The burden of prostate cancer in North Africa and Middle East, 1990–2019: Findings from the global burden of disease study

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Background: Prostate cancer (PCa) is the second most prevalent cancer among men worldwide. This study presents estimates of PCa prevalence, incidence, death, years-of-life-lost (YLLs), years-lived-with-disability (YLDs), disability-adjusted-life-years (DALYs), and the burden attributable to smoking during 1990-2019 in North Africa and Middle East using data of Global Burden of Diseases (GBD) Study 2019.

Methods: This study is a part of GBD 2019. Using vital registration and cancer registry data, the estimates on PCa burden were modeled. Risk factor analysis was performed through the six-step conceptual framework of Comparative Risk Assessment.

Results: The age-standardized rates (95% UI) of PCa incidence, prevalence, and death in 2019 were 23.7 (18.5-27.9), 161.1 (126.6-187.6), and 11.7 (9.4-13.9) per 100,000 population. While PCa incidence and prevalence increased by 77% and 144% during 1990-2019, respectively, the death rate stagnated. Of the 397% increase in PCa new cases, 234% was due to a rise in the age-specific incidence rate, 79% due to population growth, and 84% due to population aging. The YLLs, YLDs, and DALYs of PCa increased by 2% (-11.8-23.1), 108% (75.5-155.1), and 8% (-8.9-28.1). The death rate and DALYs rate attributable to smoking have decreased 12% and 10%, respectively. The DALYs rate attributable to smoking...
was 37.4 (15.9-67.8) in Lebanon and 5.9 (2.5-10.6) in Saudi Arabia, which were the highest and lowest in the region, respectively.

Conclusions: The PCa incidence and prevalence rates increased during 1990-2019; however, the death rate stagnated. The increase in the incidence was mostly due to the rise in the age-specific incidence rate, rather than population growth or aging. The burden of PCa attributable to smoking has decreased in the past 30 years.

KEYWORDS
cancer, global burden of disease, incidence, mortality, prostate-specific antigen, prostatic neoplasms

Introduction

Prostate cancer (PCa) is the second most prevalent cancer among men worldwide, accounting for 14.1% of all diagnosed cases with cancer in 2020 (1). PCa has the fifth rank among deaths due to neoplasm among men worldwide (2) and ranked among the top ten causes of disability-adjusted life years (DALYs) in men of older ages in 2019 (3). Smoking is the single risk factor for PCa, distinguished by the Global Burden of Disease (GBD) Study 2019 (4).

Globally, there are substantial variations in trends of PCa incidence and death (5). This could be attributable to regional population-based differences in risk factors, access to medical care, and disparate screening and diagnostic approaches across healthcare systems (6). Considering its burden (7), any change in screening, diagnosis, and management approaches could have substantial public health consequences (8). Therefore, investigation of the trends among various locations is essential in determining the accomplishments of distinct health policies and screening protocols across healthcare systems of countries. Providing policymakers with precise and reliable reports on trends and patterns of PCa empowers them to make prompt evidence-based decisions (9).

In this study, the North Africa and Middle East (NAME) super-region has been chosen to assess the burden of prostate cancer and its attributable risk factor. Despite similarities in culture and religion, the socio-economic status greatly differs across countries in the region. Currently, the countries in this region encounter numerous challenges in developmental aspects affecting their healthcare systems (10). Moreover, the lack of well-established national cancer registries challenges the accuracy of the burden estimates (11). Hence, studying the burden of disease trends in these countries using GBD as a tool could provide a more accurate picture of the current status in the health systems and efforts demanded to reduce PCa burden. Smoking is the only risk factor, for which there were enough high-quality evidence to be considered a risk factor for prostate cancer in GBD-2019 (3).

The objective of this study was to present estimates of PCa prevalence, incidence, death, years of life lost (YLLs), years lived with disability (YLDs), DALYs, and the burden attributable to smoking from 1990 to 2019 by age groups, and countries in NAME using the data of GBD-2019 (3).

Materials and methods

Data source

The data of GBD-2019 was used in the study, which includes estimations on epidemiological measures including prevalence, incidence, death, YLLs, YLDs, and DALYs for 286 causes of death, 369 diseases and injuries, and 87 risk factors in 204 countries and territories (3). NAME, a GBD super-region investigated in this study, included 21 countries: Afghanistan, Algeria, Bahrain, Egypt, Iran (Islamic Republic of), Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Sudan, Syrian Arab Republic, Tunisia, Turkey, United Arab Emirates, and Yemen (3). The data of PCa was extracted from GBD-2019: GBD code: B.1.18, International Statistical Classification of Diseases and Related Health Problems 10th Revision, World Health Organization (WHO) version 10 (ICD-10) code: C61-C61.9, D07.5, D29.1, D40.0 (for mapping death), and C61-C61.9, Z12.5, Z80.42, Z85.46 (for mapping new cases) (12, 13). The Global Health Data Exchange (GHDx) was used to extract the sources of data on PCa and its risk factor (14) (Supplementary Table 1). The detailed methods of GBD-2019 have been published previously (3). We briefly present the methods used to provide the estimates.
**Death estimates**

