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Relationships between infant mortality and socioeconomic and demographic factors in Kazakhstan: an analysis from a middle-income country in Central Asia

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Abstract

Background Infant mortality rate is an important indicator of a nation's overall health and development. Kazakhstan, like many Central Asian countries, has faced its fluctuating trends during the last decade influenced by various socioeconomic factors. This study aims to analyze the relationship between socioeconomic and infant mortality indicators in Kazakhstan from 2010 to 2021.

Methods We analyzed aggregated panel data from all 14 regions of Kazakhstan and 3 major cities (Astana, Almaty and Shymkent) over a twelve-year period, including socioeconomic and demographic variables obtained from the Bureau of National Statistics and the Ministry of Healthcare of the Republic of Kazakhstan. Log transformation was applied to achieve symmetrical distribution and standardization of selected variables. Multiple linear regression assessed the effect size of significant predictors on infant mortality.

Results The mean infant mortality rate was 10.22 per 1,000 live births, with higher rates in southern/western regions (e.g., Kyzylorda: 13.0) compared to northern areas (e.g., Pavlodar: 8.32). Our panel data analysis (2010–2021) revealed consistent socioeconomic patterns: unemployment rates and poverty levels showed positive relationship with infant mortality rates, while greater housing space per capita, lower income inequality (Gini coefficient), and higher living wages were correlated negatively. The regression model accounted for a substantial proportion of variance in infant mortality, emphasizing the role of economic stability, equitable resource distribution, and living conditions in improving infant health outcomes.

Conclusions The study examines the relationship of infant mortality with socioeconomic factors in Kazakhstan. Economic growth alone is insufficient, equitable wealth distribution and comprehensive social and healthcare investment may contribute to the sustained reductions in infant mortality indicators. These findings may be valuable for policymakers not only in Kazakhstan but also in other Central Asian nations facing similar public health challenges.

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Introduction

Infant mortality stands as an important marker of a nation's health status, with research pointing to a notable association between infant mortality and socioeconomic factors such as income inequality, unemployment, poverty, and access to healthcare [1, 2]. It is expressed as the probability of a child's death between birth and one year of age [3]. The infant mortality rate (IMR) serves as a critical gauge of overall population health, and high IMR often signifies broad structural issues such as underlying socioeconomic conditions, inadequate healthcare services, poor sanitation, and low educational attainment [4, 5].

In Kazakhstan, which is a middle-income country in Central Asia (CA), state initiatives in healthcare development such as "Densaulyk" and "Salamatty Kazakhstan" focusing on preventive care, have shown promising results in enhancing maternal, prenatal, and infant health [6]. Kazakhstan's demographic landscape, marked by population growth from natural increase and migration, faces challenges with a lower life expectancy and higher infant mortality rate compared to developed countries. Moreover, according to the TransMonEE (Transformative Monitoring for Enhanced Equity) partnership, which monitors the situation of children and women in Europe and Central Asia, the percentage of children aged 0–17 years in Central Asian countries' populations (34–42%) is significantly higher compared to selected European nations (United Kingdom, Germany, Poland), see Additional file 1 [7]. These countries were chosen to highlight disparities in child population shares between Central Asia and Europe as regional benchmarks to highlight demographic and economic contrasts, contextualizing Kazakhstan's demographic challenges. Simultaneously, Kazakhstan boasts universal literacy and extensive educational coverage [8].

The remainder of this paper is structured as follows: Sect. "Introduction" as "Background" covers existing literature in the field, identifies research gaps, and how the research being done will add to current knowledge. Section "Background" provides a detailed description of the data and methods used in the analysis. Section "Data and methods" presents the results of the study, including descriptive statistics and regression analyses. Section "Results" discusses the findings in the context of existing literature and their implications for policy. Finally, Sect. "Discussion" concludes the paper with a summary of key insights.

Background

During the past decades, Kazakhstan achieved a remarkable sixfold reduction in the IMR from 1990 to 2017, declining from 54.1 to 8.9 deaths per 1,000 live births, outpacing other CA countries [9]. A significant contributor to this reduction was Kazakhstan's 2008 adoption of World Health Organization (WHO) criteria for defining live births and stillbirths [10]. This alignment with WHO standards helped Kazakhstan reduce infant mortality by over a third by 2015, with ongoing efforts towards further reductions by 2030. Regional disparities were reported by Bayserkina et al. and official statistics, highlighting higher IMRs in southern and western Kazakhstan from 1991 to 2012 [11]. Overall, since 1990, Kazakhstan has achieved a 64% reduction in infant mortality and a 65% reduction in child mortality, meeting United Nations Millennium Development Goal 4 ahead of schedule in 2014 [12]. From 2000 to 2020, Kazakhstan achieved a 76% reduction in infant mortality (annual average reduction rate of 1.49), while Uzbekistan was the only Central Asian country to demonstrate comparable progress, with a 75% decline over the same period [13]. This significant pace of improvement reflects the CA authorities' strong commitment to pursuing Sustainable Development Goal 3 (SDG 3), which aims to ensure healthy lives and promote well-being for all ages [14].

