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Comparative Analysis of Tuberculosis Incidence Trends: New and Relapsed Cases per 100,000 Population in Iran and Its Neighbors (2010-2023)

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Abstract

Background: In 2023, there were 8.2 million Tuberculosis (TB) cases, primarily in South-East Asia. The World Health Organization (WHO) is advocating for increased funding, enhanced diagnostics, and improved healthcare to eradicate TB by 2035. Wealthy nations exhibit lower relapse rates, while poorer countries face higher risks. The challenges of drug-resistant TB and COVID-19 are complicating treatment efforts.

Objectives: This study aims to examine TB recurrence rates in Iran and neighboring countries using data from the WHO. The objective is to comprehend the rate of disease recurrence and the correlations among the results of the studied countries from 2010 to 2023.

Methods: Data on TB relapse cases from 2010 to 2023 in Iran and neighboring countries were analyzed using SPSS v27. Correlations were assessed using Pearson and Spearman tests.

Results: The study highlights TB relapse trends per 100,000 people in the Middle East and Central Asia from 2010-2023. The UAE and Jordan witnessed significant decreases in cases, while Oman and Egypt reported modest declines. Iran initially showed improvement in rates but later experienced an increase, indicating treatment challenges. Lebanon, Saudi Arabia, and Kuwait also achieved lower rates, but Iraq's rates remain high. Yemen and Qatar saw increases, prompting concerns about control. Turkey and Azerbaijan showed improvement, whereas Afghanistan and Pakistan experienced rising cases, suggesting a need for improved strategies. Accordingly, socioeconomic and healthcare factors play a critical role in effectively managing TB.

Conclusion: Enhancing diagnostic and treatment infrastructure in remote, high-incidence areas is crucial for addressing TB recurrence. Training healthcare workers, implementing Directly Observed Therapy (DOT), monitoring drug resistance, addressing social determinants, and conducting awareness campaigns are essential strategies for enhancing community education and treatment adherence.

Keywords: World Health Organization, Tuberculosis, Middle Eastern Population, Iran

1. Background

In 2023, Tuberculosis (TB) notifications reached 8.2 million, the highest since the 1990s, largely due to recovering health services after COVID-19 and many undiagnosed cases. The South-East Asia region reported nearly half of these global cases, while the African Region saw a 34% rise since 2019. The European region had a decline in notifications, with downward trends continuing into 2022 and 2023. Most cases were found in adults, with 56% men, 35% women, and 8.5% children.[1] The WHO's "Global Tuberculosis Report 2024" highlights the ongoing challenges of the TB epidemic, especially in low- and middle-income countries, stressing the need for more funding, better diagnostics, effective treatments, and strong healthcare systems. The global incidence rate remains stable at 134 cases per 100,000 people, but new cases have slightly increased. It reports that drug-resistant TB is a significant issue, with many not receiving needed treatment, prompting calls for more investments in new strategies and public health education.[2]

The recurrence of TB is a serious issue influenced by many factors like treatment adherence, individual health conditions, and genetic factors. Areas with high TB rates face more difficulties due to limited healthcare and less focus on this problem. Epidemiological studies show TB recurrence rates between 4.9% and 47%, with higher rates in regions with more TB cases and weaker healthcare systems.[3] Factors affecting recurrence include treatment adherence, HIV infection, diabetes, malnutrition, and poor living conditions like silicosis. Comorbidities and social issues, such as substance abuse, also raise the chances of TB coming back. Certain host factors, like gender differences and malnutrition, contribute to TB recurrence. Smoking is a major risk factor because it

worsens treatment response and leads to severe lung issues.[3,4]

The Pulmonary Tuberculosis (PTB) recurrence highlights a global problem, showing a recurrence rate of 2.9% within five years for treated patients. Relapses generally occur sooner than reinfections, with an average relapse time of 18 months after treatment. Most relapses happen in HIV-negative people, and they are more common in areas with low TB rates.[5]

HIV-positive individuals experience higher TB recurrence rates than the general population. Genetic factors, including specific Single Nucleotide Polymorphisms (SNPs) and variations like MBL2 polymorphisms, can also play a role. Treatment duration and regimen types influence recurrence rates, with longer and more aggressive treatments reducing recurrences, especially in high-risk patients. To effectively control TB and lower recurrence, patient-centered care strategies must be implemented, integrating TB care with other health services and addressing social determinants affecting treatment adherence.[3]

Men and individuals with lower levels of education have higher rates of TB recurrence, highlighting disparities in TB treatment based on gender and socioeconomic status. These inequalities may stem from variations in health-seeking behaviors and access to healthcare. To help eliminate TB by 2035, addressing these issues is crucial. Additionally, the connection between TB recurrence and incarceration underscores the need for effective screening and treatment in prisons. It emphasizes the significance of integrated TB and HIV services and advocates for the use of Directly Observed Therapy (DOT) to enhance treatment adherence in high-burden areas.[6,7]

2. Objectives

The present study analyzing TB recurrence in Iran and neighboring countries from 2010 to 2023 used WHO data and statistical tests to explore correlations in new and relapse cases. Findings aim to highlight TB challenges over time.

3. Methods

3.1. Aims and Type of Study

Our study is an ecological correlation study on TB recurrence. We first reviewed online literature on TB recurrence, with special attention to statistics published by the WHO in this field. In this descriptive-analytical study of the statistical population of Iran and its neighboring countries in the Middle East and Central Asia, we examined the recurrence rate in these countries during the period 2010-2023. We then conducted a correlation analysis between the results of the recurrence rate in the studied countries during the study period. The aim of our study was to analyze and describe the published data of the WHO and to analyze the correlation and relationship between the direction of changes in the rate of TB recurrence during the study period based on data published by the WHO.

