

ORIGINAL ARTICLE

Rising burden of chronic kidney disease attributable to high fasting plasma glucose in the Middle East and North Africa, 1990-2023

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ABSTRACT

Introduction: Chronic kidney disease (CKD) attributable to high fasting plasma glucose (HFGP) is rising globally, particularly in regions with rapidly increasing dysglycemia such as the Middle East and North Africa (MENA). We assessed long-term trends in HFGP-attributable CKD burden across 21 MENA countries from 1990 to 2023.

Methods: Using estimates from the Global Burden of Disease 2023 study, we quantified deaths and disability-adjusted life years (DALYs) attributable to HFGP-related CKD at regional, national, age-group, and sex-specific levels. We derived age-standardized mortality rates (ASMRs) and age-standardized DALY rates (ASDRs) and evaluated temporal changes using joinpoint regression to identify significant shifts in burden across the study period.

Results: The absolute burden of HFGP-attributable CKD increased substantially across the region, with large rises in both deaths and DALYs. In contrast, ASMRs and ASDRs showed only modest changes, indicating that the increase in absolute burden was substantially influenced by demographic change, while age-standardized rates showed more modest changes in underlying age-adjusted risk. Older adults experienced the highest mortality and DALY rates, and men consistently exhibited greater burden at working ages. National patterns were heterogeneous, with some countries showing declining age-standardized rates while others demonstrated sustained increases. Joinpoint analysis revealed a transition from relative stability in the early 1990s to sustained increases after the late 2000s, with the most rapid acceleration occurring after 2019.

Conclusion: HFGP-attributable CKD is an escalating health challenge in the MENA region, driven by rising dysglycemia and demographic change, with substantial variation across countries. Strengthening early detection of dysglycemia and CKD, improving long-term glycemic and blood-pressure control, and expanding access to kidney-protective therapies are critical to mitigating the growing burden.

Keywords: Chronic kidney disease, high fasting plasma glucose, diabetes, MENA, Global Burden of Disease, DALYs.

Introduction

Chronic kidney disease (CKD) is an expanding global health challenge, responsible for substantial premature mortality and disability worldwide [1]. Recent Global Burden of Disease (GBD) estimates indicate that nearly one in ten individuals worldwide are affected, with rising deaths and disability-adjusted life years (DALYs) driven by demographic ageing, lifestyle transitions,

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and the mounting prevalence of metabolic risk factors [1]. Among these, high fasting plasma glucose (HFPG) - reflecting dysglycemia across the continuum from prediabetes to overt diabetes - has emerged as one of the fastest-growing contributors to CKD burden globally [1,2]. In 2019 alone, HFPG accounted for an estimated 5% of all deaths worldwide [2] and nearly one-third of CKD-related DALYs, underscoring the centrality of glycemic exposure in global kidney health.

The Middle East and North Africa (MENA) region has experienced some of the most rapid increases in CKD burden worldwide [4]. Over the past three decades, age-standardized CKD DALY rates have risen sharply, coinciding with regional epidemiological transitions characterized by urbanization, increased adiposity, reduced physical activity, and persistently high rates of uncontrolled diabetes [4,5]. MENA consistently ranks among the world's regions with the highest incidence of diabetes-related CKD, with type 2 diabetes serving as one of the dominant causes of CKD onset, progression, and mortality [6]. Parallel assessments of metabolic risk trends in the region have documented substantial increases in HFPG exposure in nearly all countries, with the steepest trajectories observed in middle-SDI settings where primary care capacity for early detection and long-term glycemic management remains constrained [5].

Despite the well-established link between dysglycemia and kidney dysfunction [3,7], no comprehensive assessment has yet evaluated trends in CKD specifically attributable to HFPG across all 21 MENA countries through 2023, a period marked by demographic expansion, shifts in cardiometabolic risk profiles, major health-system reforms, and recent epidemiological changes following the COVID-19 era. Existing regional studies have examined overall CKD patterns, metabolic risk burdens, and diabetes-related kidney disease [4,7], but none have focused on HFPG as a modifiable upstream exposure with rapidly increasing prevalence in MENA [2,3].

To address the gap, the present study provides a comprehensive assessment of HFPG-related CKD across the 21 MENA countries from 1990 to 2023, using standardized GBD methods. We quantify levels and trends in deaths and DALYs, examine age- and sex-specific patterns, evaluate differences by country, and characterize shifts in temporal trajectories using joinpoint regression. Our objective is to generate a comprehensive and policy-relevant epidemiological profile of HFPG-attributable CKD, supporting strategic planning for diabetes and kidney-care integration across the region.

Methods

Study design and data source

This study is a region-wide, comparative trend analysis evaluating the burden of CKD attributable to HFPG in the MENA region from 1990 to 2023. All data analyzed were sourced from the publicly available GBD database (available from <http://ghdx.healthdata.org/gbd-results-tool>), which provides standardized, age-specific, sex-

specific, and country-level estimates of disease outcomes using a unified methodological framework [8].

CKD attributable to HFPG was defined according to GBD comparative risk assessment methodology, wherein HFPG was considered a modifiable metabolic risk factor with a theoretical minimum risk exposure level of 4.8 - 5.4 mmol/l [8]. Using population attributable fractions (PAFs), GBD estimates the proportion of CKD morbidity and mortality that can be causally linked to HFPG exposure. Because HFPG is defined by a continuous fasting-glucose threshold rather than a clinical diagnosis of diabetes, PAFs estimated for HFPG-attributable CKD are conceptually broader than those for diabetes-attributable CKD: they capture prediabetic and undiagnosed dysglycemic states in addition to diagnosed diabetes, and the terms are not used interchangeably in this manuscript.

Geographic and demographic scope

The analysis covered all 21 countries within the MENA region as defined by the GBD regional classification. The study population included all individuals across age groups and both sexes. Age groups were assessed using standardized 5-year age intervals, in accordance with GBD reporting conventions. Sex-specific estimates were extracted separately for males and females.