The data of the vital registration system and the cancer registry were transformed and modeled to provide the cause-specific death estimates using death-to-incidence ratios. Data were mapped to the GBD list of disease causes. To enhance the comparability of death data sources, the following statistical methods were used: 1) reclassification and redistribution of codes that are nonspecific or unspecific, 2) regression analysis using Bayesian geospatial regression software (CODEm, Cause of Death ensemble model), and 3) adjustment of the single cause death estimates applying CoDCorrect algorithm. As many as six selected covariates for CODEm models of PCa was defined including PCa summary exposure value (+1 direction), smoking prevalence (+1 direction), healthcare access and quality index (-1 direction), education via years per capita (-1 direction), lag distributed income per capita (-1 direction), and socio-demographic index (+1 direction). Finally, the single cause death estimates were adjusted by applying CoDCorrect algorithm. YLLs were calculated using normative global life expectancy and the number of deaths by age (3).

**Incidence, prevalence, YLLs, YLDs, and DALYs estimates**

To provide estimates on the incidence and prevalence of PCa, data were collected using the existing scientific reports on cohorts, registries, population surveys, and health system administrative data. The PCa prevalence was estimated for a maximum of 10 years after incidence. Prevalence extending beyond the 10-year period was only estimated for permanent sequelae resulting from prostatectomy. To estimate disability, the total PCa prevalence was split into four sequelae including diagnosis and primary therapy, controlled phase, metastatic phase, and the terminal phase. The diagnosis and primary therapy phase were defined as the time from the onset of symptoms to the end of treatment. The controlled phase was defined as the time between finishing primary treatment and the earliest of either: 1) cure (recurrence- and progression-free survival after 10 years), 2) death from another cause, 3) progression to the metastatic phase. The metastatic phase was defined as the time period of intensive treatment for metastatic disease. The terminal phase was defined as the one-month period prior to death. Considering the long-term disability due to either incontinence or impotence from prostatectomy, additional disability beyond these four sequelae was estimated for PCa. YLDs were calculated via multiplying the prevalence of each sequela by its disability weight and by adding the procedure-related morbidity associated with PCa treatment. YLLs due to PCa were calculated using normative global life expectancy, and the number of deaths by age. PCa DALYs were calculated by summing YLDs and YLLs. DisMod-MR 2.1, a Bayesian meta-regression modelling tool, was used to ensure consistency between incidence, prevalence, remission, excess mortality, and cause-specific mortality (3).

**Decomposition investigation**

The contribution of population growth, aging, and variations in age-specific incidence rates to the witnessed PCa new cases changes was investigated. In the first step, the age structure and age-specific incidence rate of PCa in 1990 were applied to the population size of 2019. In the second step, the age structure and age-specific incidence rate of PCa in 2019 was applied to the population size of 1990. The difference between the new cases as calculated in the first and second steps was considered as the contribution of changes in age structure from 1990 to 2019. The difference between the new cases in the first step and the actual new cases in 2019 was attributed to the population growth. The differences between the value of the second step and the actual new cases in 2019 was attributed to the changes in age-specific incidence rates (15).

**Risk factor estimates**

The six-step conceptual framework of Comparative Risk Assessment (CRA) was used to estimate the attributable burden of PCa (16). Data on attributable risk factors were derived from the World Cancer Research Fund Criteria since GBD 2010 (4). Smoking was the only risk factor, about which there were enough data to be included as a risk factor of PCa in GBD-2019. After calculating the relative risks for exposures, the levels of exposure based on various age, sex, location, and years were estimated. Attributable epidemiological measures of PCa due to smoking were computed by multiplication of Population Attributable Fractions (PAFs) and were reported in YLLs, YLDs, DALYs, and death rates (17).

**Data analysis**

Age standardization was conducted using the direct method, applying a global age structure from the year 2019. Since no data were available for patients with PCa below the age of 15, data of patients aged 15 and higher were analyzed. Age-standardized rates of PCa for countries were calculated using the GBD world population standard and reported per 100,000 individuals. The 95% Uncertainty Intervals (95% UIs) were reported for each metric using 2.5% and 97.5% quintiles across 1,000 draws. The comparison regarding the differences in values of each metrics from 1990 to 2019 was computed to calculate the total and percentage of change. A regression model was used to investigate the association between Healthcare Access and Quality Index (HAQI) (18) and PCa burden. The statistical analyses and data visualizations were carried out using R statistical packages v3.4.3 (http://www.r-project.org, RRID: SCR_001905).
Results

Incidence, prevalence, and death

In 2019, there were 47,474 (95% UI 36,988-55,847) new cases of PCa, 348,924 (271,317-407,426) prevalent cases of PCa, and 19,089 (15,241-22,498) deaths due to PCa in NAME. The number of all-ages new cases, prevalent cases and deaths due to PCa has shown a 5.0-, 6.3-, and 2.9-fold increase since 1990, respectively (Supplementary Table 2).