3.2. Data Collection

Data on the new and relapse TB cases of tuberculosis per 100,000 population were collected across the study duration for Iran and neighboring countries from 2010 to 2023. The information was sourced from the WHO database, available at https://www.who.int/data/gho/data/indicators/New-and-relapse-details/GHO/New-and-relapse-TB-cases-of-TB-per-100,000-population.[7,8]

3.3. Data Distribution Analysis

A one-sample Kolmogorov-Smirnov test was conducted to assess the normality of the new and relapse TB data for some countries, including Iran and neighboring countries, from 2010 to 2023.[9]

3.4. Descriptive and Analytical Statistics Study

A study was conducted to analyze the new and relapse cases of TB for Iran and neighboring countries from 2010 to 2023, using SPSS v27 software for data analysis. Firstly, a descriptive study on the new and relapse cases of TB for Iran and neighboring countries from 2010 to 2023 has been presented. Then, the research aimed to explore the correlation between the years of study and the TB new and relapse rate. Finally, we studied the correlation between the number of relapse cases of TB in the studied countries during the study duration using the Pearson and Spearman correlation tests for this purpose.[9]

4. Results

4.1. Descriptive Study Results

The provided data shows trends in TB relapse and recurrent cases per 100,000 people in various Middle Eastern and Central Asian countries from 2010 to 2023. The trends are mixed, with some countries seeing decreases in TB relapse rates and others experiencing increases. This variability suggests that different factors are likely affecting TB control and patient outcomes in each country.

The UAE also saw a decrease in TB relapse cases from 1.9 to 0.7 per 100,000 people, reflecting the country's strong healthcare system and proactive TB control measures. Jordan saw a decrease from 4.6 to 2.2 recurrent TB cases per 100,000 people, indicating effective management and prevention strategies. This could include increased awareness, early detection, and successful treatment of initial TB cases to prevent relapse. Oman's recurrent TB rate decreased slightly from 11.2 to 9.7 per 100,000, possibly due to efforts to strengthen the healthcare system and TB control measures.

Table 1. Number of New and Relapsed TB Cases Reported per 100,000 Population in Iran and Neighboring Countries from 2010 to 2023

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Iran	13.4	14	13.9	13.7	12.5	12.4	11	10.6	10.3	9.8	6.8	7	8.1	8.2
Iraq	31.3	27.5	25.7	24.2	22.6	21.8	18.8	19.4	17.6	16.1	11.8	13.5	15.1	15.4
Egypt	10.4	9.9	9.1	8.3	7.4	7.9	7.8	7.8	7.8	7.5	6.4	6.1	7.1	8.1
Azerbaijan	82.5	98.8	67.9	61.7	60.1	55.9	52.3	52.5	50.2	47.7	36.2	35.8	38.7	38.4
Bahrain	20.3	18.6	18.5	16.6			10.8	10.1	10.3	12	13	13.1	12.3	10.4
Afghanistan	99.1	95.3	93.8	96.5	96.8	106	120.9	130.7	131.8	138.5	117.3	125.8	127.5	119.5
Jordan	4.6	4.4	4.4	4.4	4.4	4.4	4.2	5.1	3.8	4.2	2.3	2	2	2.2
Armenia	48.1	43.1	41.5	47.8	45.5	40.1	35.2	28.9	25.2	21.4	13.6	13.9	15.3	13.7
Saudi Arabia	17.7	15.1	13.6	12.3	11.2	11	9.5	9.3	9.8	9.6	7.9	8.2	8	7.6
Turkey	21.6	20.3	18.8	17.2	16.8	15.7	14.9	14.2	13.7	13.2	10.3	10.4	11.2	10.8
United Arab Emirates	1.9	1.4	1.1	1	0.7	0.7	0.7	0.7	0.9	0.9	0.7	0.7	0.6	0.7
Yemen	33.3	31.3	34.7	35.2	31.9	24.6	29.3	29.3	28.6	29.1	24.5	25.2	27	28
Kyrgyzstan	102.9	106.9	108.8	122	108.3	117.1	115	107.5	99.9	94.5	63.6	67.4	65.7	59.1
Uzbekistan	59.5	53.2	50.7	70	60.7	53.1	51.3	52.9	50.7	49.4	36.1	39.6	40.9	39.1
Qatar	33.9	30.5	38.2		21	21.8	19.4	22.2	27.2	30.7	30.7	34.9	30.1	30.6
Lebanon	10.2	9.7	12	12	10.6	10.1	10.2	10	11	13.1	11.5	8.2	8.9	8.7
Kuwait	32.5	21.5	22.1	20.1	20	19.5	20.9	23.7	19	17.8	15.7	16.9	9.8	8.5
Syrian Arab Republic	16.3	15.8	13.2	12.6	17.2	15	16	14.3	13.4	12.7	12.5	15.2	13.7	14.4
Turkmenistan	58	48.1	50.6	51.3	41.8	35.2	32.5	30.2	32.4	31.1	27.6	26.5	34.6	30.9
Oman	11.2	11	10.8	8.6	8.9	7.8	7.9	6	5.4	8	6.9	5.1	7.8	9.7
Tajikistan	91.4	89.9	81.2	67.9	68.9	68.2	67.3	64.9	61.5	60.4	42.5	41.7	42.2	42.7
Pakistan	132.6	130	128.8	136.9	143.9	149	161.9	160.9	158.8	142.2	116.2	141.7	174.2	192.2
Russian federation	87.1	78.4	73.3	73.3	70.6	68.5	63.4	57.8	53.4	50	40.1	39	38.4	37.6
Kazakhstan	139	146.9	104	108	85.6	77.4	67.1	66.7	67.8	65.1	49.3	49.4	50	46.8

