Original Article
http://mjiri.iums.ac.ir
Medical Journal of the Islamic Republic of Iran (MJIRI)

Med J Islam Repub Iran. 2026 (9 Sep);40.98. https://doi.org/10.47176/mjiri.40.98

Correlations between Surface Temperature and Atmospheric CO_2 Emissions with Health-Related Factors in WANA: An Ecological Study

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Received: 3 Sep 2025 Revised: 16 Aug 2026 Accepted: 26 Aug 2026 Published: 9 Sep 2026

Abstract

Background: Climate change impacts public health. This study aims to examine climate change-related diseases in the West Asia and North Africa (WANA) region, comparing health outcomes with global data.

Methods: This study employed a secondary data analysis with an ecological design, focusing on climate change-related diseases and their associated health outcomes in 21 countries across WANA from 1990 to 2023. Data were sourced from reputable organizations and cleaned for inconsistencies. Descriptive statistics were used to summarize the data, while correlation and regression analyses assessed the relationships between climate variables and health outcomes, utilizing SPSS version 22 for statistical analysis.

Results: The WANA region—which accounts for about 10% of the world's population—continues to warm with higher atmospheric CO2, impacting health outcomes. The annual heat-related mortality rate averages 1.95 per 100,000, indicating a slight decrease. Mental health indicators show a -1.17% change, while anxiety has surged by 21.70%. Disability-Adjusted Life Years (DALYs) have declined by 23.6%, suggesting a reduced overall disease burden in this region. Temperature is the main driver of heat-mortality risk: a 1°C increase raises heat-mortality odds by 57%. A 1% rise in CO_2 increases asthma odds by 3%, a statistically significant, public-health-relevant effect. The region differs notably from the global average and from countries with minimal climate impact.

Conclusion: The study advocates a strategy addressing climate-related mental health impacts through environmental policy, public health, and mental-health support, with recommendations to improve data collection, target vulnerable groups, develop heat action plans, and foster regional partnerships.

Keywords: Climate change, Health outcomes, West Asia, North Africa

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Cite this article as: Soori H, Ghasempour A. Correlations between Surface Temperature and Atmospheric CO_2 *Emissions* with Health-Related Factors in WANA: An Ecological Study. *Med J Islam Repub Iran.* 2026 (9 Sep);40:98. https://doi.org/10.47176/mjiri.40.98

Introduction

According to the United Nations Framework Convention on Climate Change (UNFCCC), the alteration of the planetary atmosphere goes beyond the natural climate variations that occur over comparable time periods. The changes have been directly and indirectly affected by human activities (1). Climate change is a major public health problem in the 21st century. It leads to heat waves, droughts, extreme rainfall, and poor air quality that directly or indirectly endanger human health and strain health systems.

Addressing climate change is crucial for environmental and public health. Heat-related diseases are increasing, particularly in vulnerable groups. Higher temperatures reduce air quality, causing respiratory issues like asthma

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Key Messages:

↑What is "already known" in this topic:

Rising temperatures and higher CO_2 levels are linked to health issues, including heat-related deaths, respiratory ail-ments, and mental disorders. These impacts differ regionally based on climate, vulnerability, socioeconomic factors, healthcare capacity, and adaptation. A detailed regional analysis is necessary for the West Asia and North Africa (WANA) region.

→What this article adds:

This study examines 21 WANA countries from 1990 to 2023, highlighting that rising surface temperatures correlate with increased heat-related mortality, and higher atmospheric CO_2 emissions are linked to a greater disease burden regionally.

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[DOI: 10.47176/mjiri.40.98]

and COPD. Climate change also affects the spread of diseases like malaria and worsens agricultural impacts, leading to malnutrition and increasing mental health problems such as anxiety and depression (2-4).

While it is difficult to attribute increased mortality directly to atmospheric CO_2, it is known to exacerbate respiratory conditions, resulting in higher mortality rates among individuals with COPD and asthma (5, 6).

Furthermore, identifying a single disease most attributable to increased mortality from rising surface temperatures is challenging; however, heat-related illnesses, cardiovascular diseases, and respiratory conditions are among the most significantly affected (7-9).

Climate change affects health differently across regions. Factors like location, social health, healthcare quality, and resilience play a role in health outcomes. Regional assessments are needed to find at-risk populations and guide targeted adaptation policies. In the West Asia and North Africa (WANA) region, climate change creates serious environmental challenges. Higher temperatures lead to heatwaves that adversely affect agriculture, water supplies, and public health. Desertification and land degradation impact employment and wildlife, while food security and nutrition suffer from disrupted crop yields. Climate phenomena, such as droughts and floods, pose additional risks to infrastructure and communities, contributing to respiratory diseases and heat-related diseases (10-12).

