

Temporal Trends and Geographic Associations of Circulatory Disease Hospitalizations Among Young Adults in Almaty and the Turkestan Region, 2018–2024

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Background: This study aims to assess temporal trends and geographic differences in hospitalization rates for circulatory system diseases among adults aged 18–44 years in Almaty and the Turkestan region.

Methods: This study analyzed hospitalization data for circulatory diseases (ICD-10 I00–I99) among adults aged 18–44 years in Almaty, Turkestan city, and rural Turkestan from 2018 to 2024. Crude hospitalization rates per 100,000 population were calculated using official population denominators, and admissions were classified as urgent or planned. The outcome was annual hospitalization counts stratified by year, sex, diagnosis, and geographic location. After detecting overdispersion in Poisson regression, a negative binomial model was applied, providing improved model fit and estimation of incidence rate ratios (IRRs).

Results: Hospitalization rates declined substantially through 2022, particularly in Almaty, followed by an increase by 2024. In contrast, the Turkestan region showed more moderate declines, with consistently higher hospitalization rates compared to Almaty. Cerebrovascular and hypertensive diseases were the leading contributors across regions. Urgent admissions accounted for the majority of hospitalizations. Regression analysis demonstrated significant associations with time, age, diagnostic category, and geographic location, with the highest rates observed in rural Turkestan and the lowest in Almaty. No significant sex differences were observed.

Conclusion: Hospitalization patterns for circulatory diseases among young adults varied across regions and over time, with a decline observed until 2022 followed by a rebound by 2024. These findings reflect statistically observed associations and should be interpreted cautiously, as they are based on aggregated data and do not establish causal relationships.

Keywords: circulatory system diseases, young adults, regional disparities, Kazakhstan, epidemiological trends

Introduction

Cardiovascular diseases (CVDs) remain the leading cause of morbidity and mortality globally, largely attributable to preventable and modifiable risk factors. While age-standardized mortality and disability-adjusted life years (DALYs) from CVD have declined over recent decades, emerging evidence indicates a divergent pattern among younger populations. Global estimates from 1990 to 2019 demonstrate that, despite improvements in survival, both the incidence and prevalence of CVD among youths and young adults have increased, with disproportionate rises observed in low- and middle-income settings.¹ Notable sex-specific disparities have also been documented, with faster increases in prevalence among young women and greater DALY and mortality burdens among young men. These trends are predominantly

driven by elevated blood pressure, adiposity, dyslipidemia, and clustering of lifestyle-related risk factors. Moreover, recent studies suggest that the growing burden of cardiometabolic risk, alongside increasing rates of substance use and the persistent incidence of CVD among aged individuals 18–50 years, may presage a substantial future rise in ischemic heart disease, heart failure, atrial fibrillation, and sudden cardiac death as this cohort advances in age.² Collectively, these observations emphasize the need for strengthened, youth-centred preventive strategies and health systems capable of detecting risk accumulation early.

Kazakhstan has aligned national health policy with principles of universal health coverage, prioritizing equitable access to primary health care (PHC) and expanding prevention-oriented services. Recent reforms have enhanced PHC financing and introduced standardized population-based screening protocols specifying target groups, procedures, and periodicity.^{3,4} The updated framework mandates a multistage screening process encompassing initial risk assessment, diagnostic confirmation, and structured follow-up, with compulsory documentation within electronic medical information systems—thereby facilitating continuity of care and systematic risk surveillance.⁵

Despite these system-level improvements, important challenges persist. Workforce capacity, particularly in nursing, remains an area of ongoing development. Kazakhstan's transition away from the Soviet nurse-training model has advanced over the past two decades, yet training and competency gaps remain.⁶ The introduction of nurse-led consultations represents a significant innovation within PHC, enabling nurses to conduct routine assessments, provide lifestyle counseling, deliver patient education, and coordinate diagnostic investigations. Evidence from early implementation shows improved service efficiency, reduced physician workload, and enhanced access to timely preventive care.⁷

Previous research suggests that the prevalence of CVD among young people in Kazakhstan may reach 22.4%, driven largely by modifiable behavioral and metabolic risks.⁸ However, empirical data on hospitalization patterns in this demographic remain limited. In this context, hospitalization rates may be influenced by a combination of demographic (age), geographic (urban–rural setting), and clinical (diagnostic group) factors, which operate as structural and health-system-related correlates rather than direct causal determinants.

Therefore, the aim of this study was to examine hospitalization patterns due to CVD among adults aged 18–44 years in Almaty and the Turkestan region by: (1) assessing temporal trends from 2018 to 2024, (2) comparing geographic differences between urban and rural populations, and (3) analyzing the distribution of urgent versus planned hospitalizations. This approach allows characterization of the burden of acute cardiovascular events within the context of Kazakhstan's unified national health system while focusing on statistically observable associations rather than causal effects.

Methods

Study Design and Population

This study was designed as a retrospective registry-based observational study using aggregated administrative hospitalization data. We analyzed hospitalizations for circulatory system diseases among young adults aged 18–44 years in Almaty city, Turkestan city, and rural areas of the Turkestan region for the period 2018–2024. The data were obtained from the National Research Center for Health Development (NRCHD) of the Republic of Kazakhstan through an official institutional request. NRCHD is the authorized national body responsible for centralized collection, storage, and reporting of healthcare statistics and registry-based hospitalization data in Kazakhstan.

The dataset provided to the authors consisted of de-identified aggregated hospitalization records stratified by year, sex, age, ICD-10 diagnostic category, and geographic area. The source registry included hospitalizations classified under circulatory system diseases (ICD-10 codes I00–I99). The extracted data did not permit independent verification of whether only primary discharge diagnoses were included or whether secondary diagnoses also contributed to case totals; therefore, the analysis was conducted using the registry definitions as provided by NRCHD. Data entry, ICD coding, and routine validation were performed within the national healthcare reporting system. Because the authors received only aggregated data, no independent audit of individual coding accuracy was possible.