Measures of burden

The primary metrics included: [1] total deaths due to CKD attributable to HFPG; [4] age-standardized mortality rate (ASMR) per 100,000 population; [5] total DALYs attributable to HFPG-related CKD; and [6] age-standardized DALY rate (ASDR) per 100,000 population. DALYs were calculated as the sum of years of life lost due to premature mortality and years lived with disability, following GBD methodology [8]. Age-standardized rates were calculated using the GBD world standard population to allow comparability between populations and over time. All estimates were extracted with their accompanying 95% uncertainty intervals (UIs), as reported in the GBD database.

Trend analysis

We utilized joinpoint regression analysis to detect statistically significant shifts in the temporal trends of the studied indicators. The joinpoint model determines inflection points, or “joinpoints,” where the slope of the trend significantly changes. Mathematically, the model is represented as follows: $y(t) = b_0 + b_1t + \sum_{k=1}^{j-1} b_{k+1}(t-t_k)_+$, where $(t-t_k)_+$ equals zero for $t \leq t_k$ and $(t-t_k)$ for $t > t_k$. Each t_k signifies a “joinpoint,” indicating a potential change in the linear segment slope. Continuity constraints were imposed at each joinpoint to ensure smooth transitions between segments.

Models were fitted on log-transformed rates, allowing up to four joinpoints. Model selection was based on permutation tests (4,499 replicates; overall $\alpha = 0.05$) using the Joinpoint Regression Program (Version 5.2.0; U.S. National Cancer Institute) [9]. We computed annual percentage changes for each segment and average

annual percent changes across the entire period, with 95% confidence intervals estimated on the log scale. Although direct exclusion of country-level raw data was not possible within the GBD framework, the employed estimates incorporate rigorous internal validation, uncertainty quantification, and covariate adjustments. These procedures collectively enhance data reliability and serve as intrinsic sensitivity checks.

Data extraction and validation

Estimates were systematically extracted from the GBD database's published summary tables for mortality, DALYs, sex-specific burden, age-specific patterns, and country-level variations. Age-, sex-, and country-specific data were cross-referenced for internal consistency across metrics. All extracted data were manually validated against regional totals to ensure alignment with GBD standard aggregation rules.

Ethical considerations

As the analysis was based on publicly available, de-identified secondary data from the GBD database, ethical approval was not required.

Results

Regional burden of DALYs and deaths

Between 1990 and 2023, the Middle East and North Africa region experienced a large absolute increase in the burden of CKD attributable to HFPG. Total DALYs attributable to HFPG-related CKD rose from 415,672.6 (95% UI: 216,190.6-686,012.3) in 1990 to 1,560,390.2 (916,501.9-2,256,354.8) in 2023 (Table 1). Over the same period, deaths attributable to HFPG-related CKD increased from 17,590.2 (8,864.2-29,443.4) to 66,182.3 (37,703.5-97,847.3) (Table 2). ASDR showed a modest rise from 278.26 (145.18-456.81) to 339.21 (198.10-488.83) per 100,000, while ASMR changed from 14.37 (7.24-23.96) to 16.88 (9.56-24.69) per 100,000. The total percent change (TPC) in ASDR for the region was 0.22 (95% UI-0.15 to 0.90) and the regional TPC for ASMR was 0.17 (-0.21 to 0.87), indicating that the rise in absolute deaths and DALYs was only partially reflected in changes to age-standardized rates (Tables 1 and 2). Because absolute counts capture the combined influence of population growth, population ageing, and underlying epidemiological (age-specific risk) change, whereas age-standardized rates remove the effects of population size and age structure to isolate the epidemiological component, this divergence indicates that demographic expansion and ageing of the MENA population, rather than a rise in the underlying age-specific risk of HFPG-attributable CKD, were the principal drivers of the increase in absolute deaths and DALYs over the study period.

Sex-specific mortality and burden

Sex-specific patterns mirrored the regional picture of rising absolute burden but modest change in standardized rates. Female DALYs rose from 185,333.8 (83,476.6-

323,237.9) in 1990 to 795,533.5 (448,213.0-1,196,030.5) in 2023, with ASDR increasing from 247.81 (113.66-436.11) to 341.94 (193.19-513.60) per 100,000 and a female ASDR TPC of 0.38 (-0.25 to 1.53) (Table 2). Male DALYs increased from 230,338.8 (119,965.5-408,482.9) to 764,856.7 (451,418.1-1,193,552.5), with male ASDR rising from 312.41 (162.16-542.07) to 338.66 (199.50-522.86) per 100,000 and a male TPC of 0.08 (-0.27 to 0.84). Mortality similarly escalated in absolute numbers for both sexes; while sex-disaggregated death counts from the GBD tables show increases consistent with DALY trends, the ASMR changes for both sexes remained small, and their UIs encompassed zero, reflecting statistical uncertainty in directional change after age standardization (Tables 1 and 2).

Country-level mortality patterns

Country-level analyses revealed marked heterogeneity in both absolute deaths and age-standardized mortality. Egypt recorded one of the largest increases in absolute deaths, rising from 4,654.7 (2,199.3-8,144.8) in 1990 to 18,602.0 (10,916.1-28,330.6) in 2023, accompanied by an increase in ASMR from 25.82 to 37.86 per 100,000 (Tables 1 and 2). Saudi Arabia's deaths attributable to HFPG-related CKD increased from 1,076.0 to 3,435.4 with an ASMR rise from 26.95 to 35.69 per 100,000. Contrasting trajectories were evident in several Gulf states where ASMRs declined: Kuwait's ASMR fell in parallel with its ASDR, evidenced by a TPC of -0.37 (95% UI -0.50 to -0.20), and Qatar showed a declining ASMR with a TPC of -0.28 (-0.51 to 0.08). These opposing country patterns point to diverging epidemiological transitions across the region, with populous North African states showing large absolute increases in deaths while some high-income countries achieved reductions in age-standardized mortality. Estimates for smaller-population countries, including Bahrain, Qatar, and Kuwait, should be interpreted with caution, as their comparatively smaller absolute counts and wider UIs may limit the precision of country-specific trends (Tables 1 and 2) (Supplementary Figures 1 and 2).