The age-standardized incidence rate and prevalence of PCa in the region was 23.7 (18.5-27.9) and 161.1 (126.6-187.6) per 100,000 population. The age-standardized death rate of PCa in the region was 11.7 (9.4-13.9). The incidence rate of PCa ranged from 12.0 (8.5-17.0) in Egypt to 73.8 (47.9-103.4) in Lebanon. The prevalence of PCa ranged from 51.0 (38.8-64.7) in Afghanistan to 542.6 (362.0 to 751.2) in Lebanon. Simultaneously, the death rate of PCa has varied from 7.0 (5.1-9.7) in Egypt to 25.7 (16.0-37.7) in Lebanon (Table 1).

The incidence rate and prevalence have shown an incessantly growing pattern since 1990, while the death rate

| Location                  | ASIR1 per 100,000 population | ASPR2 per 100,000 population | ASDR3 per 100,000 population |
|---------------------------|-------------------------------|-------------------------------|------------------------------|
|                           | 1990                          | 2019                          | 1990                         | 2019                          | 1990                         | 2019                          | Percent changes |
| North Africa and Middle East |                               |                               |                              |                               |                              |                               | Percent changes |
| Afghanistan               | 11.5 (8.3-15.7)               | 13.5 (10.0-17.5)              | 17.4 (10-49.4)               | 18.0 (13.4-25.0)              | 32.3 (-3.7-75.6)             | 69.7 (53.1-89.1)              | 123.4 (92.5-170.1)          |
| Algeria                   | 136.1 (102.0-176.2)           | 180.0 (134.3-250.0)          | 361.1 (28.5-51.0)           | 318.6 (46.2-51.0)             | 51 (38.8-64.7)              | 41.2 (6.5-81.7)               | 139.1 (101.0-190.3)        |
| Bahrain                   | 23.1 (17.2-28.8)              | 33.8 (25.3-45.0)              | 46.5 (4.9-103.7)            | 114.4 (88.6-141.6)           | 236.4 (178-319.2)           | 106.5 (451.0-190.7)          | 190.7 (139.1-231.0)        |
| Egypt                     | 7.2 (6.1-9.3)                 | 12.0 (8.5-17.0)               | 66 (19.1-138.8)             | 33.3 (28.4-39.5)              | 73 (51.3-103)               | 119.4 (58.3-208.2)           | 145.3 (92.5-230.7)         |
| Iran (Islamic Republic of) | 15.8 (12.2-19.6)              | 30.0 (21.3-34.7)              | 89.4 (50.9-132.5)           | 90.4 (70.8-110.4)             | 219.2 (158.3-257.6)          | 142.3 (95.1-207.9)           | 207.9 (139.1-281.7)        |
| Jordan                    | 140.1 (109.9-179.0)           | 24.5 (17.1-32.4)              | 74.7 (27.5-137.6)           | 74.9 (59.9-94.8)              | 172.6 (121.6-230.0)          | 130.4 (67.5-218.8)           | 168.9 (109.4-247.2)        |
| Kuwait                    | 16.1 (12.4-24.2)              | 31.2 (23.0-42.9)              | 94.2 (48.3-151.5)           | 119.7 (93.8-148.7)           | 247.4 (183.6-340.9)          | 106.5 (55.9-169.8)           | 169.8 (106.5-257.6)        |
| Lebanon                   | 30.4 (23.1-38.2)              | 73.8 (47.9-103.4)             | 142.8 (70.1-243.7)          | 156.1 (123.4-195.2)           | 542.6 (362-751.2)            | 247.6 (147.2-395.6)          | 248.7 (171.8-427.3)        |
| Libya                     | 13.0 (8.2-17.6)               | 19.6 (14.2-26.1)              | 51 (2.1-139.1)              | 74.1 (49.3-97.6)              | 131.2 (95.2-173.1)           | 77.1 (19.9-230.7)            | 158.9 (102.7-257.6)        |
| Morocco                   | 8.7 (6.3-11.6)                | 15.5 (11.1-20.2)              | 78.4 (27.8-135.3)           | 38.7 (20.5-73.3)              | 216.7 (170.2-289.9)          | 134.9 (69.9-207.6)           | 168.9 (106.5-257.6)        |
| Oman                      | 15.8 (10.6-22.0)              | 29.6 (23.7-39.1)              | 87.7 (34.5-176.2)           | 90.3 (63.3-123.1)             | 197.9 (137.2-252.5)          | 140.1 (76.3-229.8)           | 160.8 (105.9-247.2)        |
| Palestine                 | 23.7 (16.2-32.9)              | 31.5 (20.5-40.6)              | 32.7 (16.4-103.8)           | 119.3 (85.2-162.9)           | 298.1 (207.8-420.3)          | 65.9 (18.4-147)              | 67.9 (15.1-230.8)          |
| Qatar                     | 19.6 (14.7-26.2)              | 42.3 (29.9-58.1)              | 116.2 (51.8-203.5)          | 103.4 (80.8-136.8)           | 176.2 (130.7-259.9)          | 188.2 (97.6-310.5)           | 199.9 (151.1-260.0)        |
| Saudi Arabia              | 12.9 (7.5-20.5)               | 23.4 (17.2-35.0)              | 82.1 (20-278.8)             | 70.4 (46.1-105.1)             | 77.2 (53.6-104.6)            | 150.2 (67.8-380.7)           | 170.0 (107.7-380.7)        |
| Sudan                     | 9.5 (6.6-13.2)                | 14.9 (10.4-19.9)              | 56.5 (17.8-116.1)           | 37.7 (28.4-50.2)              | 133.3 (93.9-208)             | 104.9 (53.7-218.4)           | 218.4 (130.0-328.7)        |
| Syrian Arab Republic      | 11.7 (7.8-18.8)               | 19.5 (13.3-31.4)              | 66.9 (9.9-166)              | 63.4 (46.5-89.9)              | 153.1 (108.9-215.8)          | 110.2 (39.8-225.3)           | 154.2 (95.7-288.8)         |
| Tunisia                   | 11.6 (8.6-15.3)               | 21.3 (14.9-30.5)              | 82.9 (21.8-174.8)           | 65.6 (50.8-84.2)              | 249.4 (173.9-330.6)          | 133.4 (58.6-248.1)           | 113.7 (64.4-186.7)         |