Study Population and Variables

The study population included hospitalized young adults aged 18–44 years with circulatory system diseases recorded during 2018–2024 in the selected administrative areas. The main outcome variable was the number of CVD hospitalizations for each stratum defined by year, sex, age, ICD-10 diagnostic group, and geographic area. Annual hospitalization rates per 100,000 population were also calculated descriptively using official population denominators for each administrative unit and year. Predictor variables in the regression analysis included: (1) year (categorical; reference category = 2018); (2) age (continuous, in years); (3) sex (male, female); (4) diagnostic group, categorized into ICD-10 subgroups (I00–I02, I05–I09, I10–I13, I15, I20, I21, I22, I24, I25, I26–I28, I30–I52, I60–I69, and other I-group diseases); and (5) place of residence (Almaty city, Turkestan city, rural Turkestan region). Categorical predictors were dummy-coded for regression modeling.

Hospitalizations were additionally classified as urgent or planned. This variable was used for descriptive analysis only and was not included in the primary regression model.

Statistical Analysis

Because the dependent variable represented count data, a Poisson regression model was initially considered. The expected hospitalization count for observation i was modeled as:

$$\log(\lambda_i) = \beta_0 + \beta_1 * (\text{age}) + \beta_2 * (\text{gender}) + \beta_3 * (\text{ICD10}) + \beta_4 * (\text{Accommodation}) + \beta_5 * (\text{year})$$

Where $\log(\lambda_i)$ denotes the expected count for observation i , and $\log(\text{population}_i)$ was included as an offset term to account for differences in population size between geographic areas and calendar years. Thus, exponentiated coefficients were interpreted as incidence rate ratios (IRRs) reflecting relative changes in hospitalization rates rather than simple case counts.

Assessment of the Poisson model demonstrated substantial overdispersion (dispersion statistic = 6.47), indicating that the variance exceeded the mean. Therefore, a negative binomial regression model was fitted as the primary analytic model. This model introduces an additional dispersion parameter and provides more reliable standard errors and confidence intervals under overdispersed count data conditions. In the final model, the estimated dispersion parameter was $\theta=1.073$.

Year was modeled as a categorical variable rather than a continuous term in order to capture potentially non-linear temporal changes in hospitalization rates across the study period. This approach was considered especially appropriate given possible year-to-year fluctuations related to healthcare access, reporting patterns, and pandemic-era disruptions.

Model coefficients were estimated by maximum likelihood and reported as IRRs with corresponding p -values. Model fit was assessed using residual deviance, null deviance, Akaike information criterion (AIC), and log-likelihood. The residual deviance of the final model was substantially lower than the null deviance, indicating improved explanatory performance. Observations with missing data ($n = 289$) were excluded prior to modeling. No patient-level imputation was performed because the source dataset was aggregated.

Sensitivity analyses were limited due to the aggregated structure of the dataset; however, model robustness was assessed through comparison of Poisson and negative binomial models and evaluation of goodness-of-fit indicators.

Methodological Limitations

The available registry dataset did not include individual-level information on comorbidities, socioeconomic factors, health behaviors, outpatient management, or medication use; therefore, these determinants could not be evaluated in the regression model. In addition, because only aggregated administrative data were available, the authors could not independently validate ICD coding procedures or distinguish primary from secondary diagnoses within the hospitalization counts. These constraints should be considered when interpreting the results.

Ethical Approval

The study was approved by the Local Ethics Committee of the Khoja Ahmet Yassawi International Kazakh Turkish University, Turkistan, Kazakhstan (№87, 14–11-2024), Almaty, Kazakhstan (in accordance with the Declaration of

Helsinki, the study involved no direct patient contact and was based on anonymized registry-level data; accordingly, the requirement for informed consent was waived by the Ethics Committee).

Results

Hospitalization per 100,000 Population (18–44 Years), CVD

In Almaty city, hospitalization rates for circulatory system diseases decreased from 77.3 per 100,000 population in 2018 to 33.4 in 2022, followed by a marked increase to 102.3 in 2024. A similar pattern was observed across sex-specific subgroups, although the magnitude of change appeared substantial. Male hospitalization rates decreased from 105.8 to 6.4 between 2018 and 2022 and subsequently increased to 129.1 in 2024, while female rates decreased from 53.6 to 2.2 and later rose to 78.6.

These pronounced reductions during 2020–2022 likely reflect the indirect effects of the COVID-19 pandemic, including reduced healthcare utilization, temporary suspension of elective admissions, and changes in hospital admission practices, rather than a true decrease in disease incidence. The subsequent rebound in 2023–2024 supports this interpretation.

In contrast, the Turkestan region demonstrated more moderate declines. In Turkestan city, hospitalization rates decreased from 2,360 to 716 per 100,000 population, while in rural areas the reduction was from 1,161 to 733. The smaller magnitude of decline compared to Almaty suggests regional differences in healthcare access, system organization, and reporting practices. The substantially higher hospitalization rates observed in Turkestan compared to Almaty may also reflect differences in referral patterns, a higher burden of cerebrovascular disease, and possible variations in admission thresholds and reporting practices.

Across all regions, cerebrovascular diseases, hypertensive disorders, and other heart diseases remained the leading contributors to hospitalization burden (Table 1 and [supplementary material 1](#)).

Type of Hospitalization (18–44 Years)

Across the entire study period, urgent hospitalizations predominated in both Almaty and the Turkestan region. In Turkestan city, urgent admissions accounted for 76–93% of all cases annually, while in rural areas this proportion ranged from 70% to 85%. Almaty demonstrated a similar pattern, with urgent admissions representing 60–65% of cases in 2018 and approximately 50% in 2024.

The predominance of urgent admissions suggests that circulatory diseases in young adults are frequently diagnosed at advanced or acute stages, particularly in regions with limited access to preventive care. This pattern was especially pronounced for cerebrovascular and hypertensive conditions (Table 2).

Regression Analysis

The negative binomial regression model demonstrated significant temporal, demographic, diagnostic, and geographic effects on hospitalization rates. The model included a population offset term ($\log(\text{population})$), and therefore incidence rate ratios (IRRs) should be interpreted as relative changes in hospitalization rates rather than absolute case counts.