Beyond health impacts, climate change has significant socio-economic implications in WANA. For instance, imbalances in production and consumptions and threatening livelihood, causing resource scarcity and inefficiencies. Ultimately, people should be displaced, evacuate their homes, and migrate. This has drawbacks on socio-economic factors, along with health impacts, which are integrated into the broader socio-economic challenges. Climate change will lead to an additional 250,000 deaths annually between 2030 and 2050 (13) and displacement of over 140 million people in low- and middle-income countries, including those in WANA (14). Competition for resources may heighten political tensions, potentially leading to conflicts over water and arable land. An updated overview of health risks from climate change in the WANA region has been urged. Beyond health impacts, climate change has significant socio-economic implications in WANA. For instance, imbalances in production and consumptions and threatening livelihood, causing resource scarcity and inefficiency (15, 16). Climate change creates health problems through extreme temperatures, environmental damage, food insecurity, and shifts in disease transmission. Understanding these risks is vital for public health planning and climate adaptation.

The critical question is whether the countries in the WANA region, which already struggle with various health indicators, are more at risk from climate change and whether their health-related indicators are worsening. Research on how climate change is affecting health in the WANA region is limited. Most studies have focused on specific countries or diseases, making it difficult to see overall trends and compare them across the region.

This study aimed to investigate climate change-related diseases in the WANA region and compare these with global data. It focused on the relationship between surface temperature, atmospheric CO_2 emissions, and health outcomes like mortality. The study examined correlations and changes over time in surface temperature and CO_2 emissions in WANA compared to global averages.

Methods

This study used secondary data analysis with an ecological design to examine climate change-related diseases. Data were sourced from the World Cities Report (4), the World Bank Annual Report (14), WHO databases, relevant health ministries, and published literature. The study focused on the latest available data, mainly from 2023, with time series spanning 1990 to 2023, using 1990 as the base year (Table 1).

We extracted relevant data for 21 countries: 16 from West Asia (Armenia, Azerbaijan, Bahrain, Cyprus, Iran, Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Pakistan, Saudi Arabia, Syria, Turkey, and the United Arab Emirates) and 5 from North Africa (Algeria, Egypt, Libya, Morocco, and Tunisia). Some of the countries' data were unavailable due to conflicts or regional crises.

Countries with minimal climate change impacts (CMCC) included Iceland, Norway, Finland, Sweden, and New Zealand. We calculated the mean values of key health and climate-related indicators across selected country groups. The outcomes included increases in mortality rates, asthma, chronic bronchitis, heart disease, heat stroke, and stress-related mental health conditions like anxiety and depression.

Inclusion criteria for the study focused on countries in the Wana with publicly available climate and health data from

Table 1. Overview of data sources used in the study

Source	Type of Data	Coverage
World Cities Report	Climate change-related diseases	WANA region
The United Nations	Total population	Specific countries
World Bank Annual Report	Economic and health data	Global and WANA
WHO Databases	Health outcomes	Global
Global Burden of Diseases	Health Outcomes	Global
Institute for Health Metrics and Evaluation (IHME)	Health Outcomes	Global
International Monetary Fund (IMF)	Surface temperature change(c^0) Global and WANA	Global and WANA
Ministries of Health	National health data	Specific countries
Global Carbon Atlas (2024)	Annual CO_2 emissions, Mt* CO_2	Global
Global Carbon Budget	Annual CO_2 emissions, tonnes per /capita	Global and WANA

* Million tonnes

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[DOI: 10.47176/mjiri.40.98]

1990 to 2023, especially the most recent data. It required countries to have comparable information from recognized sources like the World Health Organization and peer-reviewed literature.

Selected countries in the climate change minimal impact comparison group included Iceland, Norway, Finland, Sweden, and New Zealand. These nations show low risk and high adaptive capacity, based on indicators like the ND-GAIN Country Index and the Global Climate Risk Index (17). The study looked at climate indicators like temperature and CO_2 emissions, and health indicators related to climate-sensitive diseases. Countries lacking adequate data due to conflict or political instability were excluded. The study focused on the annual mean near-surface air temperature (°C) for each country from 1990 to 2023, sourced from the World Bank climate database, as a key indicator of long-term climate change.

All datasets were checked for completeness, consistency, and accuracy. Missing values were counted for each variable. Variables with less than 5% missing data were replaced with the median for continuous variables or the mode for categorical ones. Variables with over 5% missing data were included only if sensitivity analysis showed they did not significantly alter study results; otherwise, they were excluded.

Data from various sources were harmonized by standardizing variable names, measurement units, and coding. Health indicators were adjusted to comparable measures, and climate variables were standardized across countries and years.

Statistical analysis followed, leading to result interpretation, report drafting, and final revisions. Descriptive statistics provided an overview of the data. Because several variables were not normally distributed, Spearman's rank correlation coefficient was used to assess the strength and direction of the monotonic association between annual surface temperature, atmospheric CO_2 emissions, and health-related outcomes. The correlations reported in the results were calculated using data spanning the period from 1990 to 2023, with particular emphasis on trends and relationships observed up to 2021.