Socioeconomic determinants contribute to the shaping of health outcomes, particularly in infant mortality. Despite consistent investments in healthcare, education, and social sectors within the CA region, these efforts fall below the averages observed for the Organization for Economic Co-operation and Development [15]. Social determinants including poverty, access to healthcare services, and legal or social barriers significantly influence health outcomes [4]. Demographic transition theory suggests that reductions in mortality rates, including infant mortality, are closely tied to socioeconomic development and improved healthcare access [16]. Classical studies emphasize the role of maternal education and household wealth in child survival [17]. Contemporary research underscores persistent structural inequities, such as disparities in maternal healthcare utilization and wealth-related inequalities, which perpetuate disparities in infant mortality even amid economic growth [18, 19]. For instance, studies highlight how targeted policy interventions, such as expanding maternal education and strengthening healthcare infrastructure, can mitigate these inequities and accelerate progress toward child survival goals [20]. Income inequality and social policies, including maternal leave policies, may help to explain variations in infant mortality and birth outcomes across countries, even in high-income nations [21].

Studies from Kazakhstan and other countries emphasize the association of maternal and infant health with the household composition, wealth quantiles, the absence of sanitation facilities in households and life expectancy at birth [9, 22]. In low- and middle-income countries, factors such as lower population growth, better living conditions, and improved service provision are associated with lower IMR [23]. The growing proportion of Kazakhstani people living below the living wage further adds to the complexity of socioeconomic challenges [24]. Moreover, cultural factors, including attitudes and beliefs related to medical care, may interact with socioeconomic determinants to indirectly impact children's health outcomes [25].

Reductions in government health spending can be linked to negative public health outcomes. For instance, in European Union countries, a 1% decrease in government health expenditure correlated with an increase in maternal mortality rates [26]. Total, public and private health expenditures have correlations with reducing infant mortality rates, with private health expenditure having a more substantial effect [27, 28]. Factors such as poverty and unemployment can also contribute to variations in IMR. In Italy, the Gini index and total unemployment rate correlated positively with infant mortality, while mean household income showed a strong negative correlation [29]. In Korea, parental employment status was associated with infant mortality in preterm infants, while unemployment status was linked to lower birthweights and higher rates of infant mortality [30]. Addressing disadvantaged socioeconomic status through improved access to quality healthcare and increased social expenditures can have a reflective impact on IMR [31].

The aim of this study was to analyze the relationship between infant mortality rates and key socioeconomic indicators in Kazakhstan from 2010 to 2021, with a focus on identifying the most significant determinants that can inform policy interventions. The research question of this study was "How do socioeconomic indicators influence infant mortality rates in Kazakhstan from 2010 to 2021?"

Data and methods

Study area, source, and design

The dataset used in this study was panel data, comprising aggregated data for all 14 regions of Kazakhstan and 3 major cities (Astana, Almaty and Shymkent) from 2010 to 2021. It included socioeconomic and demographic variables from the Bureau of National Statistics and IMRs from the Ministry of Healthcare of the Republic of Kazakhstan [32, 33]. The dataset comprised 196 observations across all variables, representing all regions over a 12-year period.

Variables and definitions

Variable selection was based on previous literature and data availability [32, 33]:

- *Housing space per capita* measures the average living space available per individual, expressed in square meters per person. This variable represents housing conditions and living standards by indicating how much housing area is allocated to each resident.
- *Living wage (minimum wage)* refers to the legally mandated lowest monthly remuneration that employers may pay workers. It is designed to ensure a minimum standard of living for employees, covering basic needs such as food, housing, and other essentials. Defined annually by the government in tenge (KZT).
- *Average monthly salary* represents the typical gross income received by employees on a monthly basis before taxes and deductions. It serves as an indicator of general economic well-being and the standard of living for the workforce.
- *Average monthly salary in healthcare* measures the typical earnings of healthcare professionals on a monthly basis. This variable reflects investment in human resources within the health sector, impacting the quality and availability of healthcare services.
- *Gross Domestic Product (GDP)* represents the total economic output of Kazakhstan, signifying overall economic performance. It includes the market value of all final goods and services produced within a country in a specific period.
- *GDP per capita* is the GDP divided by the total population, providing a per-person measure of economic productivity and living standards. It offers insight into the average income level and economic well-being of individuals in a country.
- *Gross Regional Product (GRP)* measures the total economic output of a specific region within Kazakhstan, expressed in millions of KZT. GRP is similar to GDP but at a regional level, including the market value of all final goods and services produced in that region over a specified period.
- *Gross Regional Product per Capita*. This indicator represents the per-person economic productivity and living standards within a specific region, expressed in thousands of KZT. It is calculated by dividing the GRP by the population of that region. This metric helps assess the average income and prosperity of individuals within the region.
- *Income below the subsistence level* reflects the proportion of people earning less than what is

necessary for basic living expenses. This variable indicates poverty levels by showing how many individuals fall below the threshold required for minimal subsistence.

