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RESEARCH ARTICLE

# Trends in the burden of type 2 diabetes and its risk factors in Saudi Arabia

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**Background:** Saudi Arabia is one of the countries with the highest burdens of type-2 diabetes (T2D) in the world. The aim of this study was to analyse the changing trends in the burden of T2D and the impact of its major risk factors in Saudi Arabia from 1990 to 2019.
**Methods:** Data for T2D come from the Global Burden of Disease Study 2019. Decomposition analysis was used to decompose the long-term burden trend into population size, population age, prevalence, and disease severity.
**Results:** In 2019, T2D in Saudi Arabia caused 245 548.4 DALYs (95% UI: 187 706.3–316 976.4), with age-standardised incidence and prevalence increasing by 63.5% (95% UI: 53.8%–73.5%) and 75.7% (95% UI: 65.4%–87.1%), respectively. There was a gradual increase in the proportion of burden caused by T2D in the age group below 40 years from 1990 to 2019. T2D DALYs due to population size, ageing, and prevalence all increased to varying degrees, while T2D DALYs resulting from disease severity gradually decreased. The greatest increase in T2D DALYs has been linked to environmental particulate pollution over the past 30 years, and obesity is the main cause of T2D DALYs in Saudi Arabia.
**Conclusions:** The burden of T2D in Saudi Arabia has been increasing continuously over the past three decades, with a trend towards younger age. The decrease in disease burden due to disease severity is partially offset by population size and ageing. Considering the continued increase in the burden of T2D, it is necessary to control T2D risk factors to curb the growth of the T2D disease burden in Saudi Arabia.

**Keywords:** attributable risks, disability-adjusted life years, global burden of disease, type 2 diabetes

## Introduction

Diabetes mellitus is a metabolic disease characterised by hyperglycaemia resulting from the interaction of genetic and environmental factors.[1] Diabetes also causes complications such as devastating macrovascular (cardiovascular disease) and microvascular (diabetic kidney disease, diabetic retinopathy, and neuropathy) conditions, which lead to increased mortality, blindness, kidney failure, and overall decreased quality of life in people living with diabetes.[2]

The global prevalence of diabetes has been increasing over the past few decades and is one of the top-ten causes of adult mortality, having become one of the major public health issues of the twenty-first century.[1,3,4] Diabetes caused 1.55 million excess deaths worldwide in 2019.[5] Type 2 diabetes (T2D) accounts for more than 90% of global diabetes cases and contributes to approximately 94% of disability-adjusted life-years (DALYs) and 96% of years lived with disability (YLDs) due to diabetes.[6] According to a 2016 World Health Organization report, the population of Saudi Arabia has the second highest incidence of diabetes in the Middle East (the seventh highest in the world).[7] It is estimated that the prevalence of T2D in Saudi Arabia increased from 2 459.26 to 6 958.35 per 100 000 people during 1990–2019,[5] resulting in a significant disease burden.

Previous studies have demonstrated trends in the incidence and prevalence of T2D in Saudi Arabia and forecast future diabetes trends.[8–10] However, few studies have explored the causes of increasing disease burden and the impact of various risk factors on disease burden. To address these limitations, this study quantitatively evaluated the impact of population size, ageing, prevalence, and disease severity on the burden of T2D in Saudi Arabia using data from the Global Burden of Disease Study (GBD) 2019 and the burden of disease decomposition method, analysing the trends of major risk factors for T2D over the past 30 years. The findings represent an important addition to existing studies on the burden of T2D in Saudi Arabia and may inform the development of more targeted public health intervention strategies.

## Methods

### *Data sources*

Data for T2D in Saudi Arabia for 1990–2019 are from the GBD 2019 database.[5] GBD 2019 uses a uniform and comparable methodology to estimate the disease burden of various diseases, injuries, and risk factors for 204 countries and territories worldwide using a combination of multiple indicators. In this study, depending on the specific issue, several metrics were used, including the number and age-standardised rate of incidence, prevalence, deaths, YLDs, years of life lost due to premature mortality (YLLs), and DALYs.