Multiple linear regression examined the influence of climate variables on health outcomes, while logistic regression analyzed binary outcomes, such as the presence or absence of diseases. Comparative analyses were performed using ANOVA and Kruskal-Wallis tests, such as WANA versus global averages, and among countries with varying climate conditions. Statistical analyses were conducted using SPSS software version 22.

Results

The total population in the WANA region is approximately 802.14 million, representing approximately 10% of the global population. Table 2 presents data on temperature, atmospheric CO_2 emissions (% Mt), and relevant health outcomes in WANA. The region has experienced an average temperature increase of about 2.01°C, surpassing the global average of 1.52°C. Atmospheric CO_2 levels in WANA rose significantly, with a mean change of 207.3%, much higher than the world average of 66.24 Mt.

From 1990 to 2023, WANA's average mortality rate declined from 6.00 to 4.63, remaining below the global average. Heat-related mortality averaged 1.95 per 100,000, while asthma rates showed a slight decrease to 5.52. Mental health indicators show a -1.17% change, while anxiety has surged by 21.70%. DALYs dropped by 23.57%, slightly below the global reduction of 28.7%. These trends suggest modest improvements in general health, but rising mental health burdens may reflect growing environmental stressors.

The analysis revealed a significant connection between heat-related mortality and CO_2 emissions, with higher anxiety levels linked to increased CO_2 levels ($r = 0.470$, $P = 0.032$). Additionally, rising anxiety corresponds to rising depression ($r = 0.853$) and a moderate link to heat-related mortality ($r = 0.201$).

Table 3 shows changes in health-related outcomes among three groups: the WANA region, the global average, and countries with minimal climate impact. Countries with minimal impact recorded an increase of 0.798°C. Atmospheric CO_2 emissions in WANA increased by 207.3, surpassing the global average of 9, while countries with minimal impact had a decrease of 23 ppm. The mortality rates slightly improved in WANA (-1.64) and globally (-1.42), but dropped dramatically in minimal impact countries (-43.8). Heat-related mortality was lower in WANA at 1.95 per 100,000. Asthma rates decreased across all regions, with chronic bronchitis showing a significant drop in WANA (-24.2), while minimal impact countries experienced a 5.0 increase. Heart disease deaths declined by -59.8 in WANA, and heat stroke deaths also fell across all groups. Anxiety and depression rates increased, with WANA showing increases of 21.7% and 12.9%, respectively.

Tables 4 and 5 illustrate climate factors and health outcomes in the world, WANA, and countries with minimal climate change (CMCC). The data show that as CO2 emissions rise, global temperatures also increase. Each unit increase in global CO_2 emissions predicts a 6.876-unit increase in WANA CO_2 emissions. A strong link exists between global temperature and WANA temperature, which increases by 0.640 units, with a significant p-value of 0.002.

The coefficient of 0.983 indicates that CO_2 emissions significantly affected WANA asthma rates ($P < 0.001$).

Moreover, a significant relationship among global temperature, WANA temperature, and WANA heat-related mortality rates was evidenced. Table 6 presents a logistic regression analysis for the WANA region, demonstrating that rising temperature, CO_2 emissions, and anxiety levels are significantly associated with an increased risk of adverse health outcomes. A 1°C temperature rise increases the odds of heat-related mortality by 57%, a 1% increase in CO_2 emissions raises asthma risk by 3%, and a 1% rise in anxiety corresponds to a 10% higher chance of heat stroke mortality. Logistic regression in the WANA region revealed a significant link between higher temperatures and increased heat-related mortality risks.

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Table 2. Changes (%) in surface temperature, atmospheric CO_2 levels, and health outcomes for the selected counties and the world (based on data sources used in the study)

