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SUICIDE RATE FORECASTING IN THE CITIES OF UST-KAMENOGORSK, SEMEY, AND PAVLODAR REGION USING A MATHEMATICAL MODEL

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Abstract

Introduction. Suicides are a serious public health problem worldwide. Every year, 726,000 people die from suicide, and many more attempt suicide. Each suicide is a tragedy affecting families, communities, and entire countries, with long-term consequences for the bereaved.

Objective: Calculate the suicide forecast in the cities of Ust-Kamenogorsk, Semey, and Pavlodar region using a mathematical model.

Materials and Methods: Cohort retrospective study. Descriptive statistics were used to present absolute and relative indicators. The Student's t-test was used to compare means between two groups with normal distribution. The Pearson chi-square test was used to compare means between two categorical variables. Data from forensic examinations in Ust-Kamenogorsk, Semey, and Pavlodar region were collected for the period from 2013 to 2022, including 3657 cases of suicide. Variables: age, gender, place of residence.

Results. Among the regions, Pavlodar region occupies the leading position in completed suicides (45.6%), followed by Ust-Kamenogorsk (30.8%), and the lowest number of completed suicides is registered in the city of Semey (23.6%). Depending on gender, a greater number of completed suicides is noted among the male population (84.5%). The model describes the data as follows: the actual suicide rate for 2022 was 20.8 cases per 100,000 people, predicted – 21.2 cases per 100,000 people; for 2023 – 20.6 cases per 100,000 people, predicted – 21.1 cases per 100,000 people. Based on our model, a decrease in the suicide rate is forecasted from 20.9 cases per 100,000 people to 20.4 cases per 100,000 people from 2024 to 2028.

Conclusions. In the studied regions, a high level of suicides persists. Based on our model, a decrease in the suicide rate is projected from 20.9 cases per 100,000 people to 20.4 cases per 100,000 people from 2024 to 2028.

Keywords: Epidemiology; suicide; mortality trend; Kazakhstan.

Резюме

ПРОГНОЗИРОВАНИЕ УРОВНЯ СУИЦИДА В ГОРОДАХ УСТЬ-КАМЕНОГОРСК, СЕМЕЙ И ПАВЛОДАРСКОЙ ОБЛАСТИ С ПОМОЩЬЮ МАТЕМАТИЧЕСКОЙ МОДЕЛИ

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Введение. Самоубийства являются серьезной проблемой общественного здравоохранения во всем мире. Каждый год 726 000 человек умирает от самоубийств, и ещё больше людей пытается покончить с собой. Каждое самоубийство – это трагедия, затрагивающая семьи, сообщества и целые страны, с долговременными последствиями для родных покойного.

Цель исследования: Просчитать прогноз суицида в городах Усть-Каменогорск, Семей и Павлодарской области с помощью математической модели.

Материал и методы: Когортное ретроспективное исследование. Описательная статистика использовалась для представления абсолютных и относительных показателей. Для сравнения средних в двух группах при нормальном распределении использовался t-критерий Стьюдента. Для сравнения средних между двумя качественными переменными был использован критерий хи-квадрат Пирсона. Были собраны данные судебно-медицинских экспертиз Усть-Каменогорска, Семей и Павлодарской области за период с 2013 по 2022 год, включающие 3657 случаев смерти от суицида. Переменные: возраст, пол, место жительства.

Результаты. Среди регионов лидирующее место по совершенным суицидам занимает Павлодарская область (45,6%), на втором месте Усть-Каменогорск (30,8%), наименьшее количество совершенных самоубийств зарегистрировано в городе Семей (23,6%). В зависимости от пола большее число завершённых самоубийств отмечается среди мужской части населения (84,5%). Модель описывает данные следующим образом: фактическое значение уровня суицида за 2022 год соответствовало 20,8 случая на 100 тыс. человек, предсказано – 21,2 случая на 100 тыс. человек; за 2023 – 20,6 случая на 100 тыс. человек, предсказано – 21,1 случая на 100 тыс. человек. Исходя из нашей модели прогнозируется снижение уровня суицида с 20,9 случая на 100 тыс. человек до 20,4 случая на 100 тыс. человек с 2024 по 2028 год.

