aged 45-64 it was the highest in males in Lithuania (88.1) and in females in Belgium (18.0), while among persons aged 65 years and older rates were the highest in Republic of Korea (106.0 and 32.2, respectively)[5]. Variations in suicide rates can be attributed to many different factors, such as social, economic, personal factors, mental health[45,46]. Numerous studies confirmed association between unemployment rates and suicide rates by hanging[47]. In many countries (like Lithuania and other Eastern European countries, Brazil, the United States of America), mortality rates of suicide were linked to alcohol consumption[46,48,49]. The Serbian National health surveys (2000, 2006, 2013, 2019)[50] reported a lower prevalence of risk factors such as alcohol use and substance abuse in population of Serbia compared to most of the neighbouring countries and other countries in Europe[51]. Also, variations in mortality by hanging can be partly interpreted as the effects of availability of lethal methods, suicide prevention efforts, mental health diagnosis and treatment availability[52,53]. In India, more developed states with higher agricultural employment and higher literacy reported higher rates of suicide by hanging[44]. Although it is always a question whether the differences in suicide mortality rates are real or reflect variations in data quality worldwide, suicide by hanging is less likely to be misclassified as unintentional or undetermined death unlike other suicide methods[6].

Study about suicide mortality by hanging in 58 countries reported higher suicide mortality in males compared with females[5]. Similar to other countries, mortality rates of suicide by hanging were considerably higher (3.7:1) in men compared to women in Serbia, which might be because of the differences in alcohol use, substance abuse, mental health, marital status or unemployment between males and females. The 2019 Serbian National Health Survey determined that, in the last 12 months, 1.7% of Serbian population (3.2% of men and 0.3% of women) at least once a week drank risky on a single occasion of drinking (equivalent to 60 g of pure ethanol or more)[50]. Every month, 18.3% of men and

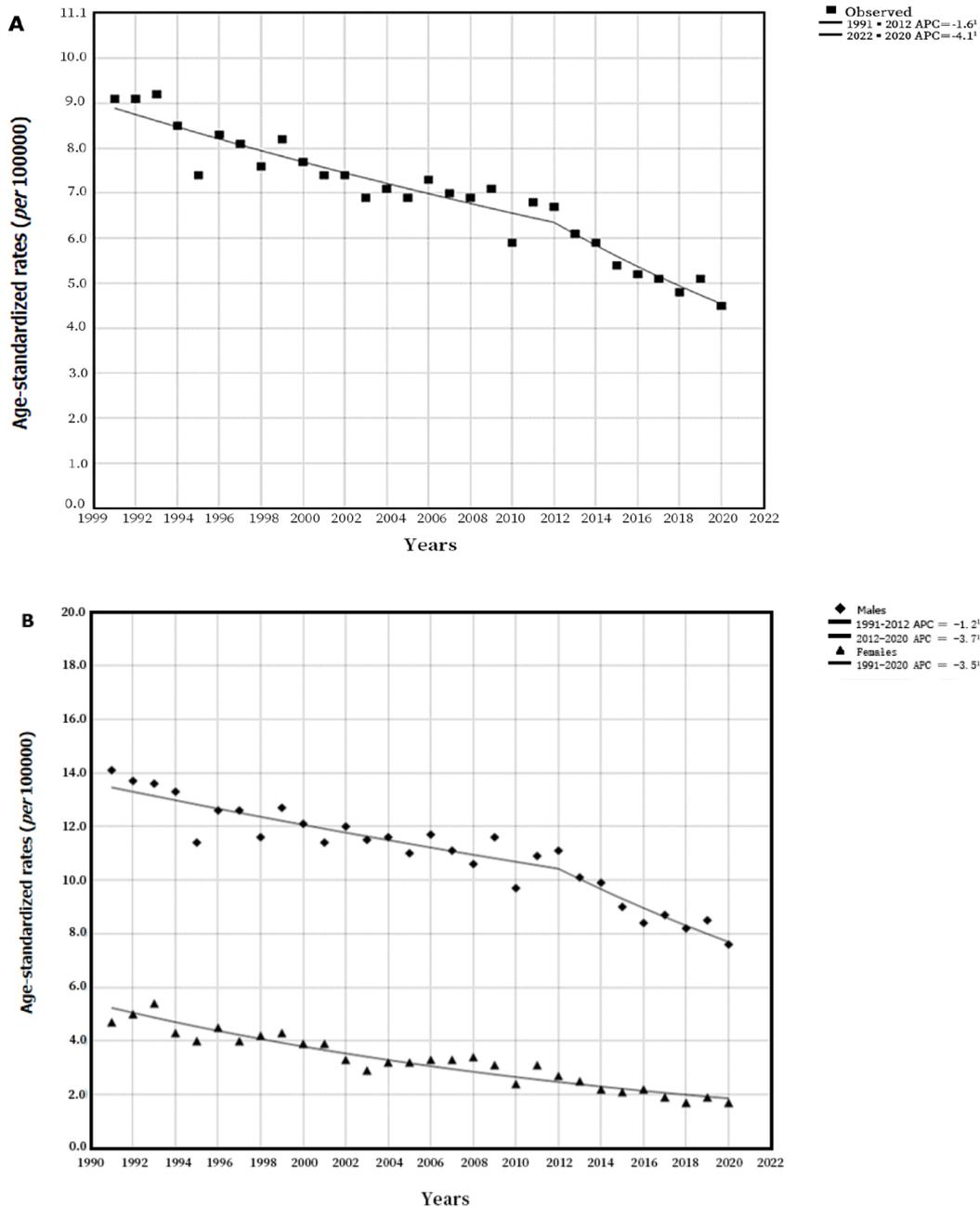
**Table 4** Age, period, and cohort effects on suicide mortality by hanging/strangulation/suffocation in Serbia, by sexes, 1991-2020