(Continued)
has stagnated. The incidence rate, the prevalence rate, and death rate during 1990 to 2019 increased by 77.4% (51.1-117.2), 143.7% (108.1-190.3), and 6% (-8.6-28.7). While the incidence rate increased in all countries in the region, the gap between the highest and lowest incidence rate among countries has widened during the past 30 years. The death rate increased in all countries except for six countries, including Saudi Arabia, Algeria, Bahrain, Turkey, Palestine, and United Arab Emirates (Table 1 and Supplementary Figures 1, 2).

Patients aged more than 70 accounted for 41.2% of all new and 29.8% of all prevalent cases. Moreover, 76.0% of deaths due to PCa were among patients aged more than 70 (Figure 1 and Supplementary Figure 3). The incidence and mortality increased in both age groups under and over 70 years; however, the increase among people under 70 years of age was more prominent with the increasing rates of 210.3% and 132.3%, respectively.

The decomposition analysis showed that 234.2% of 397% increase in cases was due to a rise in the age-specific incidence rate. Population growth and population aging accounted for 78.9% and 83.9%, respectively (Supplementary Table 3). Higher HAQI was associated with higher PCa incidence (adjusted $R^2=0.51$) and prevalence (adjusted $R^2=0.62$) (Supplementary Figure 4).

### DALYs, YLLs, and YLDs

In 2019, the age-standardized DALYs due to PCa in NAME was 186.8 (147.7-219.5) per 100,000 population. The PCa DALYs increased by 6% (-8.9-28.1) since 1990. YLLs formed the highest proportion of DALYs both in 1990 and 2019 in all countries. DALYs’ increasing trend is consistent with the pattern of YLLs and YLDs, with a 2.1% (-11.8-23.1) and 108.2% (75.5-155.1) increase since 1990. In addition, patients aged more than 70 accounted for 57.6% of all PCa DALYs. The DALYs of Algeria, Bahrain, Palestine, Saudi Arabia, and Turkey decreased (Figures 2, 3A; Table 2 and Supplementary Table 4). HAQI was not associated with PCa DALYs, YLLs, and YLDs (Supplementary Figure 4).

#### The burden of PCa attributable to smoking

The age-standardized DALYs rate and death rate attributable to smoking in NAME in 2019 was 12.8 (5.7-20.5) and 0.7 (0.3-1.2) per 100,000 population. The DALYs rate attributable to smoking varied significantly among countries, ranging from 5.9 (2.5-10.6) in Saudi Arabia to 37.4 (15.9-67.8) in Lebanon. Death rate attributable to smoking ranged from 0.3 (0.1-0.6) in Saudi Arabia to 2.1 (0.9-3.9) in Lebanon. The DALYs rate and death rate attributable to smoking in the region has decreased 10% (-28.5-15.2) and 11.9% (-30.4-12.4), respectively. While Turkey had the highest DALYs attributable to smoking in 1990, it managed to decrease it by almost 33% in 2019. In contrast, Lebanon with the second highest DALYs attributable to smoking in 1990 witnessed a 37% increase in 2019 (Figure 3B; Table 3 and Supplementary Table 5).

#### Discussion

The PCa incidence and prevalence incessantly increased, while the death rate merely stagnated. The increase in the incidence was majorly due to a rise in the age-specific incidence rate. While YLLs and DALYs of PCa slightly increased, YLDs was doubled from 1990 to 2019. The PCa death and DALYs rate attributable to smoking decreased.