Country	Total Population *1000	Surface Temperature (°C)	Co2 emission (% Mt**)	mortality rate /1000	heat-related mortality rate/ 100000	Asthma prevalence change	Chronic bronchitis death	Heart disease deaths relative	Heat Stroke mortality/100000	Heat Stroke mortality/ Change	Anxiety Prevalence	Depression Prevalence	DALY Relative
Algeria	46167	2.274	132.24	-1.64	0·78	-0.7	-33.4	-18	66.29	-16	13	6	-22
Armenia	2943	2.258	−98.84	1.42	-	-0.3	-46.1	-19	48.21	-51	35	26	-25
Azerbaijan	10318	2.16	−14.42	-1.58	1.5	-0.8	-25.8	-54	151.52	-53	28	16	-20
Bahrain	1570	2.261	218.61	-.89	-	-1.7	-50.0	-54	52.59	-48	16	3	-23
Cyprus	1345	1.866	54.51	.38	3·32	-1.9	-52.5	-63	20.33	-58	18	12	-38
Egypt	114536	2.011	255.45	-2.93	1.68	-1.6	-42.3	+12	65.24	-8	21	18	-27
Iran	90609	2.238	288.65	-2.96	11.00	-2.2	-18.6	-41	57.21	-42	21	14	-36
Iraq	45074	2.064	259.18	-2.64	2.34	-1.9	-2.0	+1	128.44	-12	17	7	-17
Jordan	11439	2.007	102.28	-1.18	1.13	-1.1	-26.0	-54	62.96	-55	16	0	-20
Kuwait	4839	1.995	162.56	.64	0.84	-1.1	-19.8	-27	37.49	-45	12	7	-29
Lebanon	5773	2.073	121.00	-1.54	2.15	-1.2	-19.0	-43	28.55	-54	36	36	-28
Libya	7306	1.473	67.12	-.07	0.97	-1.2	-11.1	0	64.09	-2	23	14	+7
Morocco	37713	2.556	208.13	-2.50	0.93	-0.4	-15.6	-10	101.53	-13	24	13	-28
Oman	5049	1.377	599.73	-3.28	0.66	0.2	-17.1	-38	94.98	-28	21	15	-21
Pakistan	247504	1.356	196.34	-4.18	-	-1.1	-7.5	+3	116.52	-23	16	4	-13
Qatar	2979	2.074	916.67	-.74	0.95	-0.7	-23.7	-65	51.69	-61	10	4	-35
Saudi Arabia	33264	1.839	304.40	-1.43	1.03	0.0	-20.6	-24	95.93	-37	12	12	-28
Syria	23595	2.092	31.08	.00	1.59	-0.1	+4.8	-18	79.31	-32	24	14	-16
Tunisia	12200	2.403	142.38	-.13	1.14	-0.9	-28.3	-30	68.10	-30	37	26	-13
Turkey	87271	2.061	184.96	-2.77	2.40	-2.9	-25.5	-19	49.06	-30	34	16	-37
United Arab Emirates	10642	1.759	219.49	-.83	0.95	-2.9	-27.9	-48	74.74	-52	21	8	-26
Total	802136	2.009	207.28	-1.64	1.95	-1.17	-24.2	-29	72.1	-35.7	21.7	12.9	-23.6
World	8091735	1.524	66.24	-1.42	2.7	-2.2	-37.0	-23	84.69	-33	18	11	-29%

*https://population.un.org/wpp/
** Million tonnes, % changes
*** Latest available 2021

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[DOI: 10.47176/mjiri.40.98]

Table 3. Relative changes in health-related outcomes in West Asia and North Africa (WANA), the world, and countries with minimal climate impact (based on data sources used in the study)

Health Outcome	WANA Region	Global Average	Countries with Minimal Climate change (CMCC) *
Surface Temperature Change (°C)	2.009	1.524	0.798
Atmospheric CO_2 emission (% Mt**)	207.28	66.24	18.38
Increase in mortality rate	-1.64	-1.42	-43.8
Annual heat-related mortality rate per 100 000 people	1.95	2.7	1.76
Asthma Prevalence change	-1.17	-2.2	-4.36
Chronic bronchitis	-24.2	-37.0	5.0
Heart disease deaths	-29	-23	-59.8
Heat Stroke Relative Change	-35.7	-33	-56.4
Anxiety Prevalence Relative Change %	21.7	18	7.9
Depression	12.9	11	3.8
DALY Relative Change %	-23.6	-29%	-27.8

* Includes Iceland, Norway, Finland, Sweden, and New Zealand (average values). ** Million tonnes, % changes

Table 4. Trends of climate change variables in the world, Countries with Minimal Climate change (CMCC) and West Asia and North Africa (WANA)