Group		Males		Females	
		Effect	95%CI	Effect	95%CI
Age	10-14	1.7	0.9-3.1	0.8	0.2-3.1
	15-19	4.4	3.0-6.4	1.6	0.7-3.6
	20-24	8.4	6.3-11.3	2.9	1.6-5.2
	25-29	9.3	7.1-12.1	3.1	1.8-5.2
	30-34	10.8	8.7-13.5	3.7	2.5-5.5
	35-39	12.7	10.5-15.4	4.2	2.9-5.9
	40-44	15.3	12.9-18.2	4.2	3.1-5.9
	45-49	17.4	14.8-20.5	5.1	3.7-6.9
	50-54	21.1	17.1-23.7	5.2	3.8-7.1
	55-59	21.5	17.3-24.3	5.2	3.7-7.1
	60-64	21.4	17.7-25.8	5.2	3.7-7.3
	65-69	21.2	17.3-25.9	5.3	3.7-7.6
	70-74	25.1	20.3-31.0	5.5	3.8-8.0
	75-79	30.8	24.5-38.5	5.7	3.9-8.4
Period	1991-1995	1.1	0.9-1.2	1.3	1.1-1.7
	1996-2000	1.0	0.9-1.2	1.2	1.0-1.5
	2001-2005	1.0	1.0-1.0	1.0	1.0-1.0
	2006-2010	1.0	0.9-1.1	0.9	0.7-1.1
	2011-2015	0.9	0.8-1.0	0.7	0.5-0.9
	2016-2020	0.7	0.6-0.8	0.5	0.4-0.7
Cohort	1916-1920	2.9	2.0-4.3	6.4	3.6-11.3
	1921-1925	2.2	1.7-2.9	4.5	2.9-7.0
	1926-1930	1.9	1.5-2.4	3.3	2.2-4.9
	1931-1935	1.7	1.4-2.1	2.7	1.9-3.9
	1936-1940	1.4	1.2-1.7	2.3	1.6-3.3
	1941-1945	1.2	1.0-1.5	1.9	1.3-2.6
	1946-1950	1.1	0.9-1.3	1.4	1.0-2.0
	1951-1955	1.1	0.9-1.3	1.1	0.8-1.5
	1956-1960	1.1	0.9-1.3	1.1	0.8-1.6
	1961-1965	1.0	1.0-1.0	1.0	1.0-1.0
	1966-1970	0.9	0.8-1.1	0.8	0.5-1.2
	1971-1975	0.9	0.8-1.2	0.6	0.4-0.9
	1976-1980	0.9	0.7-1.1	0.7	0.4-1.1
	1981-1985	0.9	0.7-1.2	0.6	0.4-1.0
	1986-1990	0.8	0.6-1.1	0.4	0.2-0.8
	1991-1995	0.7	0.4-1.0	0.5	0.2-1.1
	1996-2000	0.7	0.4-1.1	0.2	0.1-1.0
	2001-2005	0.6	0.3-1.5	0.1	0.0-4.7
	2006-2010	0.4	0.0-2.9	0.1	0.0-49.4