Age-specific mortality

Age-specific mortality exhibited a pronounced age gradient. Death rates attributable to HFPG-related CKD were low in younger adults, i.e., ~0.5 deaths per 100,000 in the 25-29 age group for both sexes and increased steadily with age. By middle age (50-54 years), death rates rose to approximately 8 deaths per 100,000 (females 8.40; males 7.72), and by older ages (70-74 years) rates exceeded 95 deaths per 100,000 in both sexes (females 95.21; males 95.56). The oldest age groups experienced the highest per-capita mortality; among those aged ≥95 years, deaths reached 550.15 per 100,000 in females and 946.40 per 100,000 in males (Supplementary Table 1). The steep age gradient underscores the concentration of HFPG-attributable CKD mortality among the elderly (Figures 1 and 2).

Table 1. Total number and age-standardized rates of disability-adjusted life years (ASR-DALYs) attributable to chronic kidney disease related to high fasting plasma glucose (HFG) in the Middle East and North Africa (MENA) region and its constituent countries, 1990–2023, with corresponding total percent change (TPC). DALYs are presented as counts and age-standardized DALY rates per 100,000 population, with 95% uncertainty intervals (UIs).

	DALYs number in 1990	DALYs number in 2023	ASR-DALY in 1990	ASR-DALY in 2023	TPC: 1990–2023	Population, 2023 (million)
North Africa and Middle East	415672.60 (216190.64–686012.28)	1560390.17 (916501.87–2256354.82)	278.26 (145.18–456.81)	339.21 (198.10–488.83)	0.22 (-0.15–0.90)	668.35
Gender						
Female	185,333.84 (83,476.61–323,237.94)	795,533.45 (448,213.00–1,196,030.53)	247.81 (113.66–436.11)	341.94 (193.19–513.60)	0.38 (-0.25–1.53)	
Male	230,338.76 (119,965.51–408,482.92)	764,856.71 (451,418.11–1,193,552.45)	312.41 (162.16–542.07)	338.66 (199.50–522.86)	0.08 (-0.27–0.84)	
Countries						
Afghanistan	19719.31 (10271.27–32941.84)	29931.87 (16570.00–46311.21)	320.23 (166.07–532.62)	292.83 (164.21–454.96)	-0.09 (-0.35–0.39)	41.45
Algeria	25105.04 (11746.58–45650.11)	116099.89 (65821.30–178485.04)	223.75 (103.93–400.16)	307.58 (173.52–472.96)	0.37 (-0.16–1.29)	46.16
Bahrain	455.19 (248.00–726.36)	2870.01 (1671.33–4421.61)	296.38 (161.98–467.13)	313.76 (175.39–485.47)	0.06 (-0.34–0.71)	1.58
Egypt	105283.29 (50820.63–179060.91)	439325.35 (256999.09–663367.38)	464.86 (227.83–800.11)	710.65 (420.99–1072.48)	0.53 (-0.08–1.70)	114.54
Iraq	28483.45 (14007.28–48379.27)	105753.21 (58755.32–154863.65)	118.18 (57.14–198.77)	138.48 (75.44–203.37)	0.21 (-0.18–1.02)	45.07
Islamic Republic of Iran	21322.72 (10526.13–34371.79)	82496.72 (47089.85–127307.38)	293.21 (146.97–471.77)	354.65 (207.22–537.67)	0.17 (-0.27–0.97)	91.57
Jordan	5109.86 (2898.79–7838.13)	33238.97 (21177.86–49540.04)	382.63 (214.02–588.34)	413.28 (261.60–613.47)	0.08 (-0.25–0.69)	11.34
Kuwait	1636.80 (1034.84–2340.18)	5770.33 (3872.40–7659.88)	367.64 (238.66–511.59)	230.61 (152.92–309.80)	-0.37 (-0.50–0.20)	4.85
Lebanon	4639.18 (2514.34–7288.16)	15919.76 (9464.88–23433.36)	216.03 (115.99–337.24)	258.79 (153.58–378.54)	0.20 (-0.17–0.90)	5.77
Libya	4023.53 (2052.97–6556.83)	21173.07 (10216.27–32104.85)	222.76 (113.95–360.55)	382.07 (183.04–583.79)	0.72 (-0.12–1.78)	7.38
Morocco	40790.03 (20445.84–71687.70)	149172.40 (84142.51–232228.53)	326.67 (168.51–555.12)	428.81 (244.64–675.36)	0.31 (-0.11–1.06)	37.84
Oman	1774.08 (945.76–3008.99)	7651.25 (4591.03–11471.60)	273.60 (145.56–458.13)	374.35 (216.86–550.65)	0.37 (-0.10–1.13)	4.64
Palestine	2553.99 (1347.04–3912.89)	9061.12 (5405.31–12933.58)	304.41 (158.42–464.08)	342.16 (200.69–487.73)	0.12 (-0.21–0.66)	5.27
Qatar	349.24 (200.12–563.81)	2354.47 (1365.74–3547.99)	375.24 (209.61–571.23)	270.18 (157.56–397.49)	-0.28 (-0.51–0.08)	2.66
Saudi Arabia	27850.48 (15486.59–43058.53)	93588.02 (56942.94–136469.06)	537.76 (295.68–822.91)	678.92 (405.57–975.67)	0.26 (-0.14–0.92)	33.26
Sudan	22807.07 (11589.46–40427.91)	76348.55 (39678.97–120385.28)	275.88 (138.74–482.60)	350.57 (183.69–552.82)	0.27 (-0.19–1.05)	49.36
Syrian Arab Republic	14539.47 (7522.24–24212.32)	58004.77 (31247.87–89208.69)	310.63 (160.31–525.38)	461.43 (244.32–701.39)	0.49 (-0.12–1.55)	23.59
Tunisia	73207.20 (35699.36–122939.32)	245839.83 (159195.95–363885.47)	232.02 (112.63–391.01)	255.26 (163.89–377.20)	0.26 (-0.14–1.05)	12.20
Turkey	7692.93 (3703.38–12701.96)	29218.14 (17500.29–43102.94)	174.31 (82.80–284.39)	219.23 (131.84–322.76)	0.10 (-0.27–0.78)	85.33
United Arab Emirates	1374.90 (719.58–2392.50)	13979.43 (8345.93–20134.86)	348.75 (179.93–576.13)	378.04 (222.25–548.15)	0.08 (-0.38–0.97)	10.03
Yemen	6727.22 (2983.78–13841.82)	21169.42 (11298.51–33420.10)	170.91 (73.99–336.64)	160.75 (83.53–257.40)	-0.06 (-0.39–0.59)	34.45