Year	World Surface Temperature Change (°C)	Worlds CO_2 emission change (% Mt*)	CMCC Surface Temperature Change (°C)	CMCC change CO_2 emission change (% Mt)	WANA Surface Temperature Change (°C)	WANA CO_2 emission change (% Mt)
1990	0.960	22.73	.77	8.52	.43	53.81
1991	0.563	23.19	.63	8.25	.19	57.69
1992	0.946	22.53	.45	8.40	-.67	62.10
1993	0.718	22.76	.16	8.58	-.04	66.75
1994	0.513	22.99	.72	8.85	.83	70.17
1995	1.212	23.53	.13	8.76	.27	71.19
1996	0.256	24.26	.56	9.28	.50	72.45
1997	0.613	24.40	.44	9.24	.27	71.54
1998	0.791	24.30	1.04	9.01	1.06	75.16
1999	1.008	24.85	1.13	9.14	1.37	78.84
2000	0.474	25.51	.83	9.07	.77	85.94
2001	0.808	25.71	1.06	9.37	1.22	86.90
2002	1.402	26.28	.93	9.48	1.13	88.27
2003	1.384	27.67	.99	9.85	.99	94.20
2004	1.000	28.63	1.32	9.70	.97	100.41
2005	1.170	29.61	1.11	9.06	.68	105.76
2006	0.741	30.63	1.37	9.52	1.23	111.28
2007	2.068	31.53	1.39	9.59	.90	112.72
2008	0.311	32.07	1.09	9.35	1.02	120.14
2009	1.065	31.54	.15	8.85	.96	124.72
2010	1.083	33.36	1.12	9.27	2.14	130.32
2011	0.692	34.50	.94	8.71	1.01	133.77
2012	0.648	35.00	.94	8.44	1.13	141.74
2013	1.138	35.30	1.96	8.33	1.22	139.27
2014	1.181	35.45	1.46	8.06	1.25	143.95
2015	1.468	35.40	1.64	7.94	1.45	148.57
2016	1.758	35.42	1.36	7.83	1.60	153.17
2017	1.767	35.99	1.46	7.72	1.41	160.14
2018	1.298	36.73	1.31	7.69	1.91	160.40
2019	1.686	37.10	2.04	7.38	1.45	165.49
2020	2.202	35.13	1.42	6.77	1.59	159.57
2021	1.722	36.99	1.71	6.85	2.09	170.45
Mean	1.08	29.72 (0.94)	1.05 (0.09)	8.65 (0.14)	1.1 (0.11)	36.85 (6.51)

* Million tonnes, % changes.

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Table 5. Trends of health outcomes in the world, countries with minimal climate change (CMCC), and West Asia and North Africa (WANA)

Year	World Mortality rate	CMCC Mortality rate	WANA Mortality rate	World Asthma	CMCC Asthma	WANA Asthma	World heat-related stroke rate	CMCC heat-related stroke rate	WANA heat-related stroke rate	World Anxiety	CMCC Anxiety	WANA Anxiety	World DALY	CMCC DALY	WANA DALY
1990	1107	650.78	1050	5.60	12.80	4.76	144.3	68.26	144.4	3.70	5.80	4.63	50766	26286	42097
1991	1098	637.74	1035	5.40	12.42	4.73	142.3	66.74	142.8	3.70	5.80	4.63	50458	25838	41392
1992	1091	629.60	1021	5.20	12.00	4.70	141.4	65.48	141.3	3.70	5.80	4.63	49963	25433	40644
1993	1091	621.44	1014	5.00	11.62	4.65	141.8	64.66	140.7	3.70	5.80	4.63	49793	25058	40192
1994	1095	605.96	996	4.90	11.30	4.61	141.4	62.54	137.5	3.70	5.80	4.63	50112	24644	39692
1995	1081	604.10	978	4.80	11.00	4.57	140.2	61.78	134.7	3.70	5.78	4.62	49261	24621	38955
1996	1064	588.16	970	4.60	10.70	4.53	137.5	59.88	133.4	3.70	5.76	4.63	48631	24076	38430
1997	1046	576.64	970	4.50	10.36	4.46	134.7	58.38	133.2	3.70	5.72	4.63	47984	23787	38031
1998	1036	565.08	959	4.40	10.06	4.40	132.8	56.98	131.9	3.80	5.70	4.62	47544	23460	37436
1999	1025	556.90	950	4.30	9.78	4.34	131.7	55.40	130.4	3.80	5.68	4.62	27123	23239	37023
2000	1013	543.70	937	4.20	9.52	4.29	130.6	53.30	128.7	3.80	5.66	4.62	46572	22946	36414
2001	1000	533.86	925	4.10	9.32	4.27	129.6	51.78	127.3	3.80	5.64	4.63	45939	22661	35787
2002	990	526.28	915	4.00	9.08	4.23	128.6	50.52	125.3	3.80	5.66	4.63	45341	22408	35334
2003	981	513.54	908	3.90	8.84	4.20	127.8	48.36	122.8	3.80	5.66	4.63	44725	22095	35208
2004	967	501.68	896	3.80	8.62	4.18	125.0	46.02	120.4	3.80	5.64	4.62	44220	21855	34650
2005	946	493.28	894	3.80	8.44	4.15	121.7	43.28	118.7	3.80	5.64	4.63	43341	21504	34501
2006	915	478.52	884	3.70	8.32	4.13	115.4	41.78	116.5	3.80	5.64	4.63	42207	21253	34085
2007	896	473.58	875	3.70	8.20	4.12	112.0	40.76	114.9	3.80	5.66	4.65	41301	21099	33540
2008	886	466.84	824	3.80	8.06	4.09	110.3	39.50	113.9	3.80	5.66	4.67	40758	20902	33084
2009	865	459.42	858	3.80	7.94	4.07	107.9	38.42	111.6	3.80	5.70	4.70	39778	20706	32582
2010	854	451.64	839	3.80	7.84	4.05	105.9	37.18	108.2	3.80	5.68	4.70	39355	20479	32056
2011	836	446.76	829	3.70	7.74	4.00	102.7	36.64	105.2	3.80	5.68	4.71	38582	22214	31874
2012	817	438.24	818	3.60	7.60	3.91	99.7	35.44	102.2	3.70	5.68	4.72	37706	20060	31775
2013	805	430.34	807	3.50	7.46	3.84	97.6	33.76	100.0	3.70	5.66	4.74	37025	19841	31418
2014	793	422.36	811	3.40	7.30	3.77	95.8	32.84	99.0	3.70	5.66	4.75	36430	19622	31992
2015	780	416.42	805	3.40	7.24	3.71	94.1	31.62	97.7	3.70	5.66	4.76	35831	19431	31694
2016	768	411.94	797	3.40	7.18	3.66	93.1	30.30	97.0	3.70	5.66	4.75	35272	19335	31404
2017	756	406.86	781	3.30	7.12	3.62	91.6	28.94	94.8	3.70	5.68	4.74	34731	19244	30911
2018	746	399.74	749	3.30	7.08	3.59	90.4	27.94	92.3	3.70	5.68	4.72	34215	19096	29567
2019	735	391.62	735	3.30	7.04	3.56	89.3	26.88	91.0	3.70	5.70	4.71	33760	18973	28912
2020	795	385.78	861	3.30	6.98	3.60	88.3	25.60	89.9	4.30	6.26	5.50	35137	18995	31739
2021	835	382.88	893	3.30	6.94	3.59	87.5	25.50	87.7	4.40	6.26	5.63	36203	18935	32148