Wald Chi-square tests for estimable functions, *P* value

Net drift	< 0.000	< 0.000
All period rate ratios	< 0.000	< 0.000
All cohort rate ratios	< 0.000	< 0.000
All local drifts	0.092	0.897

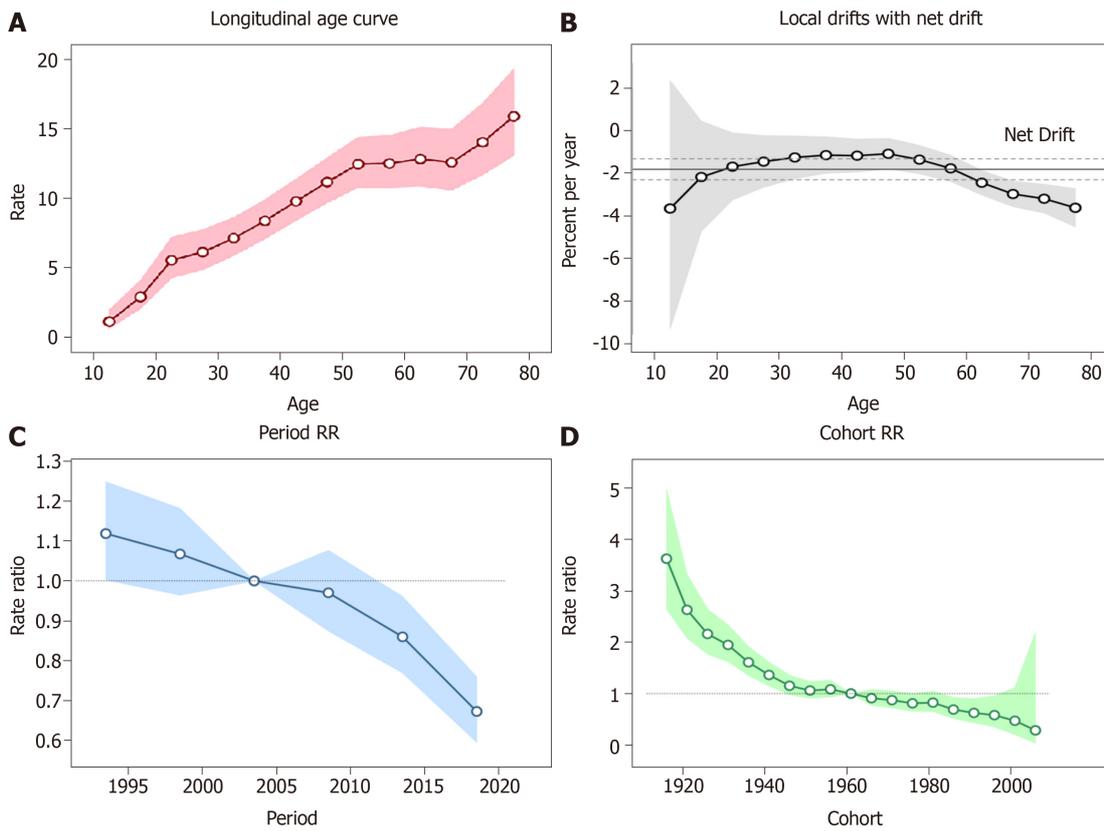
CI: Confidence interval.



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**Figure 1** Trend in suicide mortality by hanging/strangulation/suffocation in Serbia, 1991-2020. A: Joinpoint regression analysis; all: 1 Joinpoint; final selected model: 1 Joinpoint; B: By sex, 1991-2020; joinpoint analysis; Males: 1 Joinpoint vs Females: 0 Joinpoints. Final selected model: Males-1 Joinpoint, Females-0 Joinpoints. Rejected parallelism. <sup>1</sup>Indicates that the APC is significantly different from zero at the alpha = 0.05 level. APC: Average percentage change.