Compared with 2018 (reference year), incidence rate ratios (IRRs) indicated substantial reductions in hospitalization rates during 2020–2024, with the largest declines observed in 2022 (IRR = 0.552; –45%), followed by 2020 (IRR = 0.576; –42%) and 2021 (IRR = 0.636; –36%). These findings are consistent with pandemic-related disruptions in healthcare utilization.

Age was a significant predictor (IRR = 1.066; $p < 2 \times 10^{-16}$), indicating a 6.5% increase in hospitalization rate per additional year of age (Table 3).

Large IRR values observed for certain diagnostic groups (eg., IRR $\approx$ 30) reflect relative differences between ICD categories with low baseline frequencies, rather than absolute increases in risk. These values should therefore be interpreted with caution as category-specific effects rather than individual-level risk estimates.

Table 1 Treated Cases per 100,000 Population (18–44 Age)

Years		2018	2019	2020	2021	2022	2023	2024
Gender		Total						
Region		Almaty city						
Population		848528	861,239	876,687	891,585	861,473	891,652	916516
Acute rheumatic fever	I00-I02	0.00	0.00	0.00	0.00	0.00	0.00	0,00
Chronic rheumatic heart diseases	I05-09	0.00	0.00	0.00	0.00	0.00	0.00	0,00
Hypertensive diseases	I10-I13	47.26	49.58	19.16	19.74	1.39	39.93	41,57
Secondary hypertension	I15	0.35	0.46	0.46	0.00	0.00	0.45	0,11
Angina pectoris	I20	0.00	0.00	0.00	0.00	0.00	0.00	0,00
Acute myocardial infarction	I21	12.61	13.12	17.34	14.13	0.93	15.48	13,97
Subsequent myocardial infarction	I22	0.00	0.00	0.00	0.00	0.00	0.00	0,00
Other acute ischaemic heart diseases	I24	0.00	0.00	0.00	0.00	0.00	0.00	0,00
Chronic ischaemic heart disease	I25	4.01	6.15	5.93	9.42	0.93	6.73	8,07
Pulmonary heart disease and diseases of pulmonary circulation	I26-28	0.00	0.00	0.00	0.00	0.00	0.00	0,00
Other heart diseases	I30-52	0.35	0.70	1.14	1.01	0.00	5.61	6,98
Cerebrovascular diseases	I60-69	1.77	2.21	0.91	1.23	0.00	2.58	0,65
Other diseases within group I (circulatory system diseases)		10,96	7.32	12.78	19.07	0.93	21.20	30.99
Total		77,31	79.54	57.72	64.60	4.18	91.96	102.34
Region		Turkestan region						
Population		720376	705,090	709,922	710,589	717,585	718,503	720416
Acute rheumatic fever	I00-I02	0.14	0.14	0.28	0.00	0.28	0.28	0,00
Chronic rheumatic heart diseases	I05-09	23.74	19.57	3.94	3.52	2.51	2.23	1,67
Hypertensive diseases	I10-I13	143.26	151.61	179.17	202.79	172.94	196.24	202,11
Secondary hypertension	I15	138.12	217.70	39.44	25.47	21.88	18.23	27,07
Angina pectoris	I20	20.96	21.13	24.79	43.77	42.64	38.69	42,48
Acute myocardial infarction	I21	4.86	3.55	7.18	6.75	5.71	7.52	8,61
Subsequent myocardial infarction	I22	0.28	0.14	0.28	0.28	0.42	0.56	0,42
Other acute ischaemic heart diseases	I24	1.25	3.26	2.39	2.25	2.23	1.25	0,56
Chronic ischaemic heart disease	I25	19.99	17.87	11.13	20.26	14.35	11.13	17,77
Pulmonary heart disease and diseases of pulmonary circulation	I26-28	3.19	2.55	4.93	4.08	3.90	4.18	5,69
Other heart diseases	I30-52	73.85	72.33	54.65	66.85	74.42	81.28	89,95
Cerebrovascular diseases	I60-69	649.38	547.73	199.18	162.40	171.55	162.28	153,38
Other diseases within group I (circulatory system diseases)		289,15	283.65	179.03	180.70	166.25	183.85	178.92

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Table 1 (Continued).

Years		2018	2019	2020	2021	2022	2023	2024
Total		1368,17	1341.25	706.42	719.12	679.08	707.72	728.61
Region		Turkestan city						
Population		124430	120,984	124,789	126,683	174,984	176,371	177958
Acute rheumatic fever	I00-I02	0.00	0.00	0.00	0.00	0.57	0.57	0,00
Chronic rheumatic heart diseases	I05-09	41.79	47.11	8.81	2.37	2.29	1.70	1,12
Hypertensive diseases	I10-13	180.02	178.54	142.64	224.18	148.01	178.03	160,15
Secondary hypertension	I15	24.11	42.15	12.02	4.74	4.57	5.67	14,61
Angina pectoris	I20	72.33	69.43	97.77	198.92	121.73	80.51	96,65
Acute myocardial infarction	I21	8.84	3.31	5.61	13.42	12.00	6.80	12,92
Subsequent myocardial infarction	I22	0.80	0.83	0.80	0.00	0.57	0.00	0,00
Other acute ischaemic heart diseases	I24	0.00	1.65	12.82	12.63	9.14	2.83	0,00
Chronic ischaemic heart disease	I25	48.22	25.62	12.02	39.47	14.29	11.34	16,30
Pulmonary heart disease and diseases of pulmonary circulation	I26-28	1.61	2.48	7.21	1.58	1.71	1.70	1,69
Other heart diseases	I30-52	148.68	110.76	96.96	101.04	84.01	86.18	86,54
Cerebrovascular diseases	I60-69	1621.80	1224.13	287.69	210.76	164.59	121.90	160,71
Other diseases within group I (circulatory system diseases)		211,36	181.02	171.49	177.61	121.15	146.28	165.77
Total		2359,56	1887.03	855.84	986.71	684.63	643.53	716.46
Region		Rural area of Turkestan region						
Population		595946	584,106	585,133	583,906	542,601	542,132	542458
Acute rheumatic fever	I00-I02	0.17	0.17	0.34	0.00	0.18	0.18	0,00
Chronic rheumatic heart diseases	I05-09	19.97	13.87	2.91	3.77	2.58	2.40	1,84
Hypertensive diseases	I10-13	135.58	146.04	186.97	198.15	180.98	202.16	215,87
Secondary hypertension	I15	161.93	254.06	45.29	29.97	27.46	22.32	31,15
Angina pectoris	I20	10.24	11.13	9.23	10.10	17.14	25.09	24,70
Acute myocardial infarction	I21	4.03	3.60	7.52	5.31	3.69	7.75	7,19
Subsequent myocardial infarction	I22	0.17	0.00	0.17	0.34	0.37	0.74	0,55
Other acute ischaemic heart diseases	I24	1.51	3.60	0.17	0.00	0.00	0.74	0,74
Chronic ischaemic heart disease	I25	14.10	16.26	10.94	16.10	14.38	11.07	18,25
Pulmonary heart disease and diseases of pulmonary circulation	I26-28	3.52	2.57	4.44	4.62	4.61	4.98	7,01
Other heart diseases	I30-52	58.23	64.37	45.63	59.43	71.32	79.69	91,07
Cerebrovascular diseases	I60-69	446.35	407.63	180.30	151.91	173.79	175.42	150,98