- *Gini coefficient* is a measure of income inequality within a population, where 0 represents perfect equality (everyone has the same income) and 1 indicates maximal inequality (one person has all the income). It helps assess distributional fairness and economic disparity within society.
- *Unemployed population (unemployment rate)* is the total number of individuals or percentage of the labor force that is jobless but actively seeking employment. This indicator impacts economic stability and social well-being by reflecting labor market conditions and potential financial distress among households.
- *Average age of women* represents the mean age of women in the population. This demographic statistic can influence trends related to fertility, health outcomes, and social dynamics within a community.
- *Average age of mothers at birth* indicates the mean age of women when they give birth. This demographic measure can impact maternal and infant health outcomes, influencing both prenatal care practices and overall birth statistics.

Data analysis

Descriptive statistics were employed to summarize central tendencies, dispersions, and distributions. Pearson correlation analysis was conducted to identify relationships and potential multicollinearity among the variables. Variables that had a Pearson correlation coefficient (r) greater than 0.8 were excluded from further analysis to avoid multicollinearity issues [34]. We checked for multicollinearity using Variance Inflation Factors (VIFs). A VIF greater than 5 typically indicates significant multicollinearity among independent variables in a regression model [34]. Variables with VIF > 5 were excluded from the final model to avoid multicollinearity issues. Assumptions for multicollinearity, linearity, independence, and homoscedasticity were checked. The remaining variables included in the analysis were IMR, living wage, unemployed population, Gini coefficient, income below the subsistence level, housing space per capita, gross domestic product per capita, and average age of women.

In the analysis presented, all selected variables were subjected to a natural logarithm (ln) transformation. Many socioeconomic and health-related variables often have right-skewed distributions, where the majority of observations are concentrated at lower values with a long tail extending to higher values [35]. Applying the logarithmic transformation can mitigate the effects of skewness, resulting in a more symmetric distribution and data standardization [36].

Statistical analyses were performed with IBM SPSS 27.0, Standard Edition. Mean levels of infant mortality were assessed with a one sample t-test. In this study, linear regression analysis was employed to examine trends in IMR across all regions of Kazakhstan from 2010 to 2021. This approach allowed to identify statistically significant trends and quantify the average annual changes in IMR over the study period [37].

We employed a fixed effects regression model to analyze our panel data. Multiple linear regression was used to measure the effect size (B) of the previously detected statistically significant predictors in infant mortality. Significance was based on a 95% confidence interval (95% CI).

Results

The mean infant mortality rate for 2010–2021 across all Kazakhstan was 10.22 ± 3.27 (95% CI: 9.55–10.61), indicating moderate variability across the regions studied. The geographical distribution of average IMR across the study period, as shown in Fig. 1, highlights spatial variations, with regions such as Kyzylorda (average IMR: 13.0) having higher rates compared to northern areas like Akmola (average IMR: 9.15) or Pavlodar (average IMR: 8.32).

Table 1 presents the descriptive statistics for all study variables. The analysis revealed significant regional variations across socioeconomic indicators. The living wage averaged 22,657.32 ± 7,249.51 KZT, while unemployment stood at 23.51 ± 12.62 thousand people. Income disparities were evident in the average monthly salary (141,097.67 ± 65,036.44 KZT) and healthcare sector wages (107.25 ± 44.90 thousand KZT). The Gini coefficient (0.25 ± 0.04) indicated moderate income equality, with 3.46 ± 2.02% of the population below the subsistence level. Housing conditions averaged 21.97 ± 3.08 m^2 per capita. Demographic measures showed women's average age at 34.22 ± 3.60 years, with mothers averaging 28.50 ± 0.83 years at childbirth and a birth rate of 81 per 1,000 women aged 15–49.

Table 2 presents the results of the IMR trend analysis across the regions of Kazakhstan and the cities of national significance (Almaty and Astana). Overall, all regions showed a decline in IMR, however, in Northern Kazakhstan, this trend is not statistically significant ($p > 0.05$). The most substantial average annual decreases in IMR are observed in the East Kazakhstan, Kyzylorda, and South Kazakhstan regions, with annual average changes in IMR of -1.13, -1.15, and − 0.94 units, respectively.