Выводы. В исследуемых регионах сохраняется высокий уровень суицидов. Исходя из нашей модели прогнозируется снижение уровня суицида с 20,9 случая на 100 тыс. человек до 20,4 случая на 100 тыс. человек с 2024 по 2028 год.

Ключевые слова: эпидемиология, суицид, тенденция смертности, Казахстан.

Түйіндеме

**МАТЕМАТИКАЛЫҚ МОДЕЛЬДІ ПАЙДАЛАНА ОТЫРЫП,
ӨСКЕМЕН, СЕМЕЙ ҚАЛАЛАРЫ МЕН ПАВЛОДАР ОБЛЫСЫНДАҒЫ
СУИЦИД ДЕҢГЕЙІН БОЛЖАУ**

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Кіріспе. Өз-өзіне қол жұмсау бүкіл әлемде қоғамдық денсаулық сақтаудың күрделі мәселесі болып табылады. Жыл сайын 726 000 адам өз-өзіне қол жұмсау салдарынан қайтыс болады және одан да көп адам өзіне қол жұмсауға әрекеттенеді. Өрбір өз-өзіне қол жұмсау - бұл марқұмның отбасы үшін ұзаққа созылатын салдары бар отбасыларға, қауымдастықтарға және бүкіл елдерге әсер ететін қайғылы оқиға.

Мақсаты: Математикалық модель арқылы Өскемен, Семей және Павлодар облысындағы суицидтің болжамын есептеу.

Құралдар мен әдістер: Когортты ретроспективті зерттеу. Абсолютті және салыстырмалы көрсеткіштерді көрсету үшін сипаттама статистикасы пайдаланылды. Студенттің t-тесті қалыпты таралу жағдайында екі топтағы ортаны салыстыру үшін пайдаланылды. Екі сапалық айнымалылар арасындағы ортаны салыстыру үшін Пирсон хи-квадрат сынағы қолданылды. 2013-2022 жылдар аралығында Өскемен, Семей және Павлодар облыстарының сот-медициналық сараптамаларынан деректер жиналды, оның ішінде суицидтен 3657 адам қайтыс болды. Айнымалылар: жасы, жынысы, тұрғылықты жері.

Нәтижелер. Өңірлер арасында өз-өзіне қол жұмсау бойынша бірінші орында Павлодар облысы (45,6%), екінші орында Өскемен (30,8%), ең аз Семей қаласында (23,6%); . Жынысы бойынша аяқталған суицидтердің саны халықтың ерлер бөлігінде (84,5%) байқалады. Модель деректерді келесідей сипаттайды: 2022 жылға суицидтің нақты деңгейі 100 мың адамға 20,8 жағдайға сәйкес келді, болжамды - 100 мың адамға 21,2 жағдай; 2023 жылға – 100 мың адамға 20,6 жағдай, болжамды – 100 мың адамға 21,1 жағдай. Біздің үлгі бойынша суицид деңгейі 2024 жылдан 2028 жылға дейін 100 мың адамға шаққанда 20,9 жағдайдан 100 мың адамға 20,4 жағдайға дейін төмендейді деп болжануда.

Қорытындылар. Зерттелген аймақтарда суицидтің жоғары көрсеткіштері сақталуда. Біздің үлгі бойынша суицид деңгейі 2024 жылдан 2028 жылға дейін 100 мың адамға шаққанда 20,9 жағдайдан 100 мың адамға 20,4 жағдайға дейін төмендейді деп болжануда.

Түйінді сөздер: *эпидемиология, суицид, өлім тенденциясы, Қазақстан.*

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Introduction

Suicide is a serious public health problem globally [1, 4]. Each year, 726,000 people die by suicide, and many more attempt it. Every suicide is a tragedy affecting families, communities, and entire countries, with long-term consequences for those left behind. Suicide affects all age groups and in 2021 was the third leading cause of death among young people aged 15–29 worldwide [17]. Despite a significant reduction in overall suicide mortality rates in recent years, this trend is not universal. Suicidal ideation and behaviors continue to pose significant challenges for public policy and healthcare systems [2, 13]. Kazakhstan has one of the highest suicide rates globally, with a higher frequency among men than women [3, 5, 15]. However, women more often contemplate and attempt suicide [8, 15]. In 2019, Kazakhstan saw a 7.4% increase in suicides compared to 2018 (3800 vs. 3500 cases). Notably, over 73.6% of suicides occurred while sober, with 71.9% among men and approximately 80% among women. Suicidal behavior varies by sex, age group, geographical area, and socio-political conditions, and is linked to various risk factors, highlighting the etiological heterogeneity of this problem [7, 14].