(Continued)

Table 1 (Continued).

Years	2018	2019	2020	2021	2022	2023	2024
Other diseases within group I (circulatory system diseases)	305,40	304.91	180.64	181.36	180.80	196.08	183.24
Total	1161,18	1228.20	674.55	661.07	677.29	728.60	732.59

Table 2 Hospital Admissions for CVD in Turkestan Region and Almaty by Care Type

	Turkestan Region						Almaty		
ICD	City			Rural					
	Planning	Urgent	Total	Planning	Urgent	Total	Planning	Urgent	Total
	2018								
I00-I02	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.0)	1 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
I05-I09	8 (1.1)	44 (2.0)	52 (1.8)	89 (2.5)	30 (0.9)	119 (1.7)	0 (0.0)	0 (0.0)	0 (0.0)
I10-I13	23 (3.3)	201 (9.0)	224 (7.6)	108 (3.1)	700 (20.6)	808 (11.7)	139 (62.1)	262 (60.6)	401 (61.1)
I15	24 (3.4)	6 (0.3)	30 (1.0)	727 (20.7)	238 (7.0)	965 (13.9)	0 (0.0)	3 (0.7)	3 (0.5)
I20	31 (4.4)	59 (2.6)	90 (3.1)	7 (0.2)	54 (1.6)	61 (0.9)	4 (1.8)	103 (23.8)	107 (16.3)
I21	0 (0.0)	11 (0.5)	11 (0.4)	1 (0.0)	23 (0.7)	24 (0.3)	0 (0.0)	0 (0.0)	0 (0.0)
I22	0 (0.0)	1 (0.0)	1 (0.0)	0 (0.0)	1 (0.0)	1 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
I24	0 (0.0)	0 (0.0)	0 (0.0)	6 (0.2)	3 (0.1)	9 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)
I25	14 (2.0)	46 (2.1)	60 (2.0)	69 (2.0)	15 (0.4)	84 (1.2)	22 (9.8)	12 (2.8)	34 (5.2)
I26-I28	0 (0.0)	2 (0.1)	2 (0.1)	2 (0.1)	19 (0.6)	21 (0.3)	0 (0.0)	0 (0.0)	0 (0.0)
I30-I52	54 (7.7)	131 (5.9)	185 (6.3)	218 (6.2)	129 (3.8)	347 (5.0)	3 (1.3)	0 (0.0)	3 (0.5)
I60-I69	492 (70.4)	1526 (68.2)	2018 (68.7)	1456 (41.4)	1204 (35.4)	2660 (38.4)	14 (6.3)	1 (0.2)	15 (2.3)
I70-I99	53 (7.6)	210 (9.4)	263 (9.0)	834 (23.7)	986 (29.0)	1820 (26.3)	42 (18.8)	51 (11.8)	93 (14.2)
Total	699 (100.0)	2237 (100.0)	2936 (100.0)	3517 (100.0)	3403 (100.0)	6920 (100.0)	224 (100.0)	432 (100.0)	656 (100.0)
	2019								
I00-I02	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.0)	0 (0.0)	1 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
I05-I09	13 (3.1)	44 (2.4)	57 (2.5)	51 (1.4)	30 (0.8)	81 (1.1)	0 (0.0)	0 (0.0)	0 (0.0)
I10-I13	28 (6.6)	188 (10.1)	216 (9.5)	212 (5.8)	641 (18.2)	853 (11.9)	148 (58.7)	279 (64.4)	427 (62.3)
I15	24 (5.6)	27 (1.5)	51 (2.2)	1181 (32.4)	303 (8.6)	1484 (20.7)	2 (0.8)	2 (0.5%)	4 (0.6)
I20	12 (2.8)	72 (3.9)	84 (3.7)	8 (0.2)	57 (1.6)	65 (0.9)	0 (0.0)	0 (0.0)	0 (0.0)
I21	0 (0.0)	4 (0.2)	4 (0.2)	0 (0.0)	21 (0.6)	21 (0.3)	3 (1.2)	110 (25.4)	113 (16.5)
I22	0 (0.0)	1 (0.1)	1 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
I24	0 (0.0)	2 (0.1)	2 (0.1)	15 (0.4)	6 (0.2)	21 (0.3)	0 (0.0)	0 (0.0)	0 (0.0)
I25	7 (1.6)	24 (1.3)	31 (1.4)	77 (2.1)	18 (0.5)	95 (1.3)	41 (16.3)	12 (2.8)	53 (7.7)

(Continued)

Table 2 (Continued).