Figure 2 illustrates the region-specific trends in infant mortality rate from 2010 to 2021, revealing variations in both the rate and pattern of change across Kazakhstan's

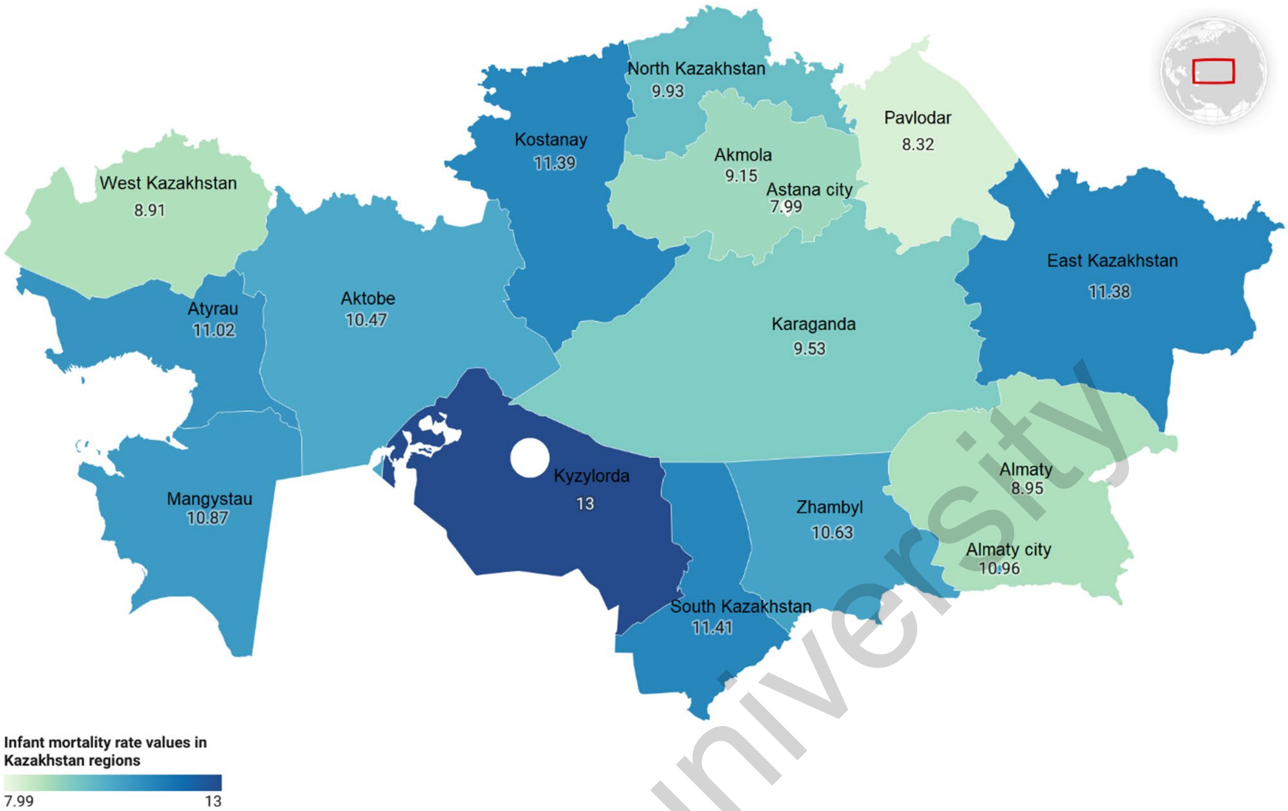

Fig. 1 Choropleth map of average infant mortality rate by region in Kazakhstan, 2010–2021

Table 1 Descriptive statistics of selected variables

Variables	Mean	95%CI		SD	Skewness
IMR, cases per 1000 live births	10.22	9.55	10.61	3.27	1.26
Living wage, in thousands KZT	22.66	21.58	23.95	7.25	0.69
Unemployed population, in thousands people	23.51	22.03	25.00	12.62	1.03
Average monthly salary, in thousands KZT	141.10	137.58	159.74	65.04	0.95
Average monthly salary in healthcare, in thousands KZT	107.25	103.21	117.99	44.90	1.25
Gini coefficient	0.25	0.25	0.26	0.04	-0.27
Income below the subsistence level, in percents	3.46	3.15	3.76	2.02	0.92
Housing space per capita, in square meters	21.97	21.46	22.47	3.08	0.98
Gross Regional Product, mln KZT	2831.63	2621.81	3347.15	2048.53	1.56
Gross Regional Product per Capita, thousands KZT	3418.99	3079.89	3758.10	2046.09	1.19
Average age of women, years	34.22	33.65	34.79	3.60	0.07
Birth rate, per 1000 women aged 15–49	80.16	76.50	83.82	24.17	0.37
Average age of mothers at birth, years	28.50	28.36	28.63	0.83	0.37

regions. Each panel represents the IMR trend for an individual region, highlighting the downward trajectories over the study period.