Life registration data were used to estimate all-cause mortality and to allocate each death to a single cause for cause-specific deaths. Cause of death ensemble modelling was used to assess cause-specific mortality. YLLs were calculated by multiplying the number of deaths at a specific age by the global standard life expectancy at the time of death. The specifics of this estimation can be found in previous studies.[11]

GBD 2019 generates cause-specific and sequela-specific prevalence and incidence estimates using epidemiological data from systematic literature reviews, health surveys, surveillance systems, disease registries, and hospital and claims databases.[5] GBD 2019 then uses a microsimulation framework to adjust for comorbidities. It calculates YLDs for each cause by multiplying the prevalence and corresponding disability weights for each sequela of each cause.[12] DALYs are a summary measure of health that we calculated for each stratum of age, sex, year, and cause of death by summing the fatal (YLL) and non-fatal (YLD) components.[13]

The GBD 2019 framework for comparative risk assessment classifies each of the 84 risk factors and clusters of risk factors into one of three categories: behavioural, environmental or occupational, or metabolic.[14] The GBD2019 estimate of attributable burden followed the general framework established for comparative risk assessment (CRA).[14,15] In this study, we applied the most detailed risks for the attributable risk factor analysis.

In this study, T2D was defined according to the International Classification of Diseases (ICD 10: E11–E11.1, E11.3–E11.9). The GBD world population was used to age-standardise the rates.[16]

### *Data analysis*

To analyse the changes in DALYs, risk-factor-attributed DALYs in T2D from 1990 to 2019, age-standardised DALY rates, and attributed DALY rates calculated according to the age composition of the GBD 2019 standard population were introduced to describe the trends in their disease burden by observing the percentage change in DALY values and their standardised rates over the time period.

$$\text{Percentage rate of change} = \frac{r_{y+t} - r_y}{r_y}$$

where $r_y$ and $r_{y+t}$ are the disease burden indicators in the starting and target years, respectively ($y$ represents the year and $t$ is the time interval).

To understand the factors associated with changes in DALYs due to a given disease over a certain period of time, we expressed the disease burden as the product of four factors: (1) population size, (2) population ageing, (3) prevalence, and (4) disease severity, corresponding to the four terms shown in

**Table 1:** Number of incidences, prevalence, deaths, YLDs, YLLs, DALYs, and corresponding age-standardised rates and change for T2D by sex in Saudi Arabia from 1990 to 2019

| | Male | | | Female | | | Both | | |
|---|---|---|---|---|---|---|---|---|---|
| **Variables** | **1990** | **2019** | **Percentage change (%)** | **1990** | **2019** | **Percentage change (%)** | **1990** | **2019** | **Percentage change (%)** |
| Number (thousands) | | | | | | | | | |
| Incidence | 17.2 (15.7–18.9) | 105.4 (93.3–119.6) | 511.5 (459.2–572.3) | 9.9 (9.0–10.9) | 63.8 (57.1–72.5) | 545.3 (494.6–604.4) | 27.1 (24.8–29.6) | 169.2 (151.5–189.9) | 523.8 (480.8–571.8) |
| Prevalence | 248.3 (223.3–275.5) | 1547.9 (1370.9–1765.6) | 523.5 (473.1–581.1) | 146.3 (131.6–162.0) | 938.4 (830.1–1068.2) | 541.3 (488.7–595.0) | 394.6 (358.0–434.6) | 2486.4 (2216.6–2809.0) | 530.1 (488.8–570.7) |
| Deaths | 0.7 (0.5–1.0) | 1.8 (1.4–2.2) | 156.7 (64.6–280.7) | 0.6 (0.4–0.8) | 1.0 (0.8–1.4) | 77.6 (20.1–163.8) | 1.3 (0.9–1.7) | 2.8 (2.2–3.4) | 120.6 (53.4–212.3) |
| YLDs | 16.9 (11.3–23.4) | 102.8 (66.8–147.6) | 508.3 (454.8–580.1) | 10.0 (6.7–13.8) | 62.8 (41.0–89.0) | 529.3 (466.6–598.5) | 26.9 (18.0–37.0) | 165.6 (108.8–232.9) | 516.1 (468.0–574.7) |
| YLLs | 17.2 (12.3–24.5) | 50.2 (37.5–63.4) | 191.1 (81.8–352.2) | 14.6 (10.8–19.5) | 29.8 (22.7–39.7) | 103.2 (35.8–207.7) | 31.9 (23.4–42.9) | 80.0 (61.9–101.0) | 150.7 (69.5–265.0) |
| DALYs | 34.1 (26.2–43.5) | 153.0 (115.6–199.6) | 348.1 (245.6–448.6) | 24.6 (19.3–30.5) | 92.5 (70.8–120.6) | 275.8 (191.8–368.6) | 58.8 (46.2–72.9) | 245.5 (187.7–317.0) | 317.8 (233.6–408.2) |
| Standardised rate (per 100,000) | | | | | | | | | |
| Incidence | 294.1 (270.2–320.4) | 475.6 (431.0–526.3) | 61.7 (50.0–74.7) | 264.0 (241.8–289.6) | 441.8 (399.5–491.1) | 67.4 (56.0–80.0) | 282.7 (260.4–306.4) | 462.1 (420.8–506.9) | 63.5 (53.8–73.5) |
| Prevalence | 5638.3 (5129.7–6194.5) | 9728.5 (8777.6–10881.7) | 72.5 (59.9–87.2) | 5018.1 (4534.4–5539.9) | 9037.0 (8145.5–10160.6) | 80.1 (67.1–94.2) | 5380.7 (4914.3–5869.4) | 9453.1 (8563.1–10498.6) | 75.7 (65.4–87.1) |
| Deaths | 24.7 (18.1–33.9) | 20.8 (16.8–24.7) | −−15.7 (−−43.6–22.9) | 26.2 (19.0–34.0) | 17.6 (13.8–23.2) | −−32.6 (−−53.6–0.7) | 25.2 (19.2–33.1) | 19.5 (16.1–23.7) | −−22.5 (−−43.8–7.0) |
| YLDs | 405.5 (272.8–558.0) | 690.8 (460.9–979.5) | 70.3 (55.2–89.4) | 354.3 (239.9–487.0) | 636.1 (414.5–892.0) | 79.5 (62.8–98.3) | 383.8 (260.0–523.8) | 668.9 (450.7–939.7) | 74.3 (61.6–90.0) |
| YLLs | 493.4 (355.2–694.6) | 419.6 (329.8–508.3) | −−15.0 (−−44.7–26.1) | 559.7 (412.0–744.7) | 358.6 (276.5–474.0) | −−35.9 (−−56.4 to −−4.2) | 518.5 (385.9–692.7) | 395.5 (319.1–483.1) | −−23.7 (−−46.5–7.3) |
| DALYs | 899.0 (691.0–1144.8) | 1110.4 (854.0–1407.0) | 23.5 (−4.8–52.7) | 914.1 (722.8–1127.9) | 994.6 (771.1–1275.6) | 8.8 (−14.6–36.3) | 902.3 (710.1–1117.0) | 1064.5 (829.7–1348.6) | 18.0 (−5.1–42.3) |