Table 2. Total number and age-standardized mortality rates (ASMR) for deaths attributable to chronic kidney disease related to high fasting plasma glucose (HFG) in the Middle East and North Africa (MENA) region and its constituent countries, 1990–2023, including corresponding total percent change (TPC). Death counts and ASMRs are reported with 95% uncertainty intervals (UIs).

	Deaths number in 1990	Deaths number in 2023	ASMR in 1990	ASMR in 2023	TPC 1990–2023	Population, 2023 (million)
North Africa and Middle East	17 590.20 (8864.15–29 443.42)	66 182.28 (37 703.50–97 847.33)	14.37 (7.24–23.96)	16.88 (9.56–24.69)	0.17 (-0.21–0.87)	668.35
Gender						
Female	7 843.25 (3 371.44–13 964.31)	34 427.06 (18 945.36–52 459.79)	12.40 (5.46–22.20)	16.74 (9.04–25.54)	0.35 (-0.31–1.60)	
Male	9 746.95 (4 966.60–17 199.73)	31 755.22 (17 979.60–49 906.12)	16.81 (8.76–28.92)	17.26 (9.77–27.03)	0.03 (-0.32–0.82)	
Countries						
Afghanistan	860.98 (429.42–1420.28)	1187.31 (634.75–1865.07)	16.82 (8.46–27.44)	15.30 (8.02–23.79)	-0.09 (-0.37–0.43)	41.45
Algeria	1025.76 (460.41–1883.08)	4959.20 (2674.52–7827.03)	11.25 (5.07–20.74)	14.68 (7.88–23.35)	0.31 (-0.24–1.16)	46.16
Bahrain	16.73 (8.67–27.11)	100.16 (54.38–160.44)	15.52 (7.91–24.69)	16.94 (8.79–27.10)	0.09 (-0.36–0.80)	1.58
Egypt	4654.73 (2199.31–8144.82)	18601.97 (10916.09–28330.63)	25.82 (12.04–45.93)	37.86 (22.09–57.62)	0.47 (-0.14–1.65)	114.54
Iraq	1072.01 (505.19–1871.11)	4045.33 (2149.24–6489.21)	5.45 (2.51–9.46)	6.29 (3.24–9.86)	0.20 (-0.20–1.09)	45.07
Islamic Republic of Iran	966.37 (470.00–1567.69)	3264.19 (1820.63–5020.94)	14.96 (7.26–24.37)	17.99 (10.12–27.95)	0.16 (-0.31–1.08)	91.57
Jordan	200.61 (109.10–308.27)	1397.79 (876.38–2099.07)	17.90 (9.54–27.58)	20.69 (13.00–30.68)	0.16 (-0.21–0.86)	11.34
Kuwait	56.64 (35.94–80.03)	188.34 (122.71–258.47)	18.66 (11.60–25.76)	12.41 (8.17–17.18)	-0.33 (-0.49–0.15)	4.85
Lebanon	206.46 (103.70–334.26)	810.58 (464.11–1241.62)	10.20 (5.05–16.40)	12.71 (7.23–19.28)	0.25 (-0.18–1.13)	5.77
Libya	167.45 (85.35–273.75)	870.99 (387.63–1346.01)	10.27 (5.25–16.90)	18.92 (8.38–29.33)	0.84 (-0.12–2.09)	7.38
Morocco	1903.58 (957.70–3325.79)	6736.69 (3807.82–10836.43)	18.45 (9.48–31.97)	22.72 (12.83–36.73)	0.23 (-0.17–0.92)	37.84
Oman	64.83 (34.59–112.52)	279.70 (156.32–427.50)	12.30 (6.56–21.18)	19.95 (11.12–29.75)	0.62 (0.01–1.60)	4.64
Palestine	111.28 (54.91–174.01)	365.56 (212.94–533.74)	14.70 (7.22–22.91)	16.54 (9.34–24.13)	0.13 (-0.24–0.72)	5.27
Qatar	12.17 (6.72–19.71)	70.32 (39.56–107.60)	20.47 (10.74–31.63)	15.36 (8.78–23.21)	-0.25 (-0.51–0.19)	2.66
Saudi Arabia	1075.96 (582.99–1662.69)	3435.39 (2035.53–4999.25)	26.95 (14.63–41.97)	35.69 (21.02–51.65)	0.32 (-0.12–1.09)	33.26
Sudan	953.40 (466.87–1658.52)	3193.87 (1619.63–5176.85)	14.12 (6.86–24.47)	17.49 (8.87–28.46)	0.24 (-0.21–0.99)	49.36
Syrian Arab Republic	592.53 (291.63–1012.73)	2657.33 (1317.86–4168.81)	15.54 (7.61–26.46)	27.67 (13.54–43.17)	0.78 (0.03–2.11)	23.59
Tunisia	3019.61 (1368.92–5183.56)	11432.39 (7000.63–17112.06)	11.26 (5.05–19.58)	12.76 (7.60–19.18)	0.22 (-0.22–1.10)	12.20
Turkey	310.02 (136.47–514.31)	1255.79 (713.13–1907.73)	8.57 (3.73–13.91)	10.43 (5.96–15.44)	0.13 (-0.29–0.94)	85.33
United Arab Emirates	46.38 (22.38–79.75)	430.52 (240.37–636.27)	17.08 (8.70–29.30)	24.23 (13.18–36.43)	0.42 (-0.25–1.74)	10.03
Yemen	263.08 (101.35–555.33)	838.48 (388.12–1448.45)	8.56 (3.53–16.61)	7.97 (3.72–13.86)	-0.07 (-0.43–0.73)	34.45