In the presented dataset, several indicators showed notable skewness in their distribution, and we log-transformed them to achieve a more symmetrical distribution.

In order to assess whether the average IMR (log transformed) from 2010 to 2021 significantly differs from the targeted national average for 2025 (which is 7.2 per 1000 live births [34], and the log transformed one is approximately equal to 2.0), a one-sample t-test was conducted with a null hypothesis stating that the average IMR is equal to the desired national average (Table 3). In examining the log-transformed IMR (IMR_log), the descriptive statistics reveal an average of 2.28 ± 0.29. A one-sample t-test comparing the average IMR_log to a specified test value of 2 yielded a substantial result ($t(195) = 13.350$, $p = 0.000$). The mean difference of 0.28, along with a 95% CI (0.24, 0.32), underscores the statistical significance and suggests that the average IMR_log

Table 2 IMR trend analysis results for Kazakhstan, 2010–2021

Region	2010–2021 average IMR	Annual average changes in IMR	95%CI (lower; upper)	*p*-value
Akmola	9.15	-0.85	-1.13; -0.58	< 0.001
Aktobe	10.47	-0.57	-0.92; -0.22	< 0.01
Almaty	8.95	-0.49	-0.69; -0.31	< 0.001
Atyrau	11.02	-0.66	-1.16; -0.16	< 0.05
East Kazakhstan	11.38	-1.13	-1.47; -0.79	< 0.001
Zhambyl	10.63	-0.86	-1.07; -0.66	< 0.001
West Kazakhstan	8.91	-0.45	-0.74; -0.18	< 0.01
Karaganda	9.53	-0.45	-0.71; -0.18	< 0.01
Kostanay	11.39	-0.41	-0.62; -0.21	< 0.01
Kyzylorda	13.00	-1.15	-1.62; -0.68	< 0.01
Mangystau	10.87	-0.74	-1.19; -0.29	< 0.01
Pavlodar	8.32	-0.59	-0.84; -0.34	< 0.001
North Kazakhstan	9.93	-0.29	-0.59; 0.01	> 0.05
South Kazakhstan	11.41	-0.94	-1.12; -0.77	< 0.001
Almaty city	10.96	-0.91	-1.41; -0.41	< 0.01
Astana city	7.99	-0.53	-0.78; -0.28	< 0.001