The steady increasing trends in death rates, despite the sharp increases in incidence and prevalence, could be associated with early detection via screening, or recent advances in surgical and non-surgical therapeutic approaches (19). However, compared with western regions, the burden of PCa is still low (3), which

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**TABLE 1 Continued**

| Location       | ASIR$^1$ per 100,000 population | ASPR$^2$ per 100,000 population | ASDR$^3$ per 100,000 population |
|----------------|---------------------------------|---------------------------------|---------------------------------|
|                | 1990 | 2019 | Percent changes | 1990 | 2019 | Percent changes | 1990 | 2019 | Percent changes |
| Turkey         | 19.6 (13.7-24.9) | 35.1 (24.6-46.4) | 14.3 (27.7-144.3) | 94.6 (68.2-119.5) | 161.4 (95.6-298.1) | 163.5 (88.8-263.5) | 16.2 (11.4-20.5) | 14.7(10.5-18.7) | -9 (-32.3-21.1) |
| United Arab Emirates | 17.0 (10.3-29.4) | 24.2 (13.7-46.9) | 7.2 (155) | 93.3 (61.1-155) | 72.9 (20.8-144.9) | 12.9 (7.7-24.4) | 12.8(7.4-24.7) | -0.8 (-29.2-37.3) |
| Yemen          | 10.3 (6.5-14.7) | 14.7 (10.8-19.6) | 4.3 (5.9-110.8) | 40.5 (28.9-289.9) | 216.7 (170.2-155.3) | 15.0 (6.1-20.5) | 11.9(8.6-16.0) | 19.7 (10.4-72.1) |

$^1$Age-standardized incidence rate.

$^2$Age-standardized prevalence rate.

$^3$Age-standardized deaths rate.
could be due to several factors ranging from lack of proper population-based registries to genetic differences and diet (20).

The burden of PCa varied significantly among the countries, which could be due to limited awareness and variable coverage of screenings in the region, along with the divergent development of cancer registries (21). There was a six-fold gap between Algeria, with the lowest PCa incidence, and Lebanon, which had the highest. In this regard, the difference between Lebanon and Algeria could partly be due to their healthcare system approaches towards the widespread use of prostate-specific antigen (PSA) screening tests (22, 23). This study’s findings are consistent with a previous study on Lebanese national cancer registry. In this country, age structure, and prevalence of genetic and lifestyle risk factors might be other explanations in addition to improved screenings and diagnostics (24).

Controversies over the role of PSA testing in overdiagnosis (2) and reducing disease-specific mortality (25) have casted doubt on its liability to be a national screening strategy. Nevertheless, it has been used among many populations. Early
detection by screenings needs updated healthcare systems and resources. Since there is limited data on the prevalence of PSA screening among countries in the region, further research is needed on the optimal strategies for early detection and prompt medical care. Moreover, the PSA screening utilization pattern among various groups needs to be investigated.

Patients aged>70 accounted for some 60% of all DALYs due to PCa, consistent with previous studies (26, 27). Most of the increase in incidence was attributable to a rise in the incidence rate. Although the incidence rates increased in all age-groups, they increased more among patients aged<70, resulting in higher expected mortality in the future.

Despite increased age-standardized incidence and prevalence, the death rate decreased in Saudi Arabia, Turkey, and United Arab Emirates. This finding might be reflecting the better management of PCa due to timely and efficient interventions which needs to be furthered studied and used as role models for the rest of the countries.

There were significant heterogeneities among countries in the burden of PCa attributable to smoking, which could be traced back to the time trends of smoking prevalence. The prevalence of smoking in Lebanon, the country with the highest DALYs for PCa attributable to smoking, has stagnated in recent decades (28). In comparison, the prevalence of smoking in Turkey, which was the most prosperous country in decreasing the burden of PCa attributable to smoking, has significantly decreased in the recent decades (29). Turkey remains as a country that has one of the highest attributable burdens to smoking that might also explain the higher burden of prostate cancer in this country. Countries need to reconsider their smoking elimination policies to keep up with the smoking reduction agenda of Sustainable Development Goals (30). Interestingly, in countries with decreased affordability of cigarettes such as Egypt and Turkey (31), the trend of attributable burden of PCa to smoking is not similar. Although smoking is the only risk factor recognized by