4.5% of women drank risky on a single occasion, which is a lower percentage than the European Union average[50,51]. By contrast, Serbian female population reported significantly more often the use of sedatives, sleep aids and painkillers (24.5%, 14.6%, and 44.8%, respectively) than males (11.3%, 10.4%, and 36.1%, respectively). Similar to the population in Europe, symptoms of depression were observed



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**Figure 2 Legend: Suicide mortality by hanging/strangulation/suffocation in Serbia, by sexes, 1991-2020: An age-period-cohort analysis.**

A: Longitudinal age curve of suicide by hanging mortality rates (*per* 100000 people) and 95% confidence intervals (the area colored in pink); B: Local drift value: age group-specific annual percent change (%) and 95% confidence intervals (the area colored in grey); C: Period effects for the suicide by hanging mortality rates and 95% confidence intervals (the area colored in blue); D: Cohort effects for the suicide by hanging mortality rates and 95% confidence intervals (the area colored in green). RR: Rate ratio.

more often in females (2.8%) than in males (1.5%) in Serbia in 2019. Similar to almost all countries in Eastern and Central Europe, poor social support was recorded in 15.4% of the population in Serbia, most often among residents with lower level of education, lower household income, who live in suburban settlements and the elderly[50,51].

In Serbia, mortality pattern of suicide by hanging was characterized by an initial decrease (by -1.6% *per* year) and followed by a sharp decline (by -4.1% *per* year) since 2012 (less pronounced declines observed in eldest men than in women during the study, although trends in males were parallel with trend in overall). In 2020 in Serbia, irrespective of more accelerated decreasing mortality trends of suicide by hanging in males in comparison to females in the recent decade, male-to-female rate ratio was almost 5:1, in relation to the beginning of the observed period when it was 3:1. Apart from Serbia, in both sexes together in those aged 15–65 years and above, decreasing rates of suicide by hanging have also been observed in Finland, Hungary and Switzerland from 2000 to 2015[5]. By contrast, significantly increasing death rates of suicide by hanging have been observed in some countries; for instance, in Canada by +1.1% *per* year from 1981 to 2018 for both sexes together[42], among Australians aged 10–24 years between 2004 and 2014[54], in the United States of America by +52% for all ages combined from 2000 to 2010[52], in Mexico by +11.89% from 2003 to 2012[55], in England and Wales over three decades [45], in South Korea[5,56]. Both sexes experienced an upward trend for suicide by hanging from 1969 to 2012 in Norway (by +1.5% *per* year in males and by +2.7% in females), with a particularly significant increase in 15–24 year old males[12]. The observed suicide mortality increase between 2000 and 2015 (*e.g.*, the Republic of Korea and the United States of America) could be explained by various factors, including financial crisis, increased unemployment and easy access to highly lethal methods such as hanging[5,45]. Also, the observed increase in suicide by hanging could possibly be explained by substitution with other methods, primarily of suicide by firearms or by poisoning, thanks to stricter gun control, control of pesticide use, prescription of drugs, *etc.*[57-60]. Significant differences in suicide mortality by sexes could be explained by different prevalence of the main risk factors (such as mental disorders, alcohol and drug abuse)[5]. Gender differences regarding suicidal behavior, also known as the “gender paradox of suicidal behavior”, include several factors that have a gender-dependent impact on suicidal behavior, such as stressful life events, socio-demographical factors, socio-economical factors, sexual abuse, psychiatric (co)morbidity, attitude towards antidepressant treatment, choice of suicide

methods[17]. The 2019 Serbian National Health Survey recorded depressive symptoms in 2.1% of Serbian population, which is a decrease compared to 2013 (4.1%)[50]. Also, 49.3% of Serbian population consumed alcohol: 3.1% drank every day, which is lower than in 2013 (4.7%) and 2006 (3.4%). Although different revisions of the ICD were used in Serbia, from 1991 to 1996 and from 1997 to 2000, this could not have notably affected some of the trend changes observed during the period observed, both because the changes would be reflected in trends in both sexes and because the incidence of symptoms and insufficiently defined conditions in the structure of general mortality has not changed significantly[61]. Besides this, the implementation of national guidelines for suicide prevention only in some countries might, at least partly, explain the observed differences in suicide mortality rates and trends in the world [62].