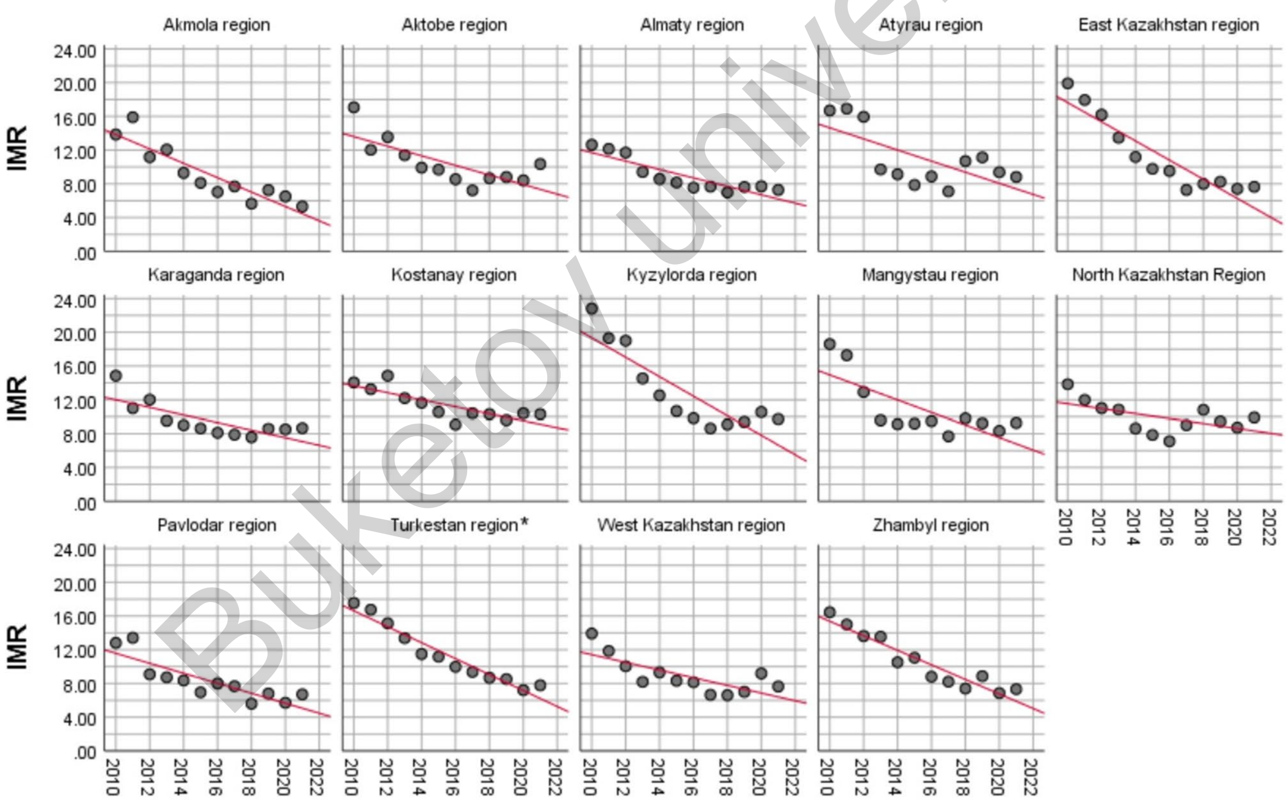

Fig. 2 Trends in infant mortality rate across regions in Kazakhstan, 2010–2021. N.B: *Until 2018 it was South Kazakhstan region

Table 3 Log transformed IMR comparison to reference of targeted log transformed IMR = 2.0

	n = 196	t-test	E.S.
IMR_log	2.28 (0.29)	t(195) = 13.35 ($p < 0.001$)	d = 0.3

differs notably from the specified test value. Additionally, Cohen's d of 0.29 indicates a small-to-medium effect, emphasizing the practical significance of the observed difference.

We conducted a Pearson correlation analysis to examine the relationships between the IMR and various factors. IMR was strongly negatively correlated with living

Table 4 Multiple linear regression determination of IMR

		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	Predictor	B	95%CI	β			Tolerance	VIF
β_0	(Constant)	8.971	(6.72; 11.222)		7.878	0.000		
β_1	Unemployed population, in thousands people	0.357	(0.236; 0.477)	0.412	5.839	0.000	0.512	1.955
β_2	GRP per Capita, thousands KZT	0.001	(-0.075; 0.076)	0.001	0.013	0.989	0.441	2.266
β_3	Gini coefficient	-0.483	(-0.833; -0.132)	-0.234	-2.725	0.007	0.346	2.894
β_4	Income below the subsistence level, in percents	0.164	(0.093; 0.235)	0.358	4.581	0.000	0.417	2.4
β_5	Housing space per capita, in square meters	-0.563	(-0.986; -0.14)	-0.257	-2.629	0.010	0.266	3.764
β_6	Living wage, in KZT	-0.472	(-0.638; -0.306)	-0.496	-5.616	0.000	0.326	3.066
β_7	Average age of women	-0.626	(-1.08; -0.171)	-0.219	-2.719	0.007	0.394	2.536

Notes: All variables were log-transformed. Dependent variable: IMR; $R^2 = 0.638$; adjusted $R^2 = 0.620$; $F_{(7,142)} = 35.775$ ($p < 0.001$), Durbin-Watson statistic of 1.7

wage (r = -0.667, $p < 0.01$), indicating that higher wages correlated with lower infant mortality levels. Similarly, average monthly salary (r = -0.542, $p < 0.01$) and average monthly salary in healthcare (r = -0.664, $p < 0.01$) both showed strong negative correlations with IMR, suggesting that increased incomes, particularly within the healthcare sector, contribute to reduced infant mortality. Additionally, housing space per capita was negatively correlated with IMR (r = -0.584, $p < 0.01$), signifying that better living conditions were linked to lower rates of infant death. Income below the subsistence level was positively correlated with IMR ($r = 0.287$, $p < 0.01$), highlighting that greater levels of poverty had relationship with higher infant mortality rates. Subsequent analysis, such as multiple regression, was implemented to understand the combined influence of these factors on IMR.

The multiple linear regression analysis revealed significant relationship between several socioeconomic factors and IMR in Kazakhstan from 2010 to 2021 (Table 4). Unemployment levels had a positive relationship with IMR (B = 0.357, β = 0.412, $p < 0.001$). Greater income inequality measured by the Gini coefficient showed negative relationship with IMR (B = -0.483, β = -0.234, $p = 0.007$). A higher percentage of the population living below the subsistence level correlated with higher IMR (B = 0.164, β = 0.358, $p < 0.001$). Increased housing space per capita was linked to decreased IMR (B = -0.563, β = -0.257, $p = 0.010$), while a higher living wage had negative realtionship with IMR (B = -0.472, β = -0.496, $p < 0.001$). Additionally, an older average age of women was related to lower IMR (B = -0.626, β = -0.219, $p = 0.007$). GRP per capita did not show a significant relationship with IMR ($p = 0.989$).