FIGURE 3
Distribution of epidemiological measures of prostate cancer by countries in 1900 and 2019: incidence, prevalence, death, and DALYs due to prostate cancer in 1990 and 2019 (A); YLLs, YLDs, deaths, and DALYs of prostate cancer attributable to smoking in 1990 and 2019 (B).
| Location          | YLLs\(^1\) rate per 100,000 population | YLDs\(^2\) rate per 100,000 population | DALYs\(^3\) rate per 100,000 population | YLLs/ DALYs | YLDs/ DALYs |
|-------------------|----------------------------------------|----------------------------------------|----------------------------------------|-------------|-------------|
|                   | 1990 | 2019 | Percent changes | 1990 | 2019 | Percent changes | 1990 | 2019 | Percent changes | 1990 (%) | 2019 (%) | 1990 (%) | 2019 (%) |
| North Africa and Middle East |                               |                                            |                                        |             |             |             |             |             |             |             |             |             |
| Afghanistan       | 192.7| 203.6| 5.6 (-18.7-34.9) | 4.6 (3.6-7.7) | 5.6 | 22.4 (-9.6-67.1) | 176.2 | 186.8 | 6 (-8.9-28.1) |         |             | 96.3 | 92.7 | 3.7 | 7.3 |
| Algeria           | 166  | 139  | -16.3 (-37.4-9.3) | 6.6 | 10 (6.6-14.8) | 51.4 (5.3-110) | 172.6 | 149  | -13.7 (-35.4-272.2) |         |             | 96.2 | 93.3 | 3.8 | 6.7 |
| Bahrain           | 268.2| 220  | -18 (-39.6-8.8)   | 11.6 (8-16.4) | 19.2 | 65.7 (15.1-133.6) | 279.8 | 239.3 | -14.5 (-36.9-222.2) |         |             | 95.9 | 91.9 | 4.1 | 8.1 |
| Egypt             | 101.5| 112 (90.3-156.3) | 10.3 (-19.9-55.6) | 3.6 | 7.1 (2.5-10.9) | 96.1 (31.6-181.1) | 105.1 | 119.1 | 13.2 (-6.7-70.3) |         |             | 96.6 | 94.0 | 5.4 | 8.4 |
| Iran (Islamic     | 173.7| 190.5| 9.7 (-8.3-36.3)   | 8.2 | 175 (11.6-242) | 114 (68.8-195.3) | 181.9 | 208.1 | 14.4 (-4.4-227.3) |         |             | 95.5 | 91.6 | 5.4 | 8.4 |
| Republic of       | 138.4| 172.6| 24.7 (-9.3-73.5)  | 5.3 | 10.2 (3.4-15.5) | 100.2 (38.6-193.5) | 143.7 | 183.3 | 27.5 (-7.4-235.7) |         |             | 96.3 | 94.2 | 3.7 | 5.8 |
| Jordan            | 167.6| 166.9| -0.4 (-25.3-33.1) | 7.1 | 14.2 (4.8-28.8) | 100.3 (44.8-182.6) | 174.7 | 181.1 | 3.7 (-22.5-234.8) |         |             | 95.9 | 92.2 | 5.4 | 8.3 |
| Kuwait            | 119.8| 146  | 21.8 (2.5-51.9)   | 9.5 | 18.8 (6.2-12.1) | 96.6 (45.4-163.2) | 129.3 (99-164.7) | 164.7 | 27.3 (1-58.4) |         |             | 92.7 | 88.6 | 7.3 | 11.4 |
| Lebanon           | 334.9| 371.9| 11.1 (-10.6-55.1) | 15.6 | 44.6 (10.6-68.4) | 185 (97.5-303.1) | 350.5 | 416.5 | 16.8 (-15.6-591.2) |         |             | 95.5 | 89.3 | 4.5 | 7.6 |
| Libya             | 148.6| 158.7| 6.9 (-24.7-64.8)  | 6.7 | 11.3 (3.9-16.4) | 67.6 (7.3-165.2) | 155.3 | 170  | 9.5 (-22.9-221.8) |         |             | 95.7 | 93.4 | 4.3 | 6.6 |
| Morocco           | 121.1| 155.9| 28.7 (-4.9-66.8)  | 4.2 (-2.7-8.1) | 5.2 | 105.3 (5.2-115.5) | 125.1 (92-164.3) | 164  | 31.1 (-3.1-215.2) |         |             | 96.8 | 95.1 | 3.2 | 4.9 |
| Oman              | 173.6| 177.2| 2.1 (-27.6-61.6)  | 8.5 | 18.5 (-12.5-25.7) | 111.3 (48.7-206) | 182.1 | 195.2 | 7.2 (-23.5-248.1) |         |             | 95.3 | 90.8 | 4.7 | 9.2 |
| Palestine         | 278.8| 265.3| -4.9 (-32.5-46.3) | 11.8 | 17 (7.3-24) | 43.8 (10.5-122.5) | 290.6 | 282.3 | -2.9 (31.3-49.7) |         |             | 95.9 | 94.0 | 4.1 | 6.0 |
| Qatar             | 216.7| 242.6| 12 (-18.2-59.3)   | 10.6 (-6.7-14.2) | 24.3 | 142.9 (15.5-349) | 226.7 | 266.9 | 17.8 (-14.4-358.8) |         |             | 96.5 | 90.9 | 4.1 | 9.1 |
| Saudi Arabia      | 158.5| 134.3| -15.2 (-41.7-74.5) | 6.3 | 14 (3.4-21.9) | 122 (45.9-353) | 164.8 | 180.3 | 10 (-38.1-222.3) |         |             | 96.2 | 90.6 | 3.8 | 9.4 |
| Sudan             | 145.1| 172.8| 19.2 (-8.9-61.8)  | 4.2 | 7.4 (2.7-6.5) | 75.2 (25.3-147.6) | 149.3 | 180.2 | 20.7 (-7.9-244.3) |         |             | 97.2 | 95.9 | 5.3 | 9.1 |

(Continued)

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\(^1\) YLL = years of life lost