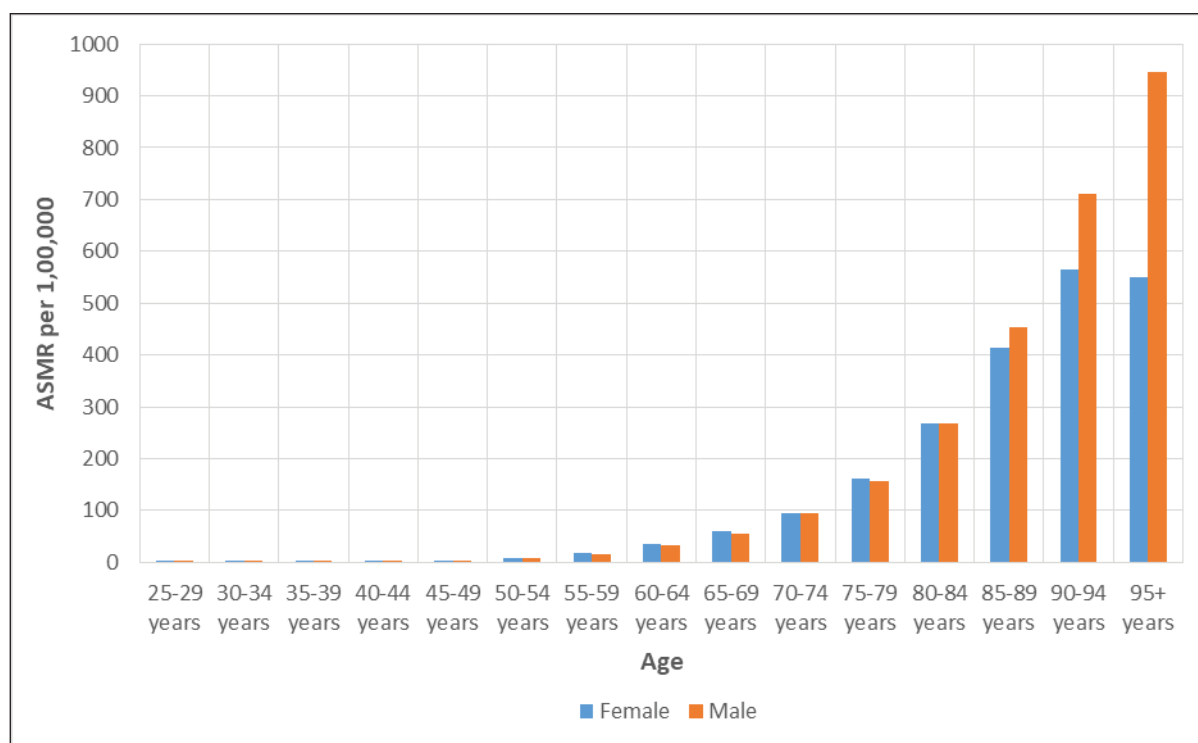


Figure 1. Age-standardized mortality rate (ASMR) for chronic kidney disease attributable to high fasting plasma glucose (HFPBG) in the Middle East and North Africa (MENA) region, stratified by sex (males, females, both sexes) across years 1990-2023 (per 100,000 population).

Joinpoint trend analysis for mortality and DALYs (1990–2023)

Joinpoint regression revealed multiple phases in the temporal trend of mortality and DALYs attributable to HFPBG-related CKD at the regional level, with significant inflection points and differing trajectories between males and females.

For mortality, the overall regional trend initially showed no statistically significant change during the early 1990s to early 2000s. This was followed by a significant decline between 2001 and 2009, where mortality rates decreased with an APC of -0.50% ($p = 0.02$). From 2009 to 2019, mortality shifted into a period of significant increase, with an APC of 1.39% ($p < 0.000001$), which further accelerated between 2019 and 2023, reaching a significant APC of 2.77% ($p < 0.000001$) (Supplementary Tables 2 and 3) (Figure 3).

Sex-specific mortality trends exhibited distinct timings and directions. Among females, mortality increased significantly between 1990 and 2001 (APC 0.41%, $p = 0.03$), followed by a non-significant phase until 2009. A significant rise then occurred from 2009 to 2015 (APC 2.18%, $p = 0.05$), which continued through 2015-2019 (APC 1.26%, $p < 0.000001$) and intensified from 2019 to 2023 (APC 3.39%, $p < 0.000001$). In contrast, male mortality experienced a significant decline during 1990-2002 and 2002-2009, after which it transitioned into a period of significant increase beginning in 2009-2019 (APC 0.92%, $p < 0.000001$) and further rising from 2019 to 2023 (APC 2.54%, $p < 0.000001$).

For DALYs, the regional trend began with a significant decline between 1990 and 2002, followed by a further significant reduction during 2002-2009 (APC -1.19%, $p = 0.006$). From 2009 to 2019, the burden reversed direction, showing a significant increase (APC 1.68%, $p < 0.000001$), which further accelerated during 2019-2023 (APC 3.58%, $p < 0.000001$) (Supplementary Tables 4 and 5) (Figure 4).

Sex-specific DALY trends also showed different phase trajectories. Among females, early trend segments demonstrated no significant change up to 2009, after which DALYs increased significantly from 2009 to 2019 (APC 2.10%, $p = 0.004$) and continued to rise markedly from 2019 to 2023 (APC 3.77%, $p < 0.000001$). In males, the first two intervals (1990-2002 and 2002-2009) showed statistically significant declines, followed by significant increases beginning 2009-2018 (APC 0.98%, CI excluding zero) and continuing through 2018-2023 (APC 2.99%, $p < 0.000001$).