Assumptions of linearity, independence, normality, and homoscedasticity were verified. The normality of residuals was confirmed with a P-P plot (see Additional file 2), showing close alignment to the expected distribution. Scatter plots of residuals versus predicted values indicated linearity and homoscedasticity, with no discernible patterns (Additional file 3). The Durbin-Watson value of 1.7 suggested no significant autocorrelation.

The model had a good fit and explained a significant proportion of variance in IMR ($R^2 = 0.638$), with an adjusted (R^2) value of 0.620 and an overall F-statistic of (F (7,142)) = 35.775 ($p < 0.001$). Collinearity statistics indicated acceptable levels of multicollinearity among predictors: VIF values ranged from a low of 1.955 for the unemployed population to a high of 3.764 for housing space per capita, while tolerance values ranged from 0.266 to 0.512.

Discussion

Understanding infant mortality in Kazakhstan contributes significantly to a broader understanding of the Central Asian region. Kazakhstan can be seen as a representative case due to its economic transition, demographic dynamics, and specific policy initiatives [38]. The country's experiences may offer insights into how similar challenges and successes play out in neighboring CA countries, because Kazakhstan's experience holds relevance for neighboring countries in CA due to shared historical and cultural ties. Regional dynamics, such as economic transition challenges, social disparities, and demographic trends, might be common across the region [39]. The sixfold reduction in infant mortality from 1990 to 2017 signals notable progress [9], raising questions about the contributing factors.

Our analysis shows that infant mortality in Kazakhstan is influenced by a combination of socioeconomic and demographic factors. Higher levels of unemployment and a greater percentage of the population living below the subsistence level had positive raleationship with IMR, suggesting that economic instability and poverty are critical risk factors for infant health. These results align with existing literature which indicate that financial hardship often limits access to essential healthcare services, adequate nutrition, and safe living conditions, all of which are crucial for infant survival [40]. Specifically, our finding that higher unemployment is linked to increased

IMR is consistent with previous research. For instance, Tejada et al. (2019) also identified a correlation between higher unemployment rates, economic discomfort, and increased child mortality rates [41]. Similarly, research in Japan by Kanamori et al. (2021) demonstrated that unemployed workers experienced higher infant mortality rates compared to other occupational groups [42], further supporting the influential role of unemployment on infant survival observed in our study. On the other hand, income inequality, as measured by the Gini coefficient, showed a negative relationship with IMR. Our findings may reflect the complexity between income distribution and healthcare access in Kazakhstan. One possible explanation is that regions with higher income inequality might also have higher overall wealth and better-funded healthcare systems, which can mitigate some adverse effects on infant health. This highlights the nuanced role of inequality, supporting Schell et al.'s (2015) assertion that the Gini index is a relevant, though complex, predictor of infant mortality in middle-income countries [43].

The negative realtionship between housing space per capita and IMR (β = -0.257, $p = 0.010$) underscores the importance of adequate living conditions for reducing infant mortality. Greater housing space mitigates overcrowding, limits exposure to infectious diseases, and fosters healthier infant environments. While this relationship remains underexplored in public health literature, our findings align with Cage and Foster's (2002) study in Scotland, which identified housing space as a determinant of infant mortality [44]. This link is further reinforced by Fisher et al. (2024), who reported higher infant mortality in areas with household crowding in England [45], aligning with our results on the protective effect of greater housing space per capita.

Our study revealed an inverse relationship between living wage levels and IMR, underlining the potential impact of economic policies on infant health outcomes. This finding aligns with research by Komro et al., who reported that increases in state minimum wages were associated with improved infant health indicators [46]. Moreover, Kate Pickett emphasizes the important role of implementing a living wage policy as the single most impactful action that local authorities can take to reduce health inequalities [47]. Consequently, ensuring that wages meet or exceed the cost of living may enhance families' capacity to access essential healthcare services, maintain adequate nutrition, and provide a safe living environment for infants.

Interestingly, GRP per capita did not show a significant relationship with IMR. This suggests that while general economic prosperity is important, it alone does not directly translate into lower infant mortality without targeted interventions addressing disparities in access to healthcare and other essential services. Overall, this finding contrasts with much of the existing literature, where researchers typically report a strong inverse relationship between economic indicators like GRP per capita and infant mortality rates [48, 49].