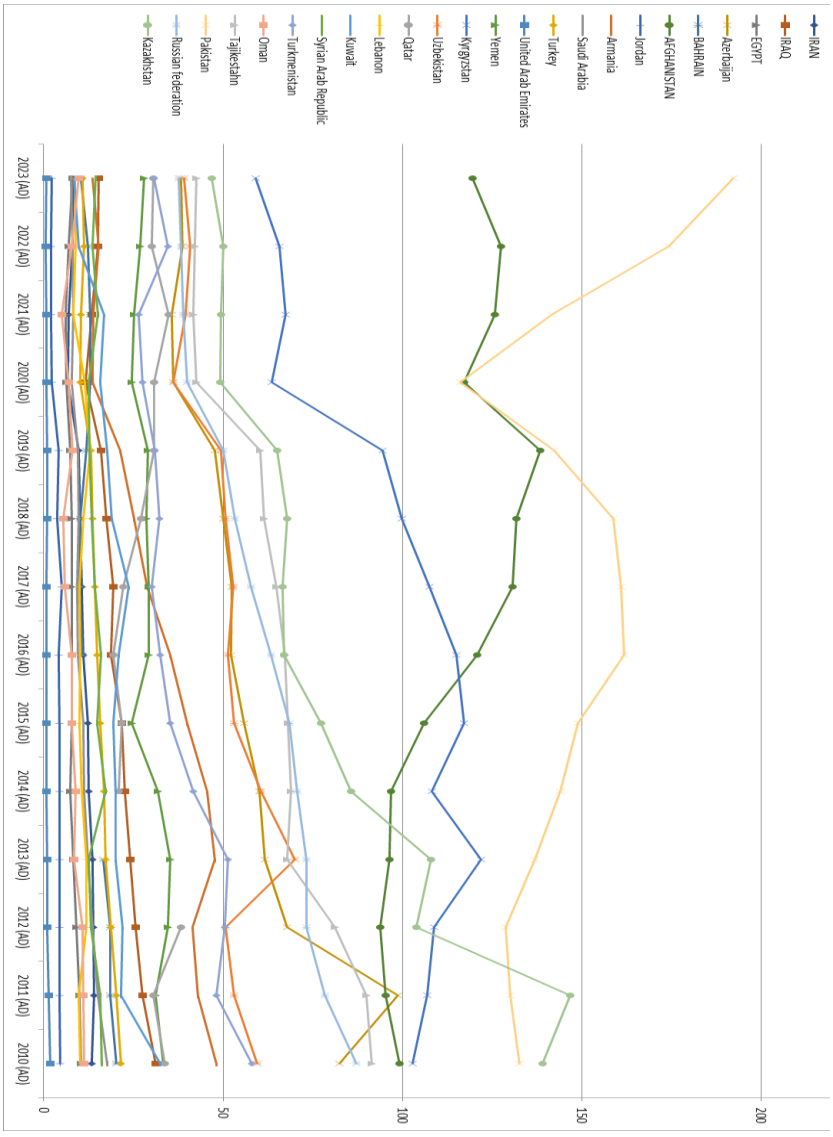

Figure 1. The number of new and relapsed TB cases reported per 100,000 population in Iran and neighboring countries from 2010 to 2023.

Egypt experienced a smaller decrease from 10.4 to 8.1 TB relapse cases per 100,000 people, suggesting some progress, but not as substantial as in other countries. Various factors like population density, socioeconomic conditions, or comorbidities like diabetes may affect TB treatment outcomes in Egypt.

In Iran, the decrease from 13.4 to 6.8 TB relapse cases per 100,000 people between 2010 and 2020 may reflect improvements in the healthcare system, such as better TB diagnosis, treatment adherence programs, and public health interventions. However, the subsequent increase to 8.2 cases per 100,000 from 2020 to 2023 could be due to reasons like potential gaps in TB treatment programs, increased drug resistance, or challenges in managing the TB patient population during the COVID-19 pandemic.

Lebanon's recurrent TB rate decreased slightly from 10.2 to 8.7 per 100,000, possibly due to efforts to improve access to healthcare and TB treatment services. Saudi Arabia experienced a decrease from 17.7 to 7.6 TB relapse cases per 100,000 people, attributed to substantial investments in healthcare and TB control programs, alongside improvements in overall population health. Bahrain's decrease in recurrent TB cases from 20.3 to 10.4 per 100,000 people suggests successful TB control efforts, possibly due to factors like better healthcare access, effective TB treatment, and public health policies. Kuwait experienced a significant decrease in recurrent TB cases from 32.5 to 8.5 per 100,000, likely due to the country's advanced healthcare system and comprehensive TB control strategies. Iraq saw a decrease from 31.3 to 15.4 TB relapse cases per 100,000 people over the same period, possibly due to improved healthcare infrastructure, enhanced TB control strategies, and increased access to treatment facilities. However, the country still has a relatively high relapse rate compared to others in the region, indicating that more efforts are needed for effective TB management.

Yemen's TB relapse cases increased slightly from 33.3 to 28.0 per 100,000, concerning given the ongoing humanitarian crisis and challenges in maintaining healthcare services in the country. Qatar's recurrent TB rate increased from 33.9 to 30.6 per 100,000, indicating a need for ongoing vigilance and improved TB control strategies.

Turkey's TB relapse rate decreased from 21.6 to 10.8 cases per 100,000, a positive trend possibly due to enhanced TB surveillance, better healthcare access, and improved treatment adherence programs. Armenia's decrease from 48.1 to 13.7 recurrent TB cases per 100,000 people is particularly dramatic, suggesting significant improvements in TB control and healthcare services.