\(^2\) YLD = years lived with disability

\(^3\) DALY = disability-adjusted life years
### TABLE 2 Continued

| Location       | YLLs/100,000 population | YLDs/100,000 population | DALYs/100,000 population | YLLs/100,000 population | YLDs/100,000 population | DALYs/100,000 population |
|----------------|-------------------------|-------------------------|--------------------------|-------------------------|-------------------------|--------------------------|
|                | 1990    | 2019    | Percent changes | 1990    | 2019    | Percent changes | 1990    | 2019    | Percent changes | 1990    | 2019    | Percent changes |
| Syrian Arab Republic | 145.3  | 147.6  | 1.6 (-31.1-9.8) | 6.1     | 11.4    | 18.8 (20.6-205.9) | 151.4  | 159    | 5.2 (-28.7-64.3) |
| Tunisia        | 128.9  | 134.2  | 4.1 (-29.3-8.6)  | 6.8     | 12.7    | 111.2         | 134.9  | 146.8  | 8.8 (-25.7-64.2)  |
|                |         |         |                |         |         |               |         |         |               |
| Turkey         | 255.4  | 215.5  | -15.6          | 9.6     | 20.9    | 116.8         | 265.4  | 168.7  | -18.8 (-37.4-20)  |
| United Arab Emirates | 204.9 | 200.9  | -1.9 (-31.5-0.2) | 8.8     | 14.1    | 59.8 (8.4-131) | 213.7  | 215    | 0.6 (-29.3-39.5)  |
| Yemen          | 155.4  | 183.4  | 18 (-12.1-72)   | 4.6     | 7.2     | 56.8 (11.7-136.5) | 160    | 190.6  | 19.1                |

1Years of Life Lost.
2Years Lived with Disability.
3Disability-Adjusted Life Years.

### TABLE 3

#### Age-standardized rates (95% UI) for YLLs, YLDs, and DALYs of prostate cancer attributable to smoking in 1990 and 2019 and their percent changes.

| Location                | YLLs/100,000 population | YLDs/100,000 population | DALYs/100,000 population | Death rate per 100,000 population |
|-------------------------|-------------------------|-------------------------|--------------------------|-----------------------------------|
|                         | 1990    | 2019    | Percent changes | 1990    | 2019    | Percent changes | 1990    | 2019    | Percent changes |
| North Africa and Middle East |   |   |   |   |   |   |   |   |
| Afghanistan             | 5.4 (2.1-10) | 7.8 (3.1-13.6) | 44.2 (2.6-102.2) | 0.6 | 1.0 | (0.2-1.7) | 83.9 (44.5-135.1) | 14.2 | 12.8 | (2.2-20) |
| Algeria                 | 13.5   | 11.8   | -13.8 (-31.5-9.8) | 0.1 | 0.2 | (0.2-0.4) | 71.3 (18.2-160.5) | 5.6 | 8.3 | (2.1-14) |
| Bahrain                 | 18.9   | 12.8   | -32 (-52.6-3.9)   | 0.3   | 1.1 | (0.3-2.1) | 36.1 (11.1-100.6) | 14.1 | 10.6 | (3.4-7.1) |
| Egypt                   | 7.5 (3.3-11.7) | 9.3 (4.1-16.1) | 24.2 (-13.4-76.6) | 0.3 | 0.6 | (0.1-1.5) | 123.4 (47.2-230.4) | 7.7 | 9.9 | (1.2-17.1) |
| Iran (Islamic Republic of) | 10.6  | 10.1   | -5.3 (-28.2-26.3) | 0.6 | 1.1 | (0.2-0.6) | 92.3 (43.9-157.7) | 12.2 | 11.1 | (0.5-18.8) |
| Iraq                    | 13.4   | 13.7   | -3 (-27.8-48.8)   | 0.5   | 0.9 | (0.2-1.4) | 66.2 (11.6-158.5) | 13.9 | 14.6 | (5.8-24.4) |
| Jordan                  | 18.1   | 14.4   | -20.4 (-48.1-22.1) | 0.8   | 1.3 | (0.3-5.5) | 64.6 (7.8-158.7) | 18.9 | 15.8 | (1.4-27.7) |
| Kuwait                  |         |         |                |         |         |               |         |         |               |

(Continued)
GBD-2019, the burden attributable to this factor does not solely explain the PCa burden. Hence, other potential risk factors such as age (32), ethnicity (33), genetic factors (34), diet (35), hormone levels (36), and obesity (37) need to be investigated in future research.

HAQI was associated with PCa incidence and prevalence. In contrast, there were no associations between HAQI and DALYs, YLLs, and YLDs. The higher PCa incidence and prevalence among countries with higher HAQI could be due to more advanced screening and detection systems, especially considering the highly variable approaches towards management of PCa burden in the super-region (38). Nevertheless, the role of HAQI in the burden of PCa needs to be further assessed in future studies.