This investigation aimed of the study was to use a mathematical model to predict the suicide rate in the cities of Ust-Kamenogorsk, Semey, and Pavlodar region.

Materials and Methods.

Design: A retrospective cohort study was conducted. Data from forensic medical examinations in Ust-Kamenogorsk, Semey, and Pavlodar region were collected for the period from 2013 to 2022, encompassing 3657 suicide deaths. Variables included: age, sex, and place of residence. Prior to data collection, the study received ethical approval from the Ethics Committee of Semey Medical University (protocol No. 4, November 20, 2021).

Statistical analysis.

The statistical analysis was conducted using SPSS version 20.0 (IBM Ireland Product Distribution Limited, Ireland). Descriptive statistics were used to present absolute and relative indicators. The Student's t-test was used to compare means between two groups with normal distribution. The Pearson chi-squared test was used to compare means between two categorical variables.

To predict the level of suicide, a mathematical model was developed with the assumption that the number of suicide cases follows a Poisson distribution, as the units of observation were discrete numbers. However, due to excessive dispersion of the data, a negative binomial regression was conducted to obtain the mathematical model. The expected value of the suicide rate for each year in Kazakhstan was modeled by the following equation:

$$E(Y) = e^{\lambda(t)},$$

where $\lambda(t)$ is the regression equation $\lambda(t) = \alpha + \beta * t$.

However, the decrease in the suicide rate in Kazakhstan did not have an exponential nature, which required an adjustment to the equation $\lambda(t) = \alpha + \beta * \ln(t)$. The population of Kazakhstan for each year, excluding the population aged 0 to 5 years, was taken as the offset variable. For constructing the model, data on the number of suicides were taken from the Committee on Legal Statistics and Special Accounts of the General Prosecutor's Office, and the population data from the Bureau of National Statistics from 2015 to 2023. The values of the year variable were recoded from 2015 to 2022 as 1 to 9, respectively. The obtained values were: $\alpha = -8.31535321$, $\beta = -0.06826177$, the sum of squared deviations of the sample values from their mean (deviance) = 8.9895 with 7 degrees of freedom.

The information on the population of the Republic of Kazakhstan aged 5 years and older was sourced from the official National Statistics Bureau from 2015 to 2023. For calculating the projected values, data for Kazakhstan were taken from the WHO report on the projected world population.

Since the population reached 20 million in 2023, we decided to take the projected values from the report for the years 2025 to 2029. [18]. Here's the translation of the paragraph:

This data was adjusted to account for 10.6% of the population aged 0 to 5 years. Negative binomial regression was used to assess the relationship between gender, age group, and area of residence to the number of completed suicides, as there was excessive dispersion in the data. Model adequacy to the data was tested using Pearson's

chi-squared statistical test for model evaluation. The obtained values were transformed into incidence rate ratios (IRR) by taking the exponent. A significance level of 0.05 was accepted as critical. Statistical analysis and graphical representation of the data were performed using the statistical software R 4.2.3.

Results

From 2013 to 2022, there were 3,657 deaths by suicide in the cities of Ust-Kamenogorsk, Semey, and Pavlodar region. The characteristics of the studied population are presented in Table 1.

Table 1.

Characteristics of the studied population.