Data are shown as *n* (95% UI). DALYs: disability-adjusted life years; UI: uncertainty interval; YLDs: years lived with disability; YLLs: years of life lost.

the following sums:

$$\text{DALY}_y = \sum_a \text{pop size}_y \cdot \frac{\text{pop age}_{ay}}{\text{pop size}_y} \cdot \frac{\text{prevalence}_{ay}}{\text{pop age}_{ay}} \cdot \frac{\text{DALY}_{ay}}{\text{prevalence}_{ay}}$$

where $a$ represents all 5-year age groups (up to the final unbounded age group of 95 years and older) and $y$ represents the year. Using the Gupta decomposition method,[17,18] the total disease burden was decomposed into the DALYs caused by each of the four factors mentioned above.

## Results

### Overall burden and trends of T2D for 1990–2019

Table 1 shows the incidence, prevalence, deaths, YLDs, YLLs, DALYs, and corresponding age-standardised rates and rates of change of T2D by sex in Saudi Arabia from 1990 to 2019. In 2019, there were 169 201 new cases of T2D in Saudi Arabia (95% UI: 151 543.7–189 934.4) and a total of 2 486 355 cases of T2D (95% UI: 2 216 629.4–2 808 991.5). In 2019, T2D caused 2 797 population deaths (95% UI: 2 211.1–3 439.2) in Saudi Arabia, resulting in 245 548.4 DALYs (95% UI: 187 706.3–316 976.4). In 2019, the incidence and prevalence of T2D were 462.1/100 000 and 9 453.1/100 000, respectively, which represented increases of 63.5% (95% UI: 53.8%–73.5%) and 75.7% (95% UI: 65.4%–87.1%), respectively, since 1990. The rates of change in standardised mortality and DALY rates for T2D from 1990 to 2019 were −22.5% (95% UI: −43.8% to 7.0%) and 18.0% (95% UI: −5.1% to 42.3%), respectively.

### T2d DALY percentages for different age groups from 1990 to 2019

Figure 1 illustrates the proportion of T2D DALYs in Saudi Arabia by age group and sex from 1990 to 2019. The proportion of T2D DALYs gradually decreased in the age groups > 80 years and 65–79 years from 1990 to 2019. In contrast, the proportion of T2D DALYs increased year by year in the age group 65 years and younger, especially in the 40–49 years age group. Among those aged 40–49 years, the proportion of T2D DALYs increased from 17.95% and 16.71% in 1990 to 23.98% and 24.01% in 2019 for men and women, respectively. In 2019, among all age groups, the 50–64 years group had the highest proportion of T2D DALYs (38.69% in men and 38.46% in women).