	Turkestan Region						Almaty		
ICD	City			Rural					
	Planning	Urgent	Total	Planning	Urgent	Total	Planning	Urgent	Total
	2018								
I26-I28	0 (0.0)	3 (0.2)	3 (0.1)	3 (0.1)	12 (0.3)	15 (0.2)	0 (0.0)	0 (0.0)	0 (0.0)
I30-I52	34 (8.0)	100 (5.4)	134 (5.9)	218 (6.0)	158 (4.5)	376 (5.2)	6 (2.4)	0 (0.0)	6 (0.9)
I60-I69	272 (64.0)	1209 (65.1)	1481 (64.9)	1129 (31.0)	1252 (35.5)	2381 (33.2)	19 (7.5)	0 (0.0)	19 (2.8)
I70-I99	35 (8.2)	184 (9.9)	219 (9.6)	749 (20.6)	1032 (29.2)	1781 (24.8)	33 (13.1)	30 (6.9)	63 (9.2)
Total	425 (100.0)	1858 (100.0)	2283 (100.0)	3644 (100.0)	3530 (100.0)	7174 (100.0)	252 (100.0)	433 (100.0)	685 (100.0)
	2020								
I00-I02	0(0.0)	0 (0.0)	0 (0.0)	2 (0.1)	0 (0.0)	2 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)
I05-I09	3(0.9)	8 (1.1)	11 (1.0)	5 (0.3)	12 (0.6)	17 (0.4)	0 (0.0)	0 (0.0)	0 (0.0)
I10-I13	56 (16.6)	122 (16.7)	178 (16.7)	610 (30.7)	484 (24.7)	1094 (27.7)	89 (32.6)	79 (33.9)	168 (33.2)
I15	10 (3.0)	5 (0.7)	15 (1.4)	229 (11.5)	36 (1.8)	265 (6.7)	3 (1.1)	1 (0.4)	4 (0.8)
I20	23 (6.8)	99 (13.6)	122 (11.4)	17 (0.9)	37 (1.9)	54 (1.4)	0 (0.0)	0 (0.0)	0 (0.0)
I21	3 (0.9)	4 (0.5)	7 (0.7)	13 (0.7)	31 (1.6)	44 (1.1)	54 (19.8)	98 (42.1)	152 (30.0)
I22	0 (0.0)	1 (0.1)	1 (0.1)	0 (0.0)	1 (0.1)	1 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
I24	7 (2.1)	9 (1.2)	16 (1.5)	1 (0.1)	0 (0.0)	1 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
I25	8 (2.4)	7 (1.0)	15 (1.4)	43 (2.2)	21 (1.1)	64 (1.6)	35 (12.8)	17 (7.3)	52 (10.3)
I26-I28	2(0.6)	7 (1.0)	9 (0.8)	7 (0.4)	19 (1.0)	26 (0.7)	0 (0.0)	0 (0.0)	0 (0.0)
I30-I52	84 (24.9)	37 (5.1)	121 (11.3)	179 (9.0)	88 (4.5)	267 (6.8)	8 (2.9)	2 (0.9)	10 (2.0)
I60-I69	68 (20.1)	291 (39.9)	359 (33.6)	421 (21.2)	634 (32.3)	1055 (26.7)	7 (2.6)	1 (0.4)	8 (1.6)
I70-I99	74 (21.9)	140 (19.2)	214 (20.0)	459 (23.1)	598 (30.5)	1057 (26.8)	77 (28.2)	35 (15.0)	112 (22.1)
Total	338 (100.0)	730 (100.0)	1068 (100.0)	1986 (100.0)	1961 (100.0)	3947 (100.0)	273 (100.0)	233 (100.0)	506 (100.0)
	2021								
I00-I02	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
I05-I09	2 (0.6)	1 (0.1)	3 (0.2)	5 (0.3)	17 (0.9)	22 (0.6)	0 (0.0)	0 (0.0)	0 (0.0)
I10-I13	70 (20.8)	214 (23.4)	284 (22.7)	605 (31.9)	552 (28.1)	1157 (30.0)	91 (31.7)	85 (29.4)	176 (30.6)
I15	5 (1.5)	1 (0.1)	6 (0.5)	131 (6.9)	44 (2.2)	175 (4.5)	0 (0.0)	0 (0.0)	0 (0.0)
I20	27(8.0)	225 (24.6)	252 (20.2)	23 (1.2)	36 (1.8)	59 (1.5)	0 (0.0)	0 (0.0)	0 (0.0)
I21	6 (1.8)	11 (1.2)	17 (1.4)	9 (0.5)	22 (1.1)	31 (0.8)	35 (12.2)	91 (31.5)	126 (21.9)
I22	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (0.1)	2 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)
I24	11 (3.3)	5 (0.5)	16 (1.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
I25	29 (8.6)	21 (2.3)	50 (4.0)	59 (3.1)	35 (1.8)	94 (2.4)	44 (15.3)	40 (13.8)	84 (14.6)

(Continued)

Table 2 (Continued).