Overall, our findings highlight key areas where policy interventions could potentially mitigate adverse outcomes in infant health. Policies aimed at reducing unemployment and poverty levels could significantly impact lowering IMR. A comprehensive strategy should include initiatives aimed at enhancing public awareness regarding health monitoring, access to medical care, and existing programs dedicated to reducing mortality. Solidarity in taking responsibility for individual health should be promoted [50]. Aligning with the principles of the Adelaide Statement on Health in All Policies, it is important to recognize that addressing infant mortality issues requires not only health policies but also broader societal policies [51]. These policies should explicitly target the social determinants of health, contributing to the reduction of inequities in infant mortality and birth outcomes. A concerted effort at both the societal and individual levels, while addressing key research gaps in the social determinants of infant mortality and birth outcomes, is necessary for achieving optimal results. Recently, Kazakhstan achieved a substantial progress towards reducing its infant mortality rate and improving overall public health. The policies "Densaulyk" and "Salamatty Kazakhstan" have played a significant role in influencing maternal, prenatal, and infant health in Kazakhstan. "Densaulyk" focused on healthcare improvements, while "Salamatty Kazakhstan" aimed at enhancing public health [52, 53]. According to Abzaliyeva et al. stable reductions in cardiovascular, maternal, and infant mortality rates observed in Kazakhstan from 2015 to 2019 were attributed to increased per capita supply of general practitioners [54]. Moreover, improving health and insurance coverage can emerge as an effective strategy to reduce state IMR [55].

While our study provides valuable insights into the socioeconomic determinants of infant mortality in Kazakhstan, several limitations should be acknowledged. Our model did not account for several potentially influential factors due to data limitations and the scope of the study. Firstly, cultural factors, which can significantly impact healthcare-seeking behaviors, child-rearing practices, and attitudes towards prenatal and postnatal care, were not included in our analysis. Cultural factors, even after economic standing adjustments, can strongly predict infant deaths [56, 57]. Secondly, we did not incorporate educational attainment levels, particularly of mothers, into our model. Despite progress in education in Kazakhstan, with the average working-age individual having 15 years of education and a literacy rate of 99.9% among young people aged 15–24 years [15], challenges persist. Thirdly, genetic predispositions and pre-existing health conditions, which can influence infant health outcomes, were not considered in our study. These factors can vary across populations and regions, potentially confounding the relationships we observed between socioeconomic factors and infant mortality.

We also acknowledge potential limitations related to data quality inherent in low- and middle-income settings like Kazakhstan. However, it's worth noting that Kazakhstan has implemented comprehensive guidelines for the collection, classification, documentation, and dissemination of medical statistics. These guidelines are in line with current international standards [58, 59]. Both the Bureau of National Statistics of Kazakhstan and the Ministry of Healthcare employ rigorous data management protocols. These include systematic audits and robust quality assurance measures. While such practices do not entirely eliminate the possibility of errors or biases in the primary data collection, they do instill a significant level of trust in the data's overall reliability and uniformity. This methodological rigor enhances our confidence in the dataset used for this study, despite the inherent limitations of secondary data analysis. Nevertheless, we acknowledge that some degree of caution is warranted when interpreting our results, given these considerations.

Conclusions

This study analyzes the relationship between infant mortality rates and various socioeconomic factors in Kazakhstan from 2010 to 2021. Our findings indicate that several key socioeconomic determinants play influential roles in infant mortality levels, highlighting both risk and protective factors. Based on these results, we recommend prioritizing policies aimed at reducing unemployment rates and alleviating poverty. Investing in housing infrastructure to decrease overcrowding and improve living conditions may positively impact infant health outcomes. Additionally, implementing and enhancing living wage policies can provide families with the financial means necessary for accessing healthcare and maintaining healthy environments. These findings may be valuable for policymakers not only in Kazakhstan but also in other Central Asian nations facing similar public health challenges.

Abbreviations

CA	Central Asia
WHO	World Health Organization
SD	Standard deviation
ES	Effect size
GRP	Gross regional product
GRP_Cap	Gross regional product per capita
GDP	Gross domestic product
KZT	Kazakhstani tenge
IMR	Infant mortality rate
IMR_log	Infant mortality rate log transformed
VIF	Variance inflation factor
P-P	Probability-Probability

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

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Author contributions

O.Z. and N.S. designed the study. O.Z., K.N., G.Zh., Zh.A., and N.Sh. performed the literature searches, O.Z., G.T., and A.K., prepared the manuscript draft. O.Z. and N.S. wrote the main manuscript, G.T., A.K. and Zh.A. collected the data. N.S., O.Z. and K.N conducted statistical analysis. All authors contributed to revising the manuscript. O.Z. and Z.K. prepared and edited the final manuscript. N.S. and Z.K. reviewed the final version.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

The present study has received ethical approval from the IRB Ethics Committee of Karaganda Medical University, protocol number 09–45, November 27, 2023. The committee has granted a waiver for the informed consent, acknowledging the retrospective nature of the study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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