Overall, joinpoint analysis demonstrated that both mortality and DALYs initially declined or remained stable in earlier decades before shifting to a period of sustained, statistically significant increases beginning in the late 2000s, with the most rapid acceleration observed between 2019 and 2023 for both sexes.

Discussion

This study provides an updated and comprehensive assessment of CKD attributable to HFPBG across the MENA region from 1990 to 2023. Although age-standardized mortality and DALY rates showed only

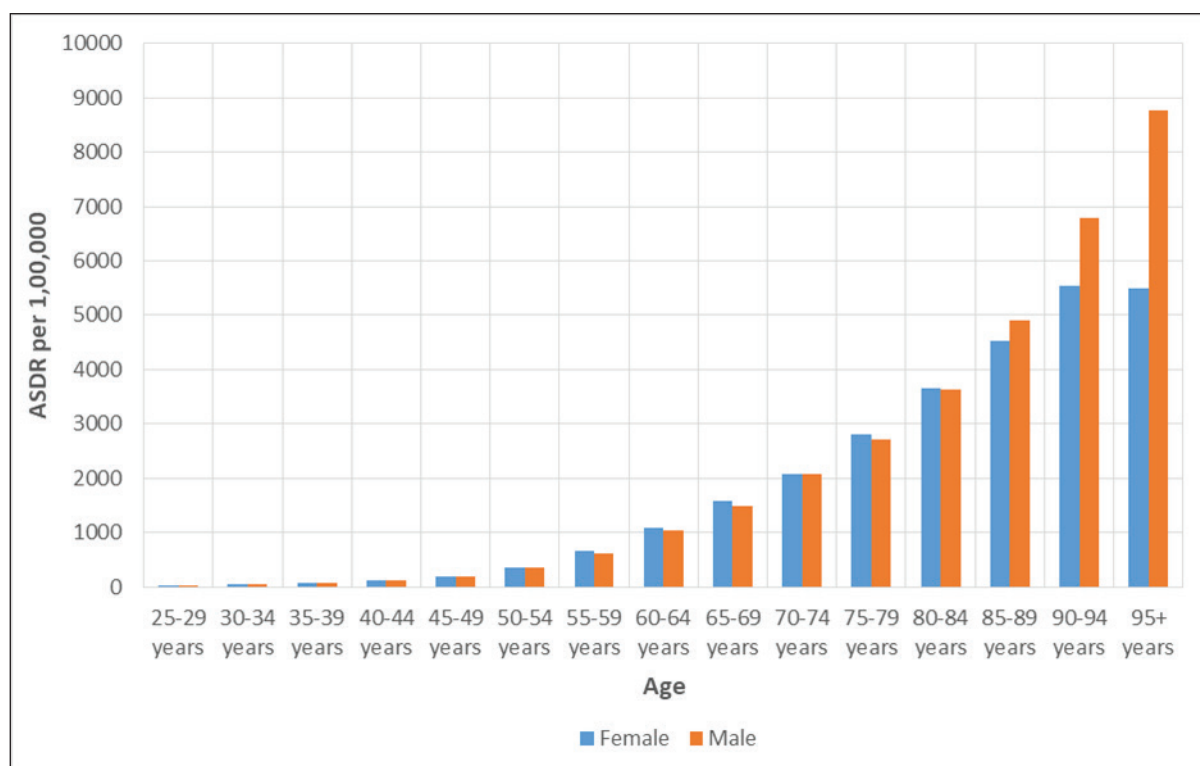


Figure 2. Age-standardized disability-adjusted life year rate (ASDR) for chronic kidney disease attributable to high fasting plasma glucose (HFGPG) in the Middle East and North Africa (MENA) region, stratified by sex (males, females, both sexes) across years 1990-2023 (per 100,000 population).

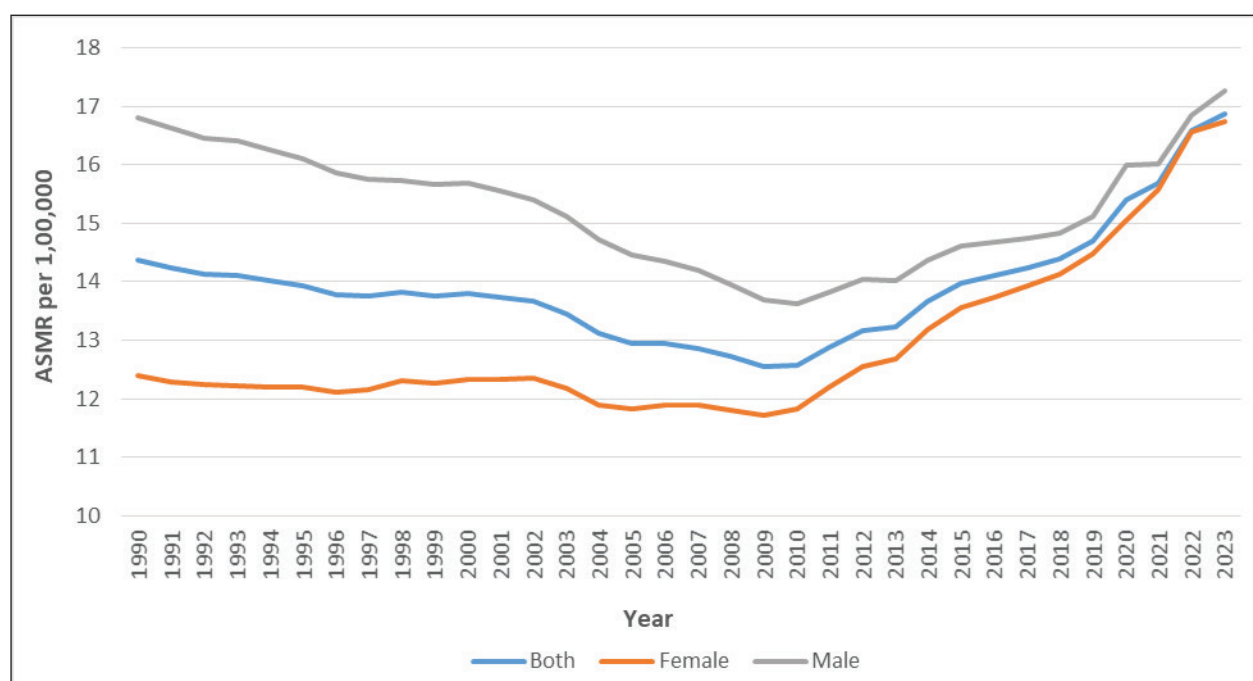


Figure 3. Temporal trend in the age-standardized mortality rate (ASMR) of chronic kidney disease attributable to high fasting plasma glucose (HFGPG) in the Middle East and North Africa (MENA) region, 1990-2023.