Variables		Total	Women	Men
Region n (%)	Semey	862 (23,6)	121 (14,1)	741 (85,9)
	Ust-Kamenogorsk	1128 (30,8)	212 (18,8)	916 (81,2)
	Pavlodar	1667 (45,6)	233 (14,0)	1434 (86,0)
Place of residence n (%)	City	2339 (63,9)	347 (14,8)	1992 (85,2)
	Village	1318 (36,1)	219 (38,7)	1099 (35,6)
The gender n (%)		3657 (100)	566 (15,5)	3091 (84,5)
Age (years) M (SD)		44,5 ($\pm 17,7$)	45,6 ($\pm 19,5$)	43,5 ($\pm 15,9$)
Age groups n (%)	5-14	21 (0,6)	4 (19,1)	17 (80,9)
	15-44	2062 (56,4)	303 (14,7)	1759 (85,3)
	45-64	1148 (31,4)	153 (13,4)	995 (86,6)
	> 64	426 (11,6)	106 (24,9)	320 (75,1)
Nationality n (%)	Kazakhs	1793 (49,0)	264 (14,7)	1529 (85,3)
	Russians	1600 (43,7)	267 (16,7)	1333 (83,3)
	Other	264 (7,3)	35 (13,3)	229 (86,7)
Standard Deviation - SD				

As shown in Table 1, among the regions, Pavlodar Region occupies the leading position in completed suicides (45.6%), followed by Ust-Kamenogorsk (30.8%), while the lowest number of completed suicides was recorded in the city of Semey (23.6%). Depending on gender, a higher number of completed suicides is observed among the male population (84.5%). Most suicides were recorded among the urban population (63.9%). The average age of the studied population was 44.5 (± 17.7) years, with the average age being almost the same for both men and women. The age group 15-44 was well represented (56.4%), followed by the age group 45-64 years (31.4%). By nationality, the majority belong to the indigenous population (49.0%), while slightly fewer are Russians (43.7%).

The results of the negative binomial regression for the East Kazakhstan and Pavlodar regions are presented.

Table 2 presents the results of the negative binomial regression model. The suicide rate was lower in the age group of 5-14 years (IRR 0.03, 95% CI 0.18 – 0.046) compared to other groups, assuming that all other variables remain unchanged in the model. The suicide rate was higher among men (IRR 6.33, 95% CI 5.61 – 7.15) compared to women, assuming that all other variables remain unchanged in the model. Residents of Pavlodar region are more likely to commit suicide (IRR 1.31, 95% CI 1.17 – 1.47) than residents of East Kazakhstan, assuming that all other variables remain unchanged in the model.

Table 2.

Values of the negative binomial regression model.

	Assessment	Standard Deviation	z-score	Pr(> z)	
(intercept)	-9.683	0.079	-122.937	0.0000	***
15-44	-0.018	0.075	-0.244	0.8074	
45-64	-0.077	0.078	-0.982	0.3263	
5-14	-3.510	0.231	-15.196	0.0000	***
Male gender	1.846	0.062	29.929	0.0000	***
Pavlodar	0.273	0.057	4.792	0.0000	***

significance: 0 <= '***' < 0.001 < '**' < 0.01 < '*' < 0.05

The sum of squares of the deviations of the sample values from their mean: 13.98 with 9 degrees of freedom.