	Turkestan Region						Almaty		
ICD	City			Rural					
	Planning	Urgent	Total	Planning	Urgent	Total	Planning	Urgent	Total
	2018								
I26-I28	0 (0.0)	2 (0.2)	2 (0.2)	14 (0.7)	13 (0.7)	27 (0.7)	0 (0.0)	0 (0.0)	0 (0.0)
I30-I52	79 (23.4)	49 (5.4)	128 (10.2)	233 (12.3)	114 (5.8)	347 (9.0)	6 (2.1)	3 (1.0)	9 (1.6)
I60-I69	69 (20.5)	198 (21.7)	267 (21.4)	387 (20.4)	500 (25.4)	887 (23.0)	11 (3.8)	0 (0.0)	11 (1.9)
I70-I99	39 (11.6)	186 (20.4)	225 (18.0)	429 (22.6)	630 (32.1)	1059 (27.4)	100 (34.8)	70 (24.2)	170 (29.5)
Total	337 (100.0)	913 (100.0)	1250 (100.0)	1895 (100.0)	1965 (100.0)	3860 (100.0)	287 (100.0)	289 (100.0)	576 (100.0)
	2022								
I00-I02	0 (0.0)	1 (0.1)	1 (0.1)	1 (0.1)	0 (0.0)	1 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
I05-I09	3 (0.8)	1 (0.1)	4 (0.3)	6 (0.3)	8 (0.4)	14 (0.4)	0 (0.0)	0 (0.0)	0 (0.0)
I10-I13	47 (13.1)	212 (25.2)	259 (21.6)	508 (27.9)	474 (25.6)	982 (26.7)	7 (36.8)	5 (29.4)	12 (33.3)
I15	4 (1.1)	4 (0.5)	8 (0.7)	84 (4.6)	65 (3.5)	149 (4.1)	0 (0.0)	0 (0.0)	0 (0.0)
I20	57 (15.9)	156 (18.6)	213 (17.8)	39 (2.1)	54 (2.9)	93 (2.5)	0 (0.0)	0 (0.0)	0 (0.0)
I21	4 (1.1)	17 (2.0)	21 (1.8)	1 (0.1)	19 (1.0)	20 (0.5)	2 (10.5)	6 (35.3)	8 (22.2)
I22	1 (0.3)	0 (0.0)	1 (0.1)	0 (0.0)	2 (0.1)	2 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)
I24	6 (1.7)	10 (1.2)	16 (1.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
I25	15 (4.2)	10 (1.2)	25 (2.1)	45 (2.5)	33 (1.8)	78 (2.1)	3 (15.8)	5 (29.4)	8 (22.2)
I26-I28	0 (0.0)	3 (0.4)	3 (0.3)	12 (0.7)	13 (0.7)	25 (0.7)	0 (0.0)	0 (0.0)	0 (0.0)
I30-I52	106 (29.6)	41 (4.9)	147 (12.3)	260 (14.3)	127 (6.9)	387 (10.5)	0 (0.0)	0 (0.0)	0 (0.0)
I60-I69	76 (21.2)	212 (25.2)	288 (24.0)	475 (26.0)	468 (25.3)	943 (25.7)	0 (0.0)	0 (0.0)	0 (0.0)
I70-I99	39 (10.9)	173 (20.6)	212 (17.7)	393 (21.5)	588 (31.8)	981 (26.7)	7 (36.8)	1 (5.9)	8 (22.2)
Total	358 (100.0)	840 (100.0)	1198 (100.0)	1824 (100.0)	1851 (100.0)	3675 (100.0)	19 (100.0)	17 (100.0)	36 (100.0)
	2023								
I00-I02	0 (0.0)	1 (0.1)	1 (0.1)	0 (0.0)	1 (0.0)	1 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
I05-I09	2 (0.5)	1(0.1)	3 (0.3)	8 (0.4)	5 (0.2)	13 (0.3)	0 (0.0)	0 (0.0)	0 (0.0)
I10-I13	69 (17.7)	245 (32.9)	314 (27.7)	478 (25.7)	618 (29.5)	1096 (27.7)	134 (31.8)	222 (55.8)	356 (43.4)
I15	6 (1.5)	4 (0.5)	10 (0.9)	67 (3.6)	54 (2.6)	121 (3.1)	3 (0.7)	1 (0.3)	4 (0.5)
I20	57 (14.6)	85 (11.4)	142 (12.5)	78 (4.2)	58 (2.8)	136 (3.4)	0 (0.0)	0 (0.0)	0 (0.0)
I21	2 (0.5)	10 (1.3)	12 (1.1)	13 (0.7)	29 (1.4)	42 (1.1)	41 (9.7)	97 (24.4)	138 (16.8)
I22	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	4 (0.2)	4 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)
I24	0 (0.0)	5 (0.7)	5 (0.4)	1 (0.1)	3 (0.1)	4 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)
I25	14 (3.6)	6 (0.8)	20 (1.8)	39 (2.1)	21 (1.0)	60 (1.5)	38 (9.0)	22 (5.5)	60 (7.3)

(Continued)

Table 2 (Continued).

	Turkestan Region						Almaty		
ICD	City			Rural					
	Planning	Urgent	Total	Planning	Urgent	Total	Planning	Urgent	Total
	2018								
I26-I28	2 (0.5)	1 (0.1)	3 (0.3)	7 (0.4)	20 (1.0)	27 (0.7)	0 (0.0)	0 (0.0)	0 (0.0)
I30-I52	130 (33.3)	22 (3.0)	152 (13.4)	272 (14.6)	160 (7.6)	432 (10.9)	50 (11.8)	0 (0.0)	50 (6.1)
I60-I69	68 (17.4)	147 (19.7)	215 (18.9)	457 (24.6)	494 (23.6)	951 (24.1)	23 (5.5)	0 (0.0)	23 (2.8)
I70-I99	40 (10.3)	218 (29.3)	258 (22.7)	438 (23.6)	625 (29.9)	1063 (26.9)	133 (31.5)	56 (14.1)	189 (23.0)
Total	390 (100.0)	745 (100.0)	1135 (100.0)	1858 (100.0)	2092 (100.0)	3950 (100.0)	422 (100.0)	398 (100.0)	820 (100.0)
	2024								
I00-I02	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
I05-I09	1 (0.3)	1 (0.1)	2 (0.2)	7 (0.4)	3 (0.1)	10 (0.3)	0 (0.0)	0 (0.0)	0 (0.0)
I10-I13	63 (15.9)	222 (25.3)	285 (22.4)	484 (27.7)	687 (30.9)	1171 (29.5)	113 (24.0)	268 (57.3)	381 (40.6)
I15	18 (4.5)	8 (0.9)	26 (2.0)	95 (5.4)	74 (3.3)	169 (4.3)	1 (0.2)	0 (0.0)	1 (0.1)
I20	39 (9.8)	133 (15.1)	172 (13.5)	53 (3.0)	81 (3.6)	134 (3.4)	0 (0.0)	0 (0.0)	0 (0.0)
I21	3 (0.8)	20 (2.3)	23 (1.8)	8 (0.5)	31 (1.4)	39 (1.0)	30 (6.4)	98 (20.9)	128 (13.6)
I22	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.1)	2 (0.1)	3 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)
I24	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	4 (0.2)	4 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)
I25	24 (6.0)	5 (0.6)	29 (2.3)	56 (3.2)	43 (1.9)	99 (2.5)	40 (8.5)	34 (7.3)	74 (7.9)
I26-I28	0 (0.0)	3 (0.3)	3 (0.2)	10 (0.6)	28 (1.3)	38 (1.0)	0 (0.0)	0 (0.0)	0 (0.0)
I30-I52	93 (23.4)	61 (6.9)	154 (12.1)	295 (16.9)	199 (8.9)	494 (12.4)	63 (13.4)	1 (0.2)	64 (6.8)
I60-I69	75 (18.9)	211 (24.0)	286 (22.4)	344 (19.7)	475 (21.4)	819 (20.6)	6 (1.3)	0 (0.0)	6 (0.6)
I70-I99	81 (20.4)	214 (24.4)	295 (23.1)	397 (22.7)	597 (26.8)	994 (25.0)	217 (46.2)	67 (14.3)	284 (30.3)
Total	397 (100.0)	878 (100.0)	1275 (100.0)	1750 (100.0)	2224 (100.0)	3974 (100.0)	470 (100.0)	468 (100.0)	938 (100.0)