Mortality from suicide by hanging in Serbia has been declining since 1991 in all age groups in both genders. The risk of death of suicide by hanging declined continuously in every subsequent birth cohort since 1916. In contrast, the earlier study on suicide-related mortality in Serbia showed non-significant declining mortality trends of suicide by hanging in males aged 20-59 in 1991-2014 period[24]. An increasing excess suicide rate in men was observed in Poland between 1970 and 2009, and the suicide rate peaked at ages 40-54 years[37]. In Canada, between 1981 and 2018, there was an increasing trend in suicide by hanging for both males and females aged 10-64, and a decreasing suicide trend at ages 65+ years[42]. In the United States of America, between 2000 and 2010, trends in suicide by hanging/suffocation increased for ages 15-69, and decreased at ages 70+ years[52]. In Japanese aged 15 or above, in 1990-2011, the trend for suicide by hanging in males increased by +2.4% *per year*, while in females it remained flat[61].

However, Serbia saw a non-significant increase in mortality of suicide by hanging in males aged 40-49 from 1991 to 2011. The possible explanations for this unfavorable trend during this period in males include the devastating effects of civil wars, the economic and political sanctions, the collapse of the economy, the hyperinflation of the national currency, the notable drop in general living standard, the poor quality of health services (shortage of drugs, medical equipment, together with a large number of wounded individuals, decreasing hospitalization rates, particularly for people aged  $\geq 60$  years), the influx of more than a million refugees and social disintegration all generated circumstances where suicide prevention and management presented a significant challenge in medical practice[63,64]. The autopsy protocols of all 44 suicides committed by war veterans in the capital Belgrade over the 1991-2000 period showed that 27.3% of veterans had posttraumatic stress disorder, 9.1% had major depression and 6.8% had schizophrenia, while most suicides (84.1%) were committed by recruits of the Yugoslav National Army who spent 3-8 mo in the zone of war operations[65]. Contrary, among migrants of the Balkan wars in Sweden during the 1991-2001 Balkan wars, in comparison to other European migrants in Sweden during the same period, the risk of death from somatic diseases and psychiatric disorders, particularly post-traumatic stress disorder, was elevated, while the risk of suicide was reduced[66]. The reason for decreased risk of suicide in migrants from the Balkan wars could possibly be because those people were not having mental health problems, maintained a high drive for survival despite adversity, and also had increased surveillance, such as more frequent health check-ups in Sweden.

But, the decline in the rates of deaths by hanging is not fully explained. Differences in the classification of causes of death and in postmortem examinations exist across countries[67]. Registration of autopsies in Serbia began in 2006, with stable autopsy rate of about 2% of all deaths from 2006 to 2015, so it is unlikely that this affected the coding of mortality from suicide by hanging[51]. Furthermore, some level of underreporting might exist[68,69]. International comparisons are also complicated by methodological differences between studies: *i.e.* some studies considering trends of suicide mortality, but not all, in analysis comprised code ICD-10 X70 together with the undetermined death (particularly codes ICD-10 Y20, Y87.0)[1-3,5,6]. However, the authors consider that the changes in trends of suicide mortality could not be explained by underreporting or misclassification alone[70].

The COVID-19 pandemic has brought other circumstances detrimental to mental health that were not seen during the economic downturns, such as fears of virus infection, social distancing, isolation at home and quarantine. Some authors indicated that quarantine was associated with negative psychological effects, such as symptoms of post-traumatic stress, depression and anxiety, observed in China and Canada during the 2003 outbreak of severe acute respiratory syndrome (SARS)[71,72]. In the context of COVID-19-related consequences, suicide prevention that must include joint measures such as financial provisions and social support programs, as well as timely access to mental healthcare and optimal treatment for mental disorders is urgently needed[73].

The changes in trends in suicide by hanging require attention from health authorities and indicate a need for innovations in approaches to suicide prevention. In order to take the right action, the understanding of the scale of the problem is critical for prevention. Recognizing changes in methods of suicide is important because preventive measures aimed toward this growing problem across certain countries are necessary (*e.g.* improving mental health literacy, less availability of the method, such as in certain hospitalized or incarcerated individuals, correctional facilities *etc.*). Further research is needed in order to allow a much better clarification of suicide trends and help in a more effective prevention of suicide by hanging[45,62].