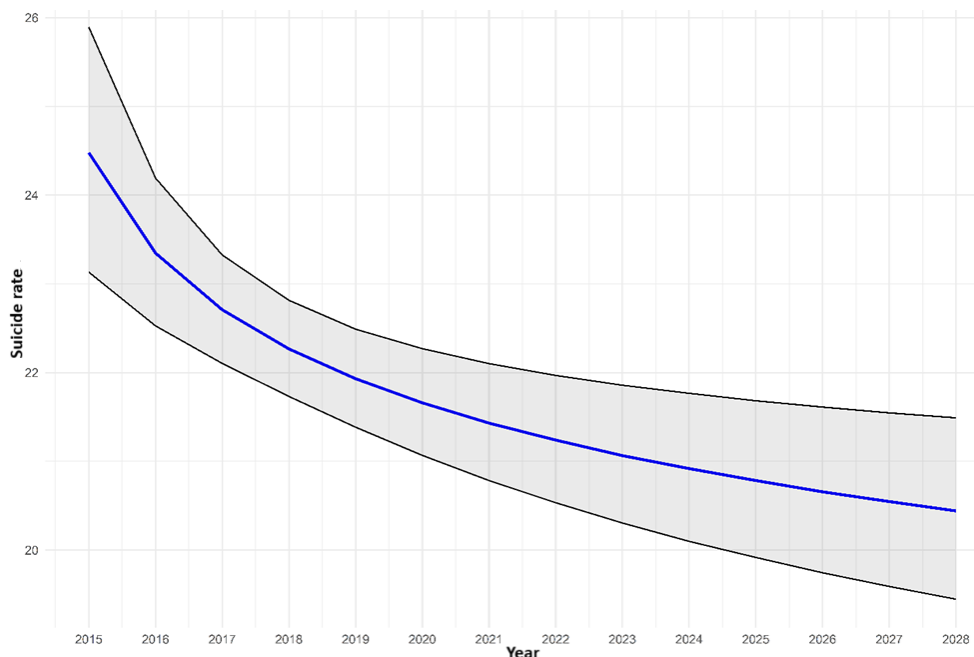


Figure 1. Prediction of suicide rate.

Table 3. Projected values of the suicide rate in Kazakhstan.

Year	Suicide rate	95 % CI
2024	20,9	20,1 – 21,8
2025	20,8	19,9 – 21,7
2026	20,7	19,7 – 21,6
2027	20,5	19,6 – 20,5
2028	20,4	19,4 – 20,4

(per 100000 per.)

Discussion of Results

As a result of our study, it was found that men commit suicide more often, which corresponds with the data obtained in research conducted by scholars *M. Ilić and I. Ilić* in Serbia, as well as by *Nurhan Dogan, Dilek Toprak, and Ismet Dogan* in Turkey [3, 5]. Research conducted by American scientists has shown that the suicide rate is consistently higher in rural areas than in cities [7, 12]. In our study, a significant prevalence of suicides among urban residents was identified. A study by Spanish researchers *Carme Saura, Manel Marzó, and Marc Saez* found that this increase is statistically significant only for women of working age (16-64 years), whereas in our study, the highest frequency of suicides among men was observed in the age group 15-64 years [10, 16]. Research by Mexican scientists demonstrated that the highest number of suicide attempts was recorded in the age group 17-24 years [6]. According to a study conducted by Pakistani scientists *Sadik Nawid and Saniya Mumtaz Tahir*, the age category of individuals who committed suicide coincides with our group—aged 15 to 64 years [9, 11]. Based on this research, a model was developed for forecasting suicides in Kazakhstan until 2028.

The model describes the data as follows: the actual suicide rate for 2015 was 23.7 cases per 100,000 people, while the projected value was 24.5 cases per 100,000 people; for 2016 – 24.7 cases per 100,000 people, with a prediction of 23.3 cases per 100,000 people; for 2017 – 22.5 cases per 100,000 people, predicted at 22.7 cases per 100,000 people; for 2018 – 21.6 cases per 100,000 people, predicted at 22.3 cases per 100,000 people; for 2019 – 22.8

cases per 100,000 people, predicted at 21.9 cases per 100,000 people; for 2020 – 20.8 cases per 100,000 people, predicted at 21.7 cases per 100,000 people; for 2021 – 22.6 cases per 100,000 people, predicted at 21.4 cases per 100,000 people; for 2022 – 20.8 cases per 100,000 people, predicted at 21.2 cases per 100,000 people; for 2023 – 20.6 cases per 100,000 people, predicted at 21.1 cases per 100,000 people.

According to our model, a decrease in the suicide rate is projected from 20.9 cases per 100,000 people to 20.4 cases per 100,000 people from 2024 to 2028.

Conclusions

In the studied regions, a high level of suicide persists. Analysis of data from 2013 to 2022 shows the highest number of cases in Pavlodar Region. A significant prevalence of suicides among the urban population is observed (twice as high as in rural areas), as well as among representatives of Kazakh and Russian nationalities aged 15 to 44 years. Among men, the highest suicide rate was recorded in the age group of 15 to 44 years.

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Madina Apbassova: methodology, and writing - review and editing

Saulesh Apbassova: writing - review and editing, and funding acquisition.

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