Geographic variation was substantial: rural areas of the Turkestan region exhibited nearly threefold higher hospitalization rates (IRR = 2.97; $p < 2 \times 10^{-16}$), while Almaty showed significantly lower rates (IRR = 0.382; $p < 2 \times 10^{-16}$). Pairwise comparisons confirmed persistent regional disparities across all years (Tables 3 and 4).

Sex Was Not a Significant Predictor (IRR = 1.039; $p = 0.15$).

Overall, the model demonstrated good fit (residual deviance = 8521.7 vs. null deviance = 18,937.4), indicating strong explanatory performance. Notably, the findings highlight a substantial burden of circulatory diseases in the 18–44 age group, which is traditionally considered low-risk, underscoring the emerging public health importance of early-onset cardiovascular disease in this population.

Discussion

This study identified marked regional variation in hospitalization rates for circulatory system diseases among young adults, with substantially higher rates observed in Turkestan city and rural Turkestan than in Almaty across the study

Table 3 Negative Binomial Regression Results (IRR, 95% CI, p-values)

Variable	IRR	95% CI	p-value
Year effects (reference: 2018)			
2019	0.985	0.902–1.076	0.7399
2020	0.576	0.523–0.633	$<2 \times 10^{-16}$
2021	0.636	0.578–0.699	$<2 \times 10^{-16}$
2022	0.552	0.499–0.612	$<2 \times 10^{-16}$
2023	0.649	0.590–0.714	$<2 \times 10^{-16}$
2024	0.717	0.652–0.788	2.55×10^{-12}
Age	1.066	1.062–1.069	$<2 \times 10^{-16}$
Sex (female)	1.039	0.984–1.097	0.152
ICD-10 groups (reference category omitted)			
I00–I02	1.925	0.833–4.856	0.139
I05–I09	30.29	13.252–75.887	6.79×10^{-15}
I10–I13	9.07	3.957–22.729	5.10×10^{-7}
I15	6.03	2.627–15.119	4.33×10^{-5}
I20	10.20	4.433–25.679	1.29×10^{-7}
I21	0.724	0.259–2.120	0.544
I22	1.051	0.441–2.718	0.912
I24	4.99	2.169–12.523	0.000258
I25	1.216	0.523–3.087	0.661
I26–I28	9.20	4.021–23.047	4.13×10^{-7}
I30–I52	30.70	13.410–76.764	5.49×10^{-15}
Other I-diseases	32.28	14.130–80.924	2.10×10^{-15}
City effects (reference category)			
Turkestan rural	2.97	2.797–3.163	$<2 \times 10^{-16}$
Almaty	0.382	0.354–0.412	$<2 \times 10^{-16}$

Notes: Acute rheumatic fever I00-I02; Chronic rheumatic heart diseases I05-09; Hypertensive diseases I10-I13; Secondary hypertension I15; Angina pectoris I20; Acute myocardial infarction I21; Subsequent myocardial infarction I22; Other acute ischaemic heart diseases I24; Chronic ischaemic heart disease I25; Pulmonary heart disease and diseases of pulmonary circulation I26-28; Other heart diseases I30-52; Cerebrovascular diseases I60-69.

period. In the adjusted analysis, rural Turkestan remained associated with significantly higher hospitalization rates, while sex was not a significant predictor after adjustment. These findings indicate that geography was more strongly associated with hospitalization patterns than sex in this dataset. However, because the study was based on aggregated administrative data, these regional differences should be interpreted as statistical associations rather than direct evidence of healthcare

Table 4 Pairwise City Comparisons (IRR)—All Years and Both Sexes

Comparison	IRR	Interpretation	p-value
Turkestan city vs. Turkestan rural	0.336	66% lower in Turkestan city	<0.0001
Turkestan city vs. Almaty	2.617	2.6× higher in Turkestan city	<0.0001
Turkestan rural vs. Almaty	7.781	Nearly 8× higher in Turkestan rural	<0.0001

inequity or differential disease causation. Possible explanations may include variation in healthcare access, referral pathways, admission thresholds, coding practices, and underlying disease structure across regions. This interpretation is broadly consistent with previous literature showing that rural populations may experience higher cardiometabolic burden and different patterns of healthcare utilization, although these mechanisms could not be directly tested in the present study.^{9–11}