Table 2. Distribution of Data Results for TB Recurrence in the Studied Countries During 2010-2023

Variables	N	Mean	Std. Deviation	Test Statistic	Asymp. Sig. (2-tailed)	Monte Carlo Sig. (2-tailed)
Year	14	2016.5	4.1833	0.084	0.200	0.998
Iran	14	10.8357	2.57611	0.157	0.200	0.451
Iraq	14	20.0571	5.69382	0.117	0.200	0.863
Egypt	14	7.9714	1.18933	0.177	0.200	0.266
Azerbaijan	14	55.6214	18.10356	0.154	0.200	0.476
Bahrain	12	13.8333	3.67209	0.246	0.044	0.045
Afghanistan	14	114.25	15.81425	0.188	0.194	0.191
Jordan	14	3.7429	1.09875	0.304	0.001	0.001
Armenia	14	30.95	13.62445	0.178	0.200	0.261
Saudi Arabia	14	10.7714	2.98726	0.199	0.138	0.136
Turkey	14	14.9357	3.67436	0.131	0.200	0.734
United Arab Emirates	14	0.9071	0.35834	0.29	0.002	0.003
Yemen	14	29.4286	3.50767	0.157	0.200	0.444
Kyrgyzstan	14	95.6214	21.94203	0.22	0.064	0.065
Uzbekistan	14	50.5143	9.34516	0.173	0.200	0.299
Qatar	13	28.5538	5.84631	0.22	0.086	0.088
Lebanon	14	10.4429	1.38103	0.141	0.200	0.622
Kuwait	14	19.1429	5.80195	0.162	0.200	0.392
Syrian Arab Republic	14	14.45	1.50933	0.119	0.200	0.85
Turkmenistan	14	37.9143	10.12338	0.249	0.019	0.021
Oman	14	8.2214	1.97919	0.13	0.200	0.744
Tajikistan	14	63.6214	16.85149	0.179	0.200	0.256
Pakistan	14	147.8071	20.13648	0.148	0.200	0.541
Russian federation	14	59.35	16.57323	0.163	0.200	0.386
Kazakhstan	14	80.2214	32.75701	0.219	0.067	0.068

Asymp. Sig. (2-tailed) < 0.05, indicates that the test distribution is normal.

Turkmenistan's recurrent TB rate decreased from 58 to 30.9 per 100,000, indicating progress in TB management despite the country's relatively high incidence of the disease. Uzbekistan had a decrease from 59.5 to 39.1 TB relapse cases per 100,000 people, indicating some success in TB control but still a relatively high burden of the disease. Azerbaijan had a significant decrease in TB relapse cases from 82.5 to 38.4 per 100,000 people, a positive trend indicating successful TB control measures, possibly attributed to improved TB detection and treatment strategies, increased investment in healthcare, and public health programs. Tajikistan's decrease from 91.4 to 42.7 recurrent TB cases per 100,000 is a notable achievement, demonstrating the impact of targeted interventions and healthcare improvements. Kyrgyzstan's decrease from 102.9 to 59.1 TB relapse cases per 100,000

Table 3. Pearson Correlation of TB Recurrence among the Countries Studied During 2010-2023

Egypt			Iraq			Iran			Year			Variable
N	Sig. (2-tailed)	Pearson Correlation	N	Sig. (2-tailed)	Pearson Correlation	N	Sig. (2-tailed)	Pearson Correlation	N	Sig. (2-tailed)	Pearson Correlation	
14	0.000	.882**	14	0.000	.946**	14	0.000	.871**	14	0.000	-.926**	**Kazakhstan**
14	0.001	.805**	14	0.000	.962**	14	0.000	.958**	14	0.000	-.987**	**Russian federation**
14	0.551	-0.174	14	0.211	-0.357	14	0.236	-0.339	14	0.033	.572*	**Pakistan**
14	0.000	.872**	14	0.000	.946**	14	0.000	.929**	14	0.000	-.958**	**Tajikistan**
14	0.000	.809**	14	0.003	.734**	14	0.013	.644*	14	0.02	-.611*	**Oman**
14	0.332	0.28	14	0.135	0.42	14	0.297	0.3	14	0.203	-0.362	**Syrian Arab Republic**
14	0.017	.625*	14	0.001	.770**	14	0.007	.681**	14	0.000	-.837**	**Kuwait**
14	0.678	0.122	14	0.564	0.169	14	0.221	0.349	14	0.235	-0.34	**Lebanon**
13	0.496	0.208	13	0.798	0.079	13	0.745	-0.1	13	0.976	0.009	**Qatar**
14	0.048	.537*	14	0.002	.760**	14	0.000	.850**	14	0.001	-.787**	**Uzbekistan**
14	0.062	0.51	14	0.005	.707**	14	0.000	.871**	14	0.000	-.810**	**Kyrgyzstan**
14	0.006	.696**	14	0.001	.769**	14	0.001	.787**	14	0.003	-.730**	**Yemen**
14	0.000	.883**	14	0.000	.987**	14	0.000	.947**	14	0.000	-.974**	**Turkey**
14	0.000	.890**	14	0.000	.961**	14	0.000	.848**	14	0.000	-.925**	**Saudi Arabia**
14	0.005	.709**	14	0.000	.919**	14	0.000	.963**	14	0.000	-.953**	**Armenia**
14	0.023	-.603*	14	0.001	-.776**	14	0.002	-.752**	14	0.001	.784**	**Afghanistan**
14	0.000	.885**	14	0.000	.922**	14	0.000	.867**	14	0.000	-.904**	**Azerbaijan**
			14	0.000	.902**	14	0.001	.799**	14	0.001	-.779**	**Egypt**
						14	0.000	.934**	14	0.000	-.943**	**Iraq**
									14	0.000	-.939**	**Iran**