Table 3 continued

| Location          | YLLs rate per 100,000 population | YLDs rate per 100,000 population | DALYs rate per 100,000 population | Death rate per 100,000 population |
|-------------------|----------------------------------|----------------------------------|-----------------------------------|----------------------------------|
|                   | 1990  | 2019  | Percent changes | 1990  | 2019  | Percent changes | 1990  | 2019  | Percent changes | 1990  | 2019  | Percent changes |
| Lebanon           | 9.3   | 9.1   | 0.8              | 1.2  | 1.5   | 0.6              | 4.0   | 4.1   | 0.6              | 21.9  | 28.3  | 6.4              |
| Libya             | 11.5  | 10.3  | 1.2              | 0.6  | 0.8   | 1.6              | 12.1  | 11.1  | 1.6              | 29.4  | 26.0  | 3.4              |
| Morocco           | 7.4   | 7.1   | 0.3              | 0.4  | 0.5   | 0.4              | 6.2   | 6.2   | 0.4              | 2.2   | 2.0   | 0.2              |
| Oman              | 8.2   | 5.8   | 0.4              | 0.7  | 0.5   | 0.5              | 6.2   | 5.7   | 0.5              | 2.3   | 1.8   | 0.5              |
| Palestine         | 23.2  | 20.5  | 1.2              | 0.4  | 0.5   | 0.7              | 6.2   | 5.5   | 0.7              | 2.3   | 1.8   | 0.5              |
| Qatar             | 10.7  | 10.4  | 0.3              | 0.5  | 0.6   | 0.7              | 6.2   | 6.2   | 0.7              | 2.3   | 1.8   | 0.5              |
| Saudi Arabia      | 5.6   | 5.3   | 0.2              | 0.6  | 0.6   | 0.6              | 6.2   | 6.2   | 0.6              | 2.3   | 1.8   | 0.5              |
| Sudan             | 8.8   | 9.7   | 0.3              | 0.4  | 0.7   | 0.7              | 6.2   | 6.2   | 0.7              | 2.3   | 1.8   | 0.5              |
| Syrian Arab Republic | 13.9 | 11.1  | 0.6              | 0.9  | 0.7   | 0.7              | 6.2   | 6.2   | 0.7              | 2.3   | 1.8   | 0.5              |
| Tunisia           | 12.1  | 11.5  | 0.6              | 0.7  | 0.7   | 0.7              | 6.2   | 6.2   | 0.7              | 2.3   | 1.8   | 0.5              |
| Turkey            | 27.9  | 27.6  | 0.3              | 0.4  | 0.4   | 0.4              | 6.2   | 6.2   | 0.4              | 2.3   | 1.8   | 0.5              |
| United Arab Emirates | 9.5  | 9.2   | 0.4              | 0.7  | 0.7   | 0.7              | 6.2   | 6.2   | 0.7              | 2.3   | 1.8   | 0.5              |
| Yemen             | 11.8  | 13.5  | 0.4              | 0.5  | 0.5   | 0.5              | 6.2   | 6.2   | 0.5              | 2.3   | 1.8   | 0.5              |

1Years of Life Lost.
2Years Lived with Disability.
3Disability-Adjusted Life Years.
**Strengths and limitations**

This study provides the opportunity to investigate the current situation and time trends of health metrics and measures in the region during the past three decades. Nevertheless, the overall quality of GBD estimates fundamentally relies on the accuracy of data sources used in the modeling. The reliability of registry data among countries with limited resources in this region with dynamic population due to immigrations and changes in ethnicities could be questionable. Thus, the GBD includes various modeling processes to overcome this limitation and presents metrics with 95% UIs. Due to insufficient evidence, smoking was the only attributable risk factor for PCa recognized by GBD-2019, which calls for further research to investigate other possible risk factors towards capturing a clearer picture of the PCa burden. Furthermore, the stage and histopathology of PCa which are determinatives of its prognosis were not considered in this study.

**Conclusions**

PCa incidence and prevalence increased from 1990 to 2019; however, the death rate had a steadier pattern. The increase in the incidence was mostly due to the rise in the age-specific incidence rate, rather than population growth or aging. The burden of PCa attributable to smoking has decreased in the past 30 years.

**Data availability statement**

Publicly available datasets were analyzed in this study. This data can be found here: https://vizhub.healthdata.org/gbd-results/.

**Ethics statement**

The studies involving human participants were reviewed and approved by institutional review board of Endocrinology and Metabolism Research Institute at Tehran University of Medical Sciences (IR.TUMS.EMRI.REC.1400.028). Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

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All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication (Supplementary Datasets 2). Author’s are credited with: Providing data or critical feedback on data sources, Developing methods or computational machinery, Providing critical feedback on methods or results, Drafting the work or revising is critically for important intellectual content, and Managing the overall research enterprise.

Funding

The GBD study is funded by Bill & Melinda Gates Foundation.

Acknowledgments

S Aljundi acknowledges the Department of Health Policy and Management, Faculty of Public Health, Kuwait University and International Centre for Casemix and Clinical Coding, Faculty of Medicine, National University of Malaysia for their
support. A M Samy acknowledges the support from the Egyptian Fulbright Mission Program and being a member of the Egyptian Young Academy of Sciences and Technology. S Haque is acknowledges support from the Deanship of Scientific Research, Jazan University, Saudi Arabia for providing the access of Saudi Digital Library for this research study.

**Conflict of interest**

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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**Supplementary material**

The Supplemental Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fonc.2022.961086/full#supplementary-material

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