modest changes, the consistently increasing absolute burden underscores the growing number of individuals progressing to kidney dysfunction as diabetes and prediabetes become more prevalent. The burden was most pronounced in older adults, with earlier increases

emerging in midlife and disproportionately affecting men.

Country-level trajectories varied considerably, pointing to heterogeneity in health systems, metabolic risk transitions, and progress in chronic disease management.

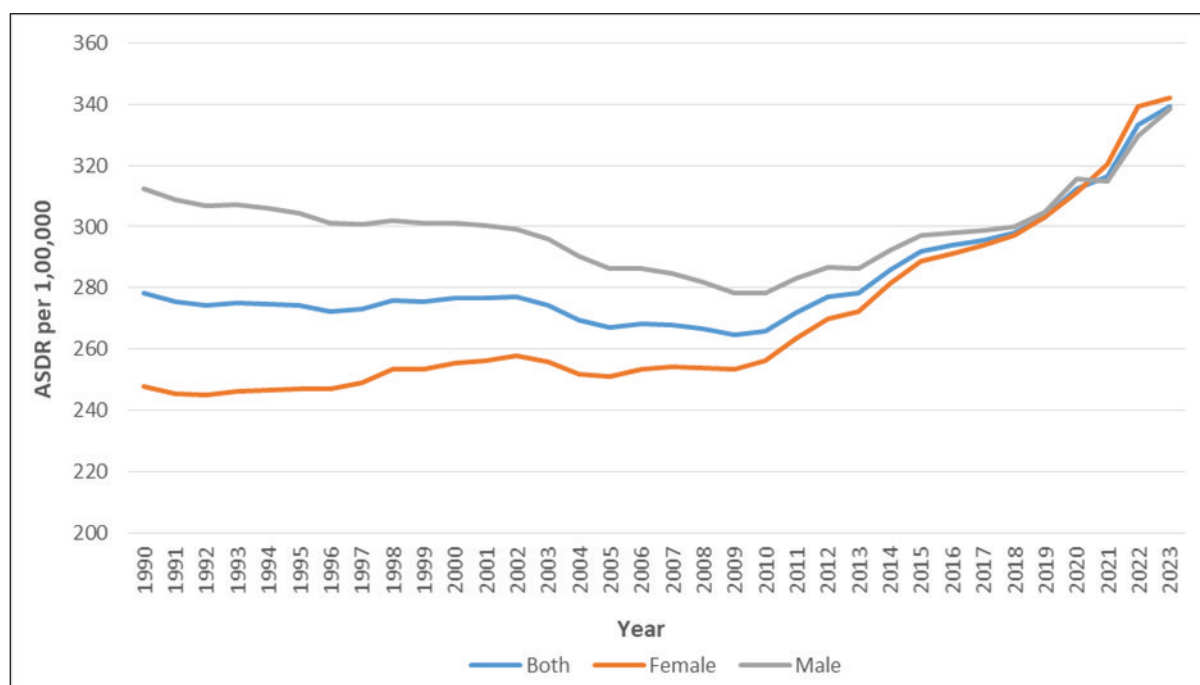


Figure 4. Temporal trend in the age-standardized disability-adjusted life year rate (ASDR) of chronic kidney disease attributable to high fasting plasma glucose (HFPG) in the Middle East and North Africa (MENA) region, 1990-2023.

For example, ASMR declined in Gulf countries such as Kuwait and Qatar, whereas it increased in large North African countries including Egypt, Morocco, and Algeria. Joinpoint analysis showed that there was a period of stability or decline at first, followed by steady growth after 2009. The fastest growth has been since 2019. The results show that both sexes are becoming more exposed to and pressured by demographic factors that affect survival, and this has been happening more quickly lately. It should be noted that several of the countries showing the most pronounced ASMR changes, including Kuwait, Qatar, and Bahrain, have comparatively small populations; their absolute case counts and age-standardized rates are correspondingly subject to wider UIs than those of more populous countries such as Egypt and Saudi Arabia. These small-population estimates should therefore be interpreted with caution, and cross-country comparisons should give greater interpretive weight to the more populous MENA states, where estimates are more statistically precise.

Our findings are consistent with, and extend, previous regional analyses highlighting the sharp rise of CKD across MENA and the dominant contribution of metabolic risks [1,4,5]. Earlier GBD-based reports documented substantial increases in CKD burden and escalating exposure to HFPG and high BMI in the region [2,4,5]. By narrowing the focus to HFPG as a discrete, upstream metabolic exposure, our analysis reveals how dysglycemia, rather than diabetes alone, continues to reshape the kidney disease landscape [1,2]. This distinction is important, as HFPG captures both diagnosed and undiagnosed diabetes, as well as prediabetic states that may remain unrecognized within health systems. The temporal pattern we observed,

particularly the shift toward rapid increases after the late 2000s and the marked acceleration in recent years, mirrors regional trends in diabetes prevalence, obesity growth, and declining physical activity documented by global metabolic risk surveillance and regional epidemiologic syntheses [1,5,10,11].