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[DOI: 10.47176/mjiri.40.98]

Table 6. Hypothetical Logistic Regression Model Examining the Association Between Climate Indicators and Health Outcomes in West Asia and North Africa (WANA)

Predictor	Coefficient (β)	Odds Ratio (OR)	95% CI for OR	*P*-value	Interpretation
Temperature Change	0.45	1.57	1.20–2.05	0.002	Each 1°C increase raises the odds of heat-related mortality by 57%. Significant positive association.
CO_2 Emissions (%)	0.03	1.03	1.01–1.05	0.015	Each 1% increase in CO_2 raises the odds of asthma by 3%. Significant but smaller effect.
Anxiety Rate (%)	0.10	1.10	1.02–1.18	0.012	An increase in anxiety raises the odds of heat stroke mortality by 10%.
Constant	-2.50	-	-	<0.001	Baseline odds when predictors are zero.

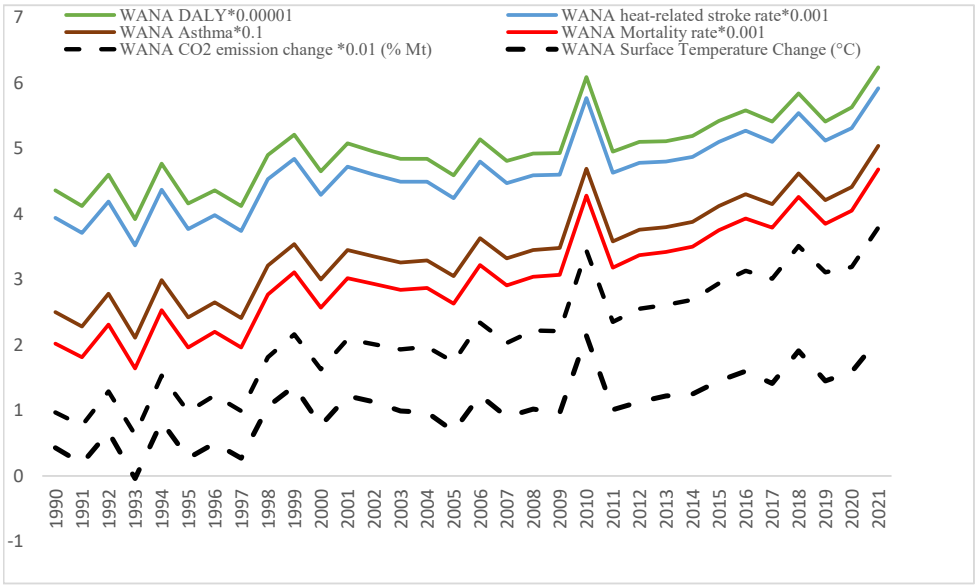


Figure 1. World Surface Temperature Change (°C) and Atmospheric CO_2 emission (% Mt) Change (ppm)/*10^{10}

Conversely, comparison countries with lower climate-related risks showed no significant associations between temperature changes and health outcomes like asthma, COPD, stroke, anxiety, depression, or DALYs. Additionally, a strong positive correlation exists between global and WANA temperatures (increase of 0.640 units, $P = 0.002$), and CO_2 emissions are closely linked to asthma rates in WANA (coefficient 0.983, $P < 0.001$), likely reflecting the impact of declining air quality and increased allergens.