Turkey			Saudi Arabia			Armenia			Afghanistan			Azerbaijan	
Sig. (2-tailed)	Pearson Correlation	N	Sig. (2-tailed)	Pearson Correlation	N	Sig. (2-tailed)	Pearson Correlation	N	Sig. (2-tailed)	Pearson Correlation	N	Sig. (2-tailed)	Pearson Correlation
0.000	.958**	14	0.000	.968**	14	0.000	.843**	14	0.002	-.761**	14	0.000	.975**
0.000	.979**	14	0.000	.918**	14	0.000	.976**	14	0.001	-.763**	14	0.000	.893**
0.115	-0.44	14	0.059	-0.515	14	0.162	-0.395	14	0.082	0.481	14	0.118	-0.438
0.000	.979**	14	0.000	.929**	14	0.000	.893**	14	0.011	-.654*	14	0.000	.942**
0.004	.717**	14	0.003	.725**	14	0.03	.580*	14	0.003	-.730**	14	0.004	.711**
0.152	0.404	14	0.212	0.355	14	0.136	0.419	14	0.222	-0.349	14	0.146	0.409
0.001	.798**	14	0.001	.804**	14	0.002	.740**	14	0.13	-0.425	14	0.006	.696**
0.367	0.261	14	0.453	0.218	14	0.293	0.303	14	0.732	-0.101	14	0.609	0.15
0.863	0.053	13	0.405	0.253	13	0.485	-0.213	13	0.647	-0.141	13	0.763	0.093
0.002	.760**	14	0.011	.656*	14	0.000	.894**	14	0.038	-.558*	14	0.017	.626*
0.002	.750**	14	0.025	.593*	14	0.000	.876**	14	0.093	-0.465	14	0.015	.633*
0.001	.769**	14	0.005	.708**	14	0.002	.743**	14	0.022	-.606*	14	0.01	.663**
		14	0.000	.964**	14	0.000	.930**	14	0.002	-.761**	14	0.000	.946**
					14	0.000	.834**	14	0.003	-.735**	14	0.000	.926**
								14	0.001	-.793**	14	0.000	.817**
											14	0.005	-.706**

Lebanon		Qatar			Uzbekistan			Kyrgyzstan			Yemen		
Pearson Correlation	N	Sig. (2-tailed)	Pearson Correlation	N	Sig. (2-tailed)	Pearson Correlation	N	Sig. (2-tailed)	Pearson Correlation	N	Sig. (2-tailed)	Pearson Correlation	N
0.207	13	0.511	0.201	14	0.007	.685**	14	0.019	.617*	14	0.003	.728**	14
0.297	13	0.754	-0.097	14	0.000	.830**	14	0.000	.839**	14	0.003	.730**	14
-0.516	13	0.258	-0.339	14	0.378	-0.255	14	0.329	-0.282	14	0.393	-0.248	14
0.305	13	0.984	-0.006	14	0.004	.718**	14	0.001	.788**	14	0.004	.710**	14
0.131	13	0.31	0.305	14	0.231	0.343	14	0.389	0.25	14	0.014	.638*	14
-0.52	13	0.187	-0.391	14	0.412	0.238	14	0.418	0.235	14	0.761	0.09	14
0.282	13	0.939	-0.023	14	0.013	.645*	14	0.007	.687**	14	0.048	.536*	14
	13	0.852	0.057	14	0.157	0.4	14	0.112	0.444	14	0.139	0.416	14
				13	0.211	-0.371	13	0.119	-0.454	13	0.49	0.21	13
							14	0.000	.869**	14	0.002	.757**	14
										14	0.025	.593*	14
													14

Tajikistan			Oman			Syrian Arab Republic			Kuwait				
N	Sig. (2-tailed)	Pearson Correlation	N	Sig. (2-tailed)	Pearson Correlation	N	Sig. (2-tailed)	Pearson Correlation	N	Sig. (2-tailed)	Pearson Correlation	N	Sig. (2-tailed)
14	0.000	.923**	14	0.003	.724**	14	0.246	0.332	14	0.003	.726**	14	0.478
14	0.000	.961**	14	0.016	.627*	14	0.131	0.424	14	0.000	.829**	14	0.303
14	0.121	-0.434	14	0.512	-0.191	14	0.764	0.088	14	0.046	-.540*	14	0.059
			14	0.012	.649*	14	0.167	0.391	14	0.000	.831**	14	0.29
						14	0.343	0.274	14	0.3	0.298	14	0.656
									14	0.193	0.37	14	0.057
												14	0.329

		Russian federation		Pakistan	
		Sig. (2-tailed)	Pearson Correlation	Sig. (2-tailed)	Pearson Correlation
	N	14	14	14	14
Russian federation	Sig. (2-tailed)	0.000		0.061	0.102
	Pearson Correlation	.910**		-0.512	-0.455

** The correlation is significant at the 0.01 level (two-tailed); * The correlation is significant at the 0.05 level (two-tailed).

people is a substantial reduction, likely resulting from targeted TB interventions and health system improvements. Kazakhstan's decrease from 139 to 46.8 recurrent TB cases per 100,000 is a substantial reduction, reflecting the effectiveness of its TB control programs and healthcare system improvements.

The increase in recurrent cases of TB in Afghanistan from 99.1 in 2010 to 119.5 per 100,000 in 2023 can be analyzed using various epidemiological principles and factors that may contribute to the re-emergence of the disease. Pakistan, however, had an increase in recurrent TB cases from 132.6 to 192.2 per 100,000 people, a concerning trend suggesting that current TB control strategies may need to be reassessed and bolstered. The high incidence of TB in the country may be exacerbated by factors like poverty, malnutrition, and limited access to healthcare.

The strength and accessibility of healthcare systems are crucial for managing TB. Countries with advanced healthcare systems, like Iran, have lower relapse rates due to effective detection and treatment. Treatment adherence is key, and factors such as patient education and access to medication play a role, with positive results seen in Jordan and Oman. Better TB surveillance improves case management, as demonstrated in Turkey and Egypt. Population density and diseases like HIV/AIDS and diabetes also affect relapse rates, with Egypt struggling due to these issues. Public health measures, such as vaccination and contact tracing, help reduce TB cases, as seen in Azerbaijan, Turkmenistan, and Uzbekistan. However, poverty, malnutrition, and poor living conditions worsen TB's impact, while wealthier nations experience lower relapse rates. Political instability in countries like Lebanon complicates TB control. The rise of drug-resistant TB strains and the COVID-19 pandemic further strain healthcare resources, worsening conditions in places like Afghanistan and Pakistan.