Another important finding was the predominance of urgent hospitalizations, which accounted for 60% to 93% of admissions depending on region and year. This pattern suggests that a large share of CVD-related hospitalizations in young adults occurred in acute care settings rather than through planned admissions. Although this may be consistent with delayed presentation, insufficient outpatient control, or limited preventive care, the current dataset does not allow direct evaluation of these pathways. The especially high proportion of urgent admissions for cerebrovascular and hypertensive diseases may indicate that these diagnostic categories contribute disproportionately to acute hospitalization burden in this age group. From a public health perspective, this finding supports the need for closer examination of ambulatory care pathways and earlier identification of high-risk young adults, but the present analysis cannot establish why urgent admissions were so common. These observations are consistent with evidence demonstrating that cumulative exposure to metabolic risk factors, particularly hypertension, substantially increases cardiovascular risk even in younger populations.^{12–14}

Age was significantly associated with higher hospitalization rates even within the relatively narrow range of 18–44 years, suggesting that cardiovascular risk accumulates measurably during early adulthood. At the same time, several diagnostic categories showed very large effect sizes in the regression model, particularly chronic rheumatic heart disease, other heart diseases, and other circulatory diseases. These estimates should be interpreted cautiously. They reflect relative differences between diagnostic categories in the fitted model and may be amplified by low baseline frequencies in the reference category. Therefore, these large IRRs should not be interpreted as direct measures of absolute risk at the individual level. Nevertheless, the pattern suggests that certain diagnostic categories may account for a disproportionate share of hospitalization burden among young adults and may warrant closer epidemiological attention.

The temporal pattern observed in Almaty also deserves consideration. Hospitalization rates declined sharply during 2020–2022 and then rebounded in 2023–2024. This pattern may be consistent with indirect effects of the COVID-19 pandemic, including reduced healthcare utilization, temporary disruption of elective and non-urgent services, changing admission thresholds, and delayed care-seeking behavior. However, because the study does not contain data on healthcare-seeking patterns or service availability, these explanations remain inferential. The magnitude of smaller decline observed in Turkestan suggests that temporal changes were not uniform across regions and may have depended on local healthcare organization, case mix, or reporting practices. Accordingly, these fluctuations should not be interpreted as direct changes in underlying disease incidence.

The public health relevance of these findings lies in the fact that they concern adults aged 18–44 years, a group often considered at relatively low short-term cardiovascular risk. The observed burden of circulatory disease hospitalization in this population indicates that serious cardiovascular morbidity is already present in early adulthood in this setting. This is particularly important because previous studies from Central Asia have documented the contribution of modifiable risk factors, including hypertension, obesity, smoking, and dyslipidemia, to cardiovascular disease patterns in the region.¹⁵ Future studies that integrate hospitalization data with individual-level clinical and behavioral information may help

determine whether these factors contribute to the regional patterns observed here and may clarify the mechanisms underlying the burden of CVD among young adults.

Strengths and Limitations

This study has several strengths. It is based on a multi-year, population-level dataset covering seven consecutive years, which allows for the assessment of temporal patterns in cardiovascular disease (CVD) hospitalizations among young adults. The inclusion of both urban and rural settings—Almaty, Turkestan city, and rural Turkestan, enables comparison of hospitalization patterns across regions within a unified national health system. In addition, the use of negative binomial regression was appropriate for overdispersed count data and allowed estimation of adjusted associations across demographic, temporal, diagnostic, and geographic factors. Finally, the focus on adults aged 18–44 years provides valuable insight into CVD burden in a population group that remains relatively underrepresented in epidemiological research.

At the same time, these findings should be interpreted in light of several important limitations. First, the analysis relies on administrative hospitalization data and therefore captures only cases reaching inpatient care, which may underestimate the true burden of CVD in the community. Second, the dataset does not include individual-level information on behavioral, socioeconomic, or clinical risk factors (eg., smoking, body mass index, blood pressure control, income, or insurance status), limiting the ability to explore causal mechanisms. Third, diagnostic coding practices may vary across facilities and regions, introducing potential misclassification. Fourth, healthcare utilization patterns during 2020–2022 were likely influenced by the COVID-19 pandemic, which complicates the interpretation of temporal trends. Fifth, the study does not include outpatient or non-hospitalized cases, restricting assessment of earlier stages of disease. Finally, the analysis was limited to selected regions and may not fully represent national patterns.

Implications for Future Research

Future research should aim to integrate hospitalization data with individual-level clinical and behavioral information to better understand the mechanisms underlying cardiovascular disease in young adults. Linking inpatient data with primary care, outpatient, and screening records would allow a more comprehensive evaluation of disease progression and early detection. Further investigation of socioeconomic factors, access to care, and healthcare system organization is needed to better interpret regional differences. In addition, continued monitoring of post-pandemic trends will be important to determine whether the observed decline and rebound in hospitalization rates represent temporary disruptions or longer-term changes in disease patterns. Such work may help inform targeted prevention strategies aimed at reducing early-onset cardiovascular disease and geographic disparities.

Conclusion

This study identified significant regional variation in hospitalization rates for circulatory system diseases among young adults aged 18–44 years, with higher rates observed in Turkestan—particularly in rural areas—compared with Almaty. A large proportion of hospitalizations occurred as urgent admissions, and hospitalization rates showed a marked decline during 2020–2022 followed by a rebound in 2023–2024. Age was also associated with increasing hospitalization rates within this population, and certain diagnostic categories contributed disproportionately to the overall burden. These findings should be interpreted cautiously, as they are based on aggregated administrative data and reflect statistical associations rather than causal relationships. The absence of individual-level clinical, behavioral, and socioeconomic information limits the ability to assess underlying mechanisms, and the analysis was restricted to selected regions. In addition, the observed temporal patterns may be related to changes in healthcare utilization during the COVID-19 pandemic rather than true changes in disease incidence. Despite these limitations, the results highlight a measurable burden of cardiovascular disease in a relatively young population. From a public health perspective, the findings suggest the importance of strengthening primary care, improving early detection, and enhancing preventive strategies, particularly in regions with higher hospitalization rates. Continued monitoring of hospitalization trends over a longer period is needed to determine whether the observed fluctuations represent temporary disruptions or longer-term changes. Further research integrating individual-level data is required to better understand the drivers of these patterns and to support the development of targeted interventions.

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Disclosure

The authors declare they have no competing interests in this work.

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