Figure 1 displays health and climate trends in the WANA region from 1990 to 2021. The WANA surface temperature change (°C) has steadily risen, as shown by the dotted black line. The heat-related mortality rate in WANA varies, with notable spikes around 2010, possibly linked to temperature rises. WANA CO_2 emission changes (%) have gradually increased, reflecting higher greenhouse gas levels. The WANA asthma rate has grown, potentially due to environmental changes and rising CO_2 levels. Overall, the figure illustrates the connection between rising temperatures, CO_2 emissions, and health outcomes.

Discussion

The findings highlighted the complex relationships between environmental factors, particularly climate change, and health outcomes in the WANA region. From 1990 to 2023, the WANA region saw rising temperatures and pollution, yet overall health improved. Mortality rates fell, heart and respiratory diseases declined, but mental health issues increased. Heat-related deaths appeared, and disease burden dropped—though less than in other regions. The reported average temperature change of 2.01°C was significantly higher than the global average of 1.52°C, with profound implications for public health. Higher temperatures exacerbated health issues, especially in vulnerable populations, diminishing physical work capacity and cognitive performance, which led to increased occupational health risks. Rising temperatures are associated with an increased risk of heat-related mortality, especially among older adults and individuals with pre-existing chronic conditions. The association appears to be more pronounced in the WANA region than in some European settings, possibly because of higher baseline temperatures, rapid urbanization, and comparatively limited climate adaptation measures. These findings are consistent with previous research demonstrating that climate change contributes to a wide range of adverse health outcomes, including increased incidence of infectious and respiratory diseases, heat-related illness and mortality, undernutrition resulting from food insecurity, and health consequences associated with sociopolitical instability (17-19).

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This study showed a strong positive association between ambient temperature and heat-related mortality, with each 1°C increase linked to a 57% rise in odds. By contrast, a 1% increase in CO_2 is associated with a 3% rise in the odds of asthma, a statistically significant but substantially smaller effect. In sum, temperature appears to have a larger impact on heat-related deaths, while CO_2-related asthma risk is meaningful but more modest, though both findings warrant attention for public health planning. The relationship between surface temperature change and atmospheric CO_2 emissions underscored the impact of greenhouse gas emissions on climate change, emphasizing the need for strategies to reduce emissions. The noteworthy warming in the region affected health outcomes, particularly in countries like Pakistan, Egypt, Iran, and Turkey, where 67% of the population resided.

High-income countries in the WANA region show greater resilience to climate-related health impacts than many low- and middle-income countries, attributed to stronger health systems, urban planning, and investment in climate adaptation and research, though not directly assessed (8, 20).

While this study did not examine age-related outcomes, literature showed that older adults, young children, low-income individuals, and those on certain medications were particularly vulnerable to heat-related illnesses (21). Some studies hypothesized that long-term exposure to increasing atmospheric CO_2 can harm health by altering acid-base homeostasis, leading to respiratory acidosis (22, 23).

Heat stroke poses a critical medical emergency in many WANA countries. Symptoms like faintness, dizziness, and loss of consciousness require immediate medical attention. Delays in treatment could lead to severe complications or death. Notably, temperatures significantly lower than the 35°C survivability threshold could still pose serious health threats (24). Studies showed that hot, dry, and hot-humid weather reduces physical activity would hinder the body's cooling mechanisms through sweat evaporation (25). Many WANA countries experienced feverish temperatures alongside high humidity, further jeopardizing health, particularly in the Persian Gulf.

A recent study showed that the likelihood of heat-related deaths surged significantly over the past two decades, emphasizing the need for adaptation to extreme heat. Implementing strong mitigation policies to limit global warming to below 2°C could have saved many lives, with efforts to achieve a 1.5°C increase being critically important (25).

The elevated asthma rates in the WANA region reflected persistent respiratory health issues associated with environmental factors. Climate change significantly impacted respiratory health, contributing to allergic respiratory diseases and asthma. Allergies were often used to assess the relationship between air pollution and these conditions (26). The ongoing concern surrounding chronic bronchitis in WANA necessitated continued attention.

Increases in anxiety and depression may relate to climate-related stressors, but socioeconomic factors, unemployment, urbanization, healthcare access, political instability, armed conflict, and psychosocial determinants also play roles. The study's ecological design limits causal inferences. Future research should use individual-level data to clarify these complex relationships. The widespread effects of climate change extend beyond environmental issues, significantly impacting mental health. Addressing these consequences could have led to sustainable solutions benefiting both the environment and human well-being. Findings underscored the urgent need for action to mitigate the mental health effects of climate change and inform tailored public health strategies. Socioeconomic factors such as unemployment, urbanization, and GDP growth offered insights into the complex relationship between climate change and mental health (27).