4.2. Data Distribution Study

The results of the One-Sample Kolmogorov-Smirnov Test indicate that the TB recurrence data for Bahrain, Jordan, the United Arab Emirates, and Turkmenistan are not normally distributed, as their Asymp. Sig. (2-tailed) values are below 0.05. Specifically, Bahrain has an Asymp. Sig. of 0.044, Jordan has 0.001, the United Arab Emirates has 0.002, and Turkmenistan has 0.019. These values suggest significant deviations from a normal distribution at the 5% level. Conversely, data from countries such as Iran, Iraq, Egypt, and others have Asymp. Sig. values greater than 0.05, indicating they are likely normally distributed. The test statistic values for normally distributed countries range from 0.084 for Iran to 0.29 for the United Arab Emirates. The Monte Carlo Sig. values confirm these results, supporting normality for countries with higher Asymp. Sig. values and non-normality for those with lower values.

4.3. Correlation Study Results

The provided data suggests an increasing trend in the rate of TB recurrence in Afghanistan and Pakistan during the

Table 4. Spearman Correlation of TB Recurrence among the Countries Studied from 2010 to 2023

Variables		Turkmenistan	United Arab Emirates	Jordan	Bahrain
Year	Correlation Coefficient	-.829**	-.747**	-.827**	-0.573
	Sig. (2-tailed)	0.000	0.002	0.000	0.051
	N	14	14	14	12
Iran	Correlation Coefficient	.859**	.700**	.773**	0.434
	Sig. (2-tailed)	0.000	0.005	0.001	0.159
	N	14	14	14	12
Iraq	Correlation Coefficient	.868**	.728**	.847**	0.455
	Sig. (2-tailed)	0.000	0.003	0.000	0.138
	N	14	14	14	12
Egypt	Correlation Coefficient	.731**	.753**	.631*	0.458
	Sig. (2-tailed)	0.003	0.002	0.015	0.135
	N	14	14	14	12
Azerbaijan	Correlation Coefficient	.877**	.705**	.838**	0.462
	Sig. (2-tailed)	0.000	0.005	0.000	0.131
	N	14	14	14	12
Bahrain	Correlation Coefficient	.594*	.650*	0.237	
	Sig. (2-tailed)	0.042	0.022	0.459	
	N	12	12	12	
Afghanistan	Correlation Coefficient	-.701**	-0.465	-0.435	
	Sig. (2-tailed)	0.005	0.094	0.12	
	N	14	14	14	
Jordan	Correlation Coefficient	.577*	0.531		
	Sig. (2-tailed)	0.031	0.051		
	N	14	14		
Armenia	Correlation Coefficient	.890**	.625*		
	Sig. (2-tailed)	0.000	0.017		
	N	14	14		
Saudi Arabia	Correlation Coefficient	.859**	.813**		
	Sig. (2-tailed)	0.000	0.000		
	N	14	14		
Turkey	Correlation Coefficient	.903**	.710**		
	Sig. (2-tailed)	0.000	0.004		
	N	14	14		
United Arab Emirates	Correlation Coefficient	.616*			
	Sig. (2-tailed)	0.019			
	N	14			
Yemen	Correlation Coefficient	.746**			
	Sig. (2-tailed)	0.002			
	N	14			
Kyrgyzstan	Correlation Coefficient	.604*			
	Sig. (2-tailed)	0.022			
	N	14			
Uzbekistan	Correlation Coefficient	.763**			
	Sig. (2-tailed)	0.001			
	N	14			
Qatar	Correlation Coefficient	-0.036			
	Sig. (2-tailed)	0.908			
	N	13			
Lebanon	Correlation Coefficient	0.311			
	Sig. (2-tailed)	0.28			
	N	14			
Kuwait	Correlation Coefficient	.587*			
	Sig. (2-tailed)	0.027			
	N	14			
Syrian Arab Republic	Correlation Coefficient	0.231			
	Sig. (2-tailed)	0.427			
	N	14			

** The correlation is significant at the 0.01 level (two-tailed); * The correlation is significant at the 0.05 level (two-tailed).

study period. This is indicated by the positive and significant correlation coefficients (0.784 and 0.572, respectively) with the study year variable. This trend is concerning as it implies that the control, prevention, and treatment measures in these countries are not as effective as in other regions. In contrast, countries like the Russian Federation, Kazakhstan, and Kyrgyzstan show negative and significant correlations with their study years, indicating a declining trend in TB recurrence. This is a positive sign of effective healthcare interventions and policies.

The lack of a clear trend in Qatar's TB recurrence rate with the study year variable, with a non-significant correlation coefficient of r = 0.009, suggests that there might be inconsistencies or challenges in their disease control efforts. This could be due to various factors such as fluctuations in healthcare funding, population mobility, or differences in TB management strategies.

The analysis of correlations between TB recurrence rates of countries reveals some notable patterns. The TB recurrence rates of Syria, Lebanon, Qatar, and Bahrain do not show significant correlations with the rate of TB recurrence in other countries. This might indicate unique challenges in disease control in these countries that are

not reflected in the broader trends observed. This could be due to specific contextual factors such as ongoing conflicts, large refugee populations, or varying healthcare systems and capacities.

Countries with significant negative correlations between their TB recurrence rates, such as the Russian Federation and Kazakhstan, are showing a strong trend towards reduced TB recurrence. These findings are important for public health professionals and policymakers to identify successful strategies that can be replicated or adapted for use in other regions, including Afghanistan and Pakistan, to improve TB control efforts.

Moreover, the significant correlations between the rates of TB recurrence in countries like Iran, Iraq, and Egypt (with coefficients ranging from 0.696 to 0.987) suggest that these countries are facing similar challenges or implementing similar interventions that affect the disease's recurrence. Understanding these commonalities can help in designing regional collaborations and sharing best practices.