The mechanisms linking HFPG to progressive kidney injury are well established. Chronic elevations in plasma glucose induce glomerular hyperfiltration, stimulate mesangial expansion, promote oxidative stress, and generate advanced glycation end-products, all of which drive early albuminuria and subsequent nephron loss. Dysglycemia also activates the renin-angiotensin-aldosterone system, contributing to intraglomerular hypertension and further accelerating structural damage. Collectively, these processes make even modest elevations in fasting glucose a clinically meaningful risk factor for CKD progression. Importantly, emerging therapies such as SGLT2 inhibitors and contemporary renoprotective agents demonstrate that modifying these pathophysiological pathways can slow progression, even in individuals without diabetes, emphasizing the clinical relevance of early detection and intervention in dysglycemia [12,13].

Understanding the regional context is critical for interpreting these findings. MENA countries have undergone rapid urbanization and dietary transitions, resulting in widespread increases in caloric intake, refined carbohydrates, and sedentary behaviors. At the same time, primary care systems in many countries face challenges in screening, sustained glycemic control, timely escalation of therapy, and long-term management of CKD risk factors. These systemic pressures contribute

to delayed diagnosis of dysglycemia and albuminuria, uneven access to kidney-protective therapies, and significant variation in outcomes between countries. The observed divergence between high-income Gulf countries where age-standardized CKD mortality is declining and populous North African countries where rates continue to rise reflects these differences in healthcare capacity, preventive infrastructure, and chronic disease integration [12,13].

The implications of these patterns are substantial. As HFPG levels continue to rise, the region will increasingly face the downstream consequences of poorly controlled glycemia, including CKD progression, cardiovascular events, and premature mortality [5]. Tackling this challenge requires a dual approach. At the population level, policies must strengthen food environments, regulate sugar-sweetened beverages, and promote active living [5]. Several MENA governments have already launched national programs that could be leveraged and scaled specifically for HFPG-attributable CKD prevention: Saudi Arabia's Health Sector Transformation Program under Vision 2030 has prioritized primary care strengthening, digital health, and non-communicable disease prevention, including nationwide preventive screening initiatives such as the "Taakad" program [14], while the United Arab Emirates' National Prediabetes and Diabetes Screening Campaign has conducted more than 150,000 community-based screenings since 2023, with integrated referral to lifestyle and pharmacologic management [15]. Extending and adapting these existing platforms to capture HFPG-relevant indicators (fasting glucose and albuminuria) rather than diabetes diagnosis alone could meaningfully improve early detection in countries that already have this screening infrastructure in place.

At the health-system level, using risk-based screening for adults 40 and older or those with cardiometabolic risks, starting ACE inhibitors or angiotensin receptor blockers for albuminuria, and making SGLT2 inhibitors more available to patients who meet the criteria are all good ways to slow the progression of CKD [11,16]. However, expanding SGLT2 inhibitor access in the region faces documented structural barriers beyond drug cost alone. A mixed-methods study of prescribing and insurance-authorization practices in Jordan found that SGLT2 inhibitors were frequently misclassified as diabetes-only medications by insurance reviewers (61% of insurance physicians), and that this misclassification was the strongest independent predictor of authorization rejection, outweighing documentation completeness or prescriber experience [17]. Comparable misalignment between evolving guideline indications and static insurance formularies is plausible across other MENA health systems with similar mixed public-private financing, suggesting that reform of reimbursement criteria, alongside efforts to reduce out-of-pocket drug costs, may be as important as clinician education in expanding access to kidney-protective therapies. Integrated cardio-renal care should be the norm because kidney problems in the MENA region are also linked to a high rate of cardiovascular death.

Our study has notable strengths. It provides the most up-to-date regional assessment of HFPG-attributable CKD using standardized, comparable methods across 21 countries and spanning more than three decades. The application of joinpoint regression offers a detailed understanding of temporal inflection points, revealing shifts in burden that would otherwise be obscured.

However, several limitations must be acknowledged. GBD estimates rely on modeled exposure distributions and risk-outcome relationships, which may be affected by limited biomarker surveys in some MENA countries, variation in fasting protocols, and underlying uncertainties in epidemiologic data. While UIs help reflect these limitations, residual biases may persist. Additionally, the observational nature of GBD data precludes causal inference, though the biological mechanisms linking HFPG to CKD are firmly established. This analysis is also descriptive rather than explanatory in design. We did not formally decompose the observed increase in absolute burden into the relative contributions of population growth, population aging, and epidemiological (age-specific risk) change, nor did we statistically correlate country-level ASMR/ASDR with candidate drivers such as diabetes prevalence, healthcare access and quality, or GDP per capita.

The pattern of a large rise in absolute burden alongside comparatively stable age-standardized rates is consistent with demographic change as the dominant driver, in line with formal decomposition analyses reported for other GBD-based metabolic-risk conditions in this region and beyond; however, we did not quantify this directly. A Das Gupta-type decomposition of population growth, aging, and epidemiological change, together with an ecological correlation analysis linking country-level rates to metabolic, health-system, and socioeconomic indicators from GBD and World Bank sources, was beyond the scope of the present analysis and is recommended as a priority for future work using this dataset.

Conclusion

In summary, HFPG-related CKD has become a growing public health concern in the MENA region, driven by rising dysglycemia, demographic change, and persistent gaps in early detection and chronic disease management. Although age-standardized rates have changed only modestly, the rapid escalation in absolute burden signals an urgent need for integrated cardio-renal-metabolic prevention strategies. Strengthening primary care, enhancing surveillance systems, and ensuring equitable access to effective therapies will be central to altering the trajectory of kidney disease over the coming decade.

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List of Abbreviations

ASDR	Age-standardized DALY rate
ASMR	Age-standardized mortality rate
ASR(s)	Age-standardized rate(s)
CKD	Chronic kidney disease
DALY(s)	Disability-adjusted life year(s)

EAPC	Estimated Annual Percentage Change
GBD	Global Burden of Disease
HFGP	High fasting plasma glucose
MENA	Middle East and North Africa
PAF(s)	Population attributable fraction(s)
TPC	Total percent change
UI(s)	Uncertainty interval(s)

Conflict of interest

The authors have no conflicts of interest to declare.

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No ethical approval was required for this study design, as all data were obtained from publicly available sources.

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Supplementary content (If any) is available online.

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