While a negative change indicated a decrease in disease burden, the smaller reduction in WANA highlighted persistent health challenges requiring further intervention. Moreover, most studies on the health impacts of climate change focused on high-income countries, a disparity that needed addressing through domestic research to provide evidence-based recommendations for lower- and middle-income countries (28).

The decrease in the average mortality rate from 6.00 in 1990 to 4.63 in 2023 was a positive indicator of health improvements in the region, though it remained below the global average. The combined asthma rate of 5.52 emphasized the continued impact of environmental factors on respiratory health. While there had been a slight decrease in asthma rates, the persistent health issues remained a concern (29).

Reducing greenhouse gas emissions improves air quality, benefiting public health and lowering long-term respiratory burdens. Regular monitoring and maintaining a clean, well-ventilated environment could help mitigate risks associated with elevated CO_2 levels (30). The identified positive relationship between CO_2 emissions and DALYs suggested that CO_2 reduction might lead to decreased DALYs (31). The strong correlation between CO_2 concentrations and heat-related mortality ($r = 0.682$) underscored the link between greenhouse gas levels and health risks, crucial for public health policy. Multiple Linear Regression analysis confirmed that heat-related mortality had a statistically significant relationship with atmospheric CO_2 emissions (coefficient of 58.670, $P = 0.019$), reinforcing the urgency for interventions aimed at reducing CO_2 emissions to lower heat-related health risks.

Table 3 highlighted the profound and varied impacts of climate change on health outcomes across regions. The WANA region faced significant challenges, including higher temperature increases and rising anxiety and depression rates, necessitating targeted public health interventions. While some positive trends, such as reduced heart disease and asthma prevalence, existed, the overall image remained a vital concern. The stark contrast in health outcomes between WANA, the global average, and countries with minimal climate impact called for a comprehensive approach to climate change that included health as a principal component. Policymakers need to prioritize adaptive strategies and resource allocation to mitigate climate change's adverse effects on health, particularly in vulnerable regions like WANA. Further

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research is essential to understand these dynamics and develop effective interventions tailored to each region's specific needs.

The strong correlation between CO_2 concentrations and heat-related mortality. Increased CO_2 emissions lead to global warming, causing frequent heat events that raise heat-related illness and mortality risk, while CO_2 is a greenhouse gas responsible for climate change (17, 18).

The limitation of the study is the unavailability of data for indicators and subject countries over the time period in establishing more specific causal relationships. An ecological study was essential for analyzing data across multiple countries to assess correlations between climate variables and health outcomes. Historical data was crucial for understanding the impacts of climate change on health in the WANA region. By analyzing trends over time, researchers could identify patterns, evaluate the effectiveness of past interventions, and forecast future challenges. Comparing health outcomes in WANA versus global averages helped inform public health strategies (32).

The potential for ecological fallacy should have been acknowledged, as not all deaths following 1990 could be directly linked to changes in temperature or CO_2 levels. While the data reveals statistically significant associations, such as between CO_2 emissions and asthma rates, or temperature rise and heat-related mortality, these do not confirm direct causal relationships. However, a significant portion of these deaths were likely related to climate change. Differences in mortality rates across countries and regions could have also been influenced by local health interventions over the years.

The finding that each one-unit increase in global CO_2 emissions predicted a 6.876-unit increase in WANA CO_2 emissions suggested a strong regional response to global climate change. This indicates that rising global emissions disproportionately affected local environmental conditions, leading to increased health risks.

Conclusion

In conclusion, the results emphasized the importance of considering mental health alongside physical health in the context of climate change. Addressing these challenges requires a multifaceted approach that integrates environmental policy, public health initiatives, and mental health support. As the region grappled with climate change impacts, urgent and immediate actions are needed to strategize protection and improve population health. Future research in the WANA region can be conducted using primary data or data collection instruments, conducting longitudinal studies, targeting vulnerable groups, developing heat health action plans, integrating climate considerations into national health policies, launching public education campaigns, and fostering regional partnerships for data sharing and collaborative research.

Acknowledgment

We would like to express our sincere gratitude to all individuals and organizations that contributed to the development of this manuscript.

Conflict of Interests

The authors declare that they have no competing interests.

Authors' Contributions

Hamid Soori: Principal investigator, statistical analysis, interpretation of results, and manuscript writing.

Aylin Ghasempour: Information gathering, statistical analysis, and manuscript submission.

Ethical Considerations

This study did not strictly require ethical committee approval due to its use of secondary data.

Funding Support

This study received no external funding.

Data Availability

N/A.

AI Use Statement

The authors used ChatGPT (OpenAI) to assist with English language editing and writing corrections. Using Turnitin showed less than 5 percent similarity.

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