5. Discussion

A study conducted in Taiwan analyzed the rate of TB recurrence among patients who completed treatment between January 1, 2012, and December 31, 2019. It aimed to enhance the understanding of TB recurrence in a region with a moderate TB burden, which could help inform TB control efforts. The study found a low recurrence rate of 2.0%, with a significant drop after 2017. Key risk factors for recurrence included a Body Mass Index (BMI) below 20 kg/m², a history of past TB, and non-conversion in sputum cultures after two months.[10] Additionally, data from over 10 million patients with pulmonary TB in China showed a recurrence rate of 0.47 per 100 person-years, with many recurrences happening within the first two years post-treatment. The recurrence rate doubled from 2015 to 2021, highlighting a higher risk for newly diagnosed patients compared to new cases. Other risk factors included being male, a minority group member, unemployed, a migrant, and aged 45 to 64.[11] In related findings from a previous study in Beijing involving 4,788 confirmed TB cases, 275 recurrent cases were identified, with a majority being labeled as relapses (69%) based on genetic testing. Significant risk factors uncovered included age (30-59 years) and previous treatment history.[12]

Recurrent Tuberculosis (RTB) in India affects 5.3% of TB patients, with a notable rate of 118 cases per 100,000 people. Men, the elderly, malnourished individuals, smokers, and alcohol users are more affected, indicating the need for targeted prevention for these groups. Monitoring and care after TB treatment are crucial, as drug resistance is more common in recurrent cases (11.3%) than in new cases (4.3%). Multidrug-resistant TB (MDR-TB) is found in recurrent cases, underscoring the importance of treatment adherence. A 24-month monitoring system is suggested, including regular checks and support for adherence, along with addressing malnutrition and substance use. Regular chest X-rays can help find asymptomatic recurrences, and educating patients about lifestyle changes can lower RTB risk.[13]

A study in Barcelona, Spain, examines the recurrence rate of TB and its risk factors in a high-incidence area. Researchers conducted a thorough analysis of TB cases over six years to improve public health strategies. They studied patients with confirmed positive cultures who finished TB treatment, adhering to ethical standards. The findings revealed a low overall recurrence rate of 1.3%, mainly occurring within three years post-treatment, which is better than in many countries with low TB rates. Higher recurrence was noted among HIV patients, inner-city residents, and those with past TB treatments, indicating these groups need targeted interventions. Relapse was more common than reinfection in recurrent cases.[14]

TB cases in the KSA decreased from 23 per 100,000 in 2000 to 8.4 in 2023, marking a 63.5% reduction. This rate is the second lowest in the Persian Gulf Cooperation Council (PGCC), following the UAE, indicating successful control efforts. While the KSA's rates are lower than the averages in the Middle East and North Africa (MENA) regions, some countries, like Jordan, report even lower incidences. The KSA's TB control strategies, including early detection and treatment, have helped meet the 20% reduction target set for 2020. However, the study notes limitations, such as insufficient demographic data and a lack of information on MDR TB cases. Additionally, the impact of COVID-19 on TB services may have resulted in underreporting and delays in diagnosis.[15]

The COVID-19 pandemic resulted in a 57% decrease in TB cases due to shifts in healthcare priorities. However, attributing increased TB transmission, deaths, and drug resistance to the pandemic needs careful analysis. The study used a method that shows data at one point but doesn’t prove direct causes. Long-term studies are required to grasp the pandemic’s lasting effects on TB management. Factors like population movement and healthcare access may have influenced TB rates. Recommendations include raising awareness, integrating TB services into primary care, and exploring economic factors affecting TB vulnerability.[16]

The COVID-19 pandemic has hindered TB diagnosis and care in the Western Pacific Region, causing a significant drop in case detection. It calls for stronger health systems, new treatment exploration, and ensuring access to health services, along with a focused recovery plan to manage TB cases and deaths.[17]

The study examined the genetic diversity and drug resistance of Mycobacterium Tuberculosis (MTB) strains

from Afghan immigrant patients in Mashhad, Iran. Molecular methods such as MIRU-VNTR, Xpert MTB/RIF, and MAS-PCR were used to analyze these strains. The research revealed a high prevalence of the NEW-1 and DELHI/CAS genotypes and identified one MDR isolate related to the Beijing genotype. The findings indicated a very low recent transmission rate of 0.21%, suggesting that most infections are from reactivated cases rather than new ones. This suggests that the origins of infections are likely in high-prevalence countries like Afghanistan or Pakistan. The study emphasizes the need for better screening and healthcare access for migrants to effectively control TB.[18]

The spread of MTB in Iran's border regions is a major public health concern, linked to migration from rural areas to cities, along with issues like weight loss. Migration can lead to higher TB rates, especially in urban areas with dense populations where close contact increases transmission. Migrants often live in crowded, poorly ventilated settings, face economic hardships, and experience food insecurity, all of which can worsen health and vulnerability to TB. Current studies suggest a link between migration and rising TB rates, but more research is needed to confirm direct causation. To address TB effectively, it is vital to improve healthcare access for migrants, implement screening and treatment, strengthen surveillance, educate about TB, and provide nutritional support. Urban healthcare systems must be prepared for an increase in TB cases due to these migration patterns.[19]

A study in Tehran analyzes reasons for TB readmissions, focusing on social, demographic, and medical factors. It finds that being married helps treatment adherence, while smoking worsens health and increases readmissions. Chronic conditions such as COPD and HIV complicate TB treatment, increasing infection risks and severity. The study emphasizes the need to address these health issues to lower readmission rates. It also distinguishes between early and late readmissions, suggesting different solutions. Recommendations include enhancing patient support, follow-up care, and education, as well as employing smoking cessation programs and DOT.[20]

Countries with strong healthcare systems, such as the UAE, Qatar, and Kuwait, typically report lower relapse and recurrence rates due to better access to medical care, early detection, and effective treatment plans. These nations invest in public health, providing high-quality services and training for healthcare providers. In contrast, nations struggling with poverty and poor living conditions, like Afghanistan and Pakistan, experience higher TB risks and relapse rates as these factors hinder treatment access and adherence. Co-existing diseases like HIV/AIDS and diabetes also worsen TB treatment outcomes. The emergence of drug-resistant TB, including MDR and Extensively Drug-Resistant (XDR) strains, complicates treatment and leads to more frequent relapses. The COVID-19 pandemic has disrupted global TB control efforts by diverting resources and restricting access to healthcare services, which may delay treatment and increase relapse rates. Egypt faces ongoing issues with poverty and overcrowding. The link between TB and other health issues can be seen in countries like Russia. A comprehensive approach to tackle TB, including public health initiatives like education and vaccination, is essential. Political instability, migration patterns, and accurate data collection also significantly impact TB dynamics and control efforts.[21]