### Strengths and limitations

To the best of our knowledge, this is the first report which quantifies national mortality trends of suicide by hanging in Serbia from the year 1991 through 2020. Another strength is that it covers the whole population of Serbia using mortality data which is evaluated as medium quality based on the WHO criteria[28], with trends analyzed by both joinpoint and age-period-cohort analysis. Thus, the satisfactory reliability and validity of mortality statistics of suicide in Serbia enable international comparison. However, there were several limitations in this study. Of course, the question of data quality always exists due to a possibility of underreporting or misclassification of suicide. Although a longer study period might provide a more accurate assessment of mortality time trends, no data were available for a longer period in Serbia. There are no separate data on mortality among population of refugees and internally displaced persons, which might confound the pattern of suicide mortality in Serbia. Also, age-period-cohort analysis has inherent limitations (such as ecological fallacy or collinearity among age, period, and cohort effects). Besides this, although this study was population-based and could not investigate individual factors that contributed to the changes in trends of suicide mortality, this is a nationwide study that suggests strong period and birth cohort effects as determinants of changes in suicide by hanging in Serbia.

## CONCLUSION

The trends in suicide mortality by hanging have been decreasing in Serbia in the last three decades in both sexes, but this was more pronounced in women than in men. Despite the decreasing trends observed in mortality of suicide by hanging, further research is needed for better clarification of trends and help in suicide prevention in the future.

## ARTICLE HIGHLIGHTS

### Research background

Hanging is one of the most commonly used methods for suicide in both sexes worldwide.

### Research motivation

Although scarce, previous research showed disparities in mortality trends of suicide by hanging across the world.

### Research objectives

The aim of this manuscript was to assess the trends of suicide mortality by hanging in Serbia, from 1991 to 2020.

### Research methods

This population-based study was based on official data. The age-standardized rates (ASRs, expressed *per* 100000 persons) were calculated by direct standardization, using the World Standard Population. Mortality trends from suicide by hanging were assessed using the joinpoint regression analysis: The average annual percent change (AAPC) with the corresponding 95% confidence interval (95%CI) was calculated. In order to address the possible underlying reasons for observed suicide trends, an age-period-cohort analysis was performed.

### Research results

Over the 30-year period studied, there were 24340 deaths by hanging (17750 males and 6590 females) in Serbia. In 2020, the ASR of deaths by hanging was 4.5 *per* 100000 persons in both sexes together (7.6 in males *vs* 1.7 in females). The trends of suicide mortality by hanging decreased significantly between 1991 and 2020 in both males (AAPC = -1.7% *per* year; 95%CI: -2.0 to -1.4) and females (AAPC = -3.5% *per* year; 95%CI: -3.9 to -3.1). The suicide by hanging rate was found to increase with increasing age in both sexes. Mortality rates of suicide by hanging had a continuously decreasing tendency in both sexes together in all age groups: The only exception was among males in 40-49 age group, with an increasing trend of suicide by hanging from 1991 to 2011 (by +0.3% *per* year).

### Research conclusions

The trends in suicide mortality by hanging have been decreasing in Serbia in the last three decades in both sexes, but this was more pronounced in women than in men.

## Research perspectives

Further research will allow a clarification of trends and help in a more effective suicide prevention.

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## FOOTNOTES

**Author contributions:** All authors equally contributed to this paper with conception and design of the study, data acquisition and analysis, drafting and critical revision and editing, and approval of the final version.

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**Institutional review board statement:** This study is approved by the Ethics Committee of the Faculty of Medical Sciences, University of Kragujevac, No. 01-14321.

**Informed consent statement:** The data used for inputs and analysis were retrieved from the official database. Official data for deaths of suicide by hanging, strangulation and suffocation were obtained from the national statistical office (unpublished data). The data are fully aggregated, without any identification data. No patient approvals were sought nor required for this study. Our research question for estimating the trends of suicide mortality was based on the number of suicide mortality figures in Serbia from 1991 to 2020. However, as our model-based analysis used aggregated data, patients were not involved in the design, or conduct or reporting or dissemination plans of the research.

**Conflict-of-interest statement:** The authors have no conflicts of interest to declare.

**Data sharing statement:** No additional data are available.

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