The epidemiological landscape of TB relapse in Iran and neighboring countries provides a snapshot of global TB trends, with socioeconomic stability and healthcare infrastructure playing crucial roles. Nations like Saudi Arabia (-57% relapse rate) and Azerbaijan (-53.5%) are meeting WHO's TB reduction goals through effective DOTS programs and healthcare investments. However, Afghanistan's 20.6% increase and Pakistan's 45% surge in recurrent cases highlight how conflict and malnutrition can lead to a breakdown in healthcare systems, as seen in the Global Tuberculosis Report 2023. Iran's trajectory is complex, with a 49% decline from 2010-2020 followed by a 20.6% rebound, showcasing the impact of pandemic disruptions on TB control efforts. Central Asian countries like Kazakhstan (-66.3%) and Tajikistan (-53.3%) have made significant progress by modernizing their Soviet-era programs with advanced diagnostics and support services. In contrast, Yemen's 15.9% increase in relapse cases demonstrates how humanitarian crises can fuel the spread of MDR-TB.

This regional variation underscores the importance of strong health systems in preventing TB relapse, particularly in the face of cross-border threats like Afghan migration, which has been linked to TB transmission in cities like Mashhad. Coordinated efforts across borders, as outlined in the End TB Strategy, are essential to combatting the challenges posed by TB relapse and ensuring global health security.

The WHO has updated its guidelines for treating TB in children and adolescents, with the aim of improving care based on new scientific findings. The guidelines focus on achieving effective treatment outcomes and preventing the development of drug-resistant TB strains. For children aged three months to 16 years with non-severe pulmonary TB, the standard treatment is a four-month course. This includes two months of intensive treatment with isoniazid, rifampicin, and pyrazinamide, with the addition of ethambutol for those at higher risk of resistance or those with HIV. The following two months involve a continuation phase with isoniazid and rifampicin only, to clear the bacteria while ensuring the completion of the treatment duration. Adolescents aged 12 years and older, especially in regions with high HIV rates or isoniazid resistance, may receive a different four-month

regimen that includes rifapentine and moxifloxacin throughout treatment. The choice of treatment is determined by the adolescent's weight, HIV status, and local drug resistance trends. Treating TB meningitis in children requires a longer and more intense approach, typically involving a six-month treatment plan that includes isoniazid, rifampicin, pyrazinamide, and ethionamide, along with corticosteroids for inflammation control. For drug-resistant forms of TB, such as MDR-TB and rifampicin-resistant TB (RR-TB), tailored regimens are necessary based on the child's resistance profile. In cases of RR-TB, medications like bedaquiline or delamanid may be considered, although there is limited evidence for their use in young children. For non-severe TB cases, a four-month regimen is recommended, while severe cases may require six months of treatment. Infants aged 0-3 months suspected of having pulmonary TB should receive a six-month treatment plan specifically adjusted for their age. In areas with high HIV prevalence and isoniazid resistance, a longer six-month regimen is suggested for children aged three months to 16 years. To improve adherence and treatment outcomes, the WHO recommends the use of Fixed-Dose Combination (FDC) tablets.[21]

6. Conclusion

To reduce TB recurrence, it is crucial to improve diagnostic and treatment facilities. This involves enhancing healthcare infrastructure and providing accurate TB tests in remote, high-incidence areas. Training healthcare workers for early detection is also necessary. Ensuring that patients adhere to their treatment plans is vital, with DOT proving effective. Support groups can motivate patients to complete their treatments, while mobile health technologies, such as apps and text reminders, can enhance communication and monitor treatment progress. Addressing drug resistance is key, as it leads to repeated TB cases. Monitoring drug-resistant strains and offering suitable second-line treatments are essential. Rapid diagnostic tests can identify drug resistance early for prompt care. Infection control in healthcare settings and ensuring the quality of TB medications help prevent the spread of resistant strains. The variation in TB recurrence rates among countries shows the need for customized approaches based on healthcare stability, migration, and socioeconomic factors. Addressing social determinants like poverty and overcrowding is necessary, often requiring collaboration with other sectors like housing and education. Public awareness campaigns should educate communities on TB, ensuring they are culturally relevant and utilize diverse communication methods. Further research is needed on factors affecting TB recurrence, especially involving migrant populations and cross-border health issues.

The analysis of TB relapse and recurrence trends in Middle Eastern and Central Asian countries from 2010 to 2023 has led to the development of a policy framework based on regional health data. Cross-cutting mechanisms include implementing standardized e-health records, monitoring high-risk groups post-treatment, and placing TB detection tools at COVID testing sites. An operational note highlights the need for specific monitoring methods due to uneven TB occurrence. The framework emphasizes the importance of healthcare infrastructure, conflict mitigation, and managing urban TB transmission risks. Costs are outweighed by potential savings from effective interventions, with a timeline indicating priority phases for implementation.

Research Highlights

What Is Already Known?

From 2010 to 2023, trends in TB cases show varying patterns across Middle Eastern and Central Asian countries. Factors affecting TB management include effective healthcare systems, treatment adherence, and enhanced TB surveillance. Sociodemographic and socioeconomic factors, along with public health interventions, play crucial roles. Political instability, especially in Lebanon, and challenges like drug-resistant TB and COVID-19, negatively impact TB control efforts.

What Does This Study Add?

The study emphasizes the complexity of managing TB, influenced by various healthcare systems and external factors such as conflicts and migration. It identifies potential areas for improvement in countries with rising TB rates, like Afghanistan and Pakistan, while advocating for the sharing of effective strategies across regions. This underscores the need for tailored public health approaches and regional collaboration to enhance TB control efforts.

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Conflict of Interest Disclosures

The author declared that there is no conflict of interest.

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