### Temporal trends in burden of T2D decomposition

Figure 2 shows the decomposition of T2D DALY values from 1990 to 2019 relative to 1990 by population size, ageing, prevalence, and disease severity. T2D DALYs continued to increase over the 30-year period, with varying degrees of increase in DALYs due to population size, ageing, and prevalence (increased by 179.35%, 96.66%, and 132.72%, respectively). The DALYs due to disease severity gradually decreased by 90.92%.

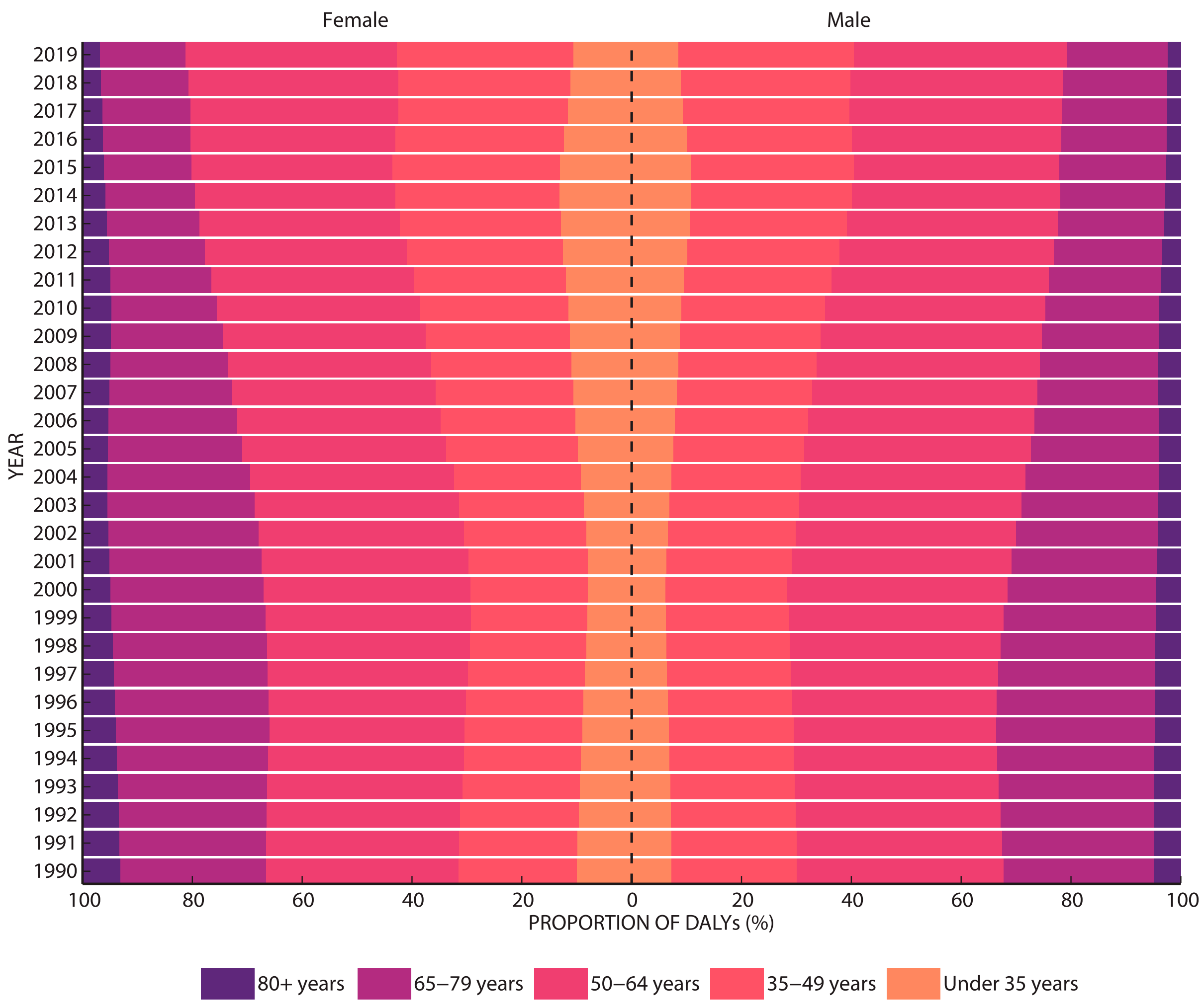


Figure 1. The proportion of DALYs due to T2D by age group in Saudi Arabia, by sex, 1990–2019. DALY: Disability-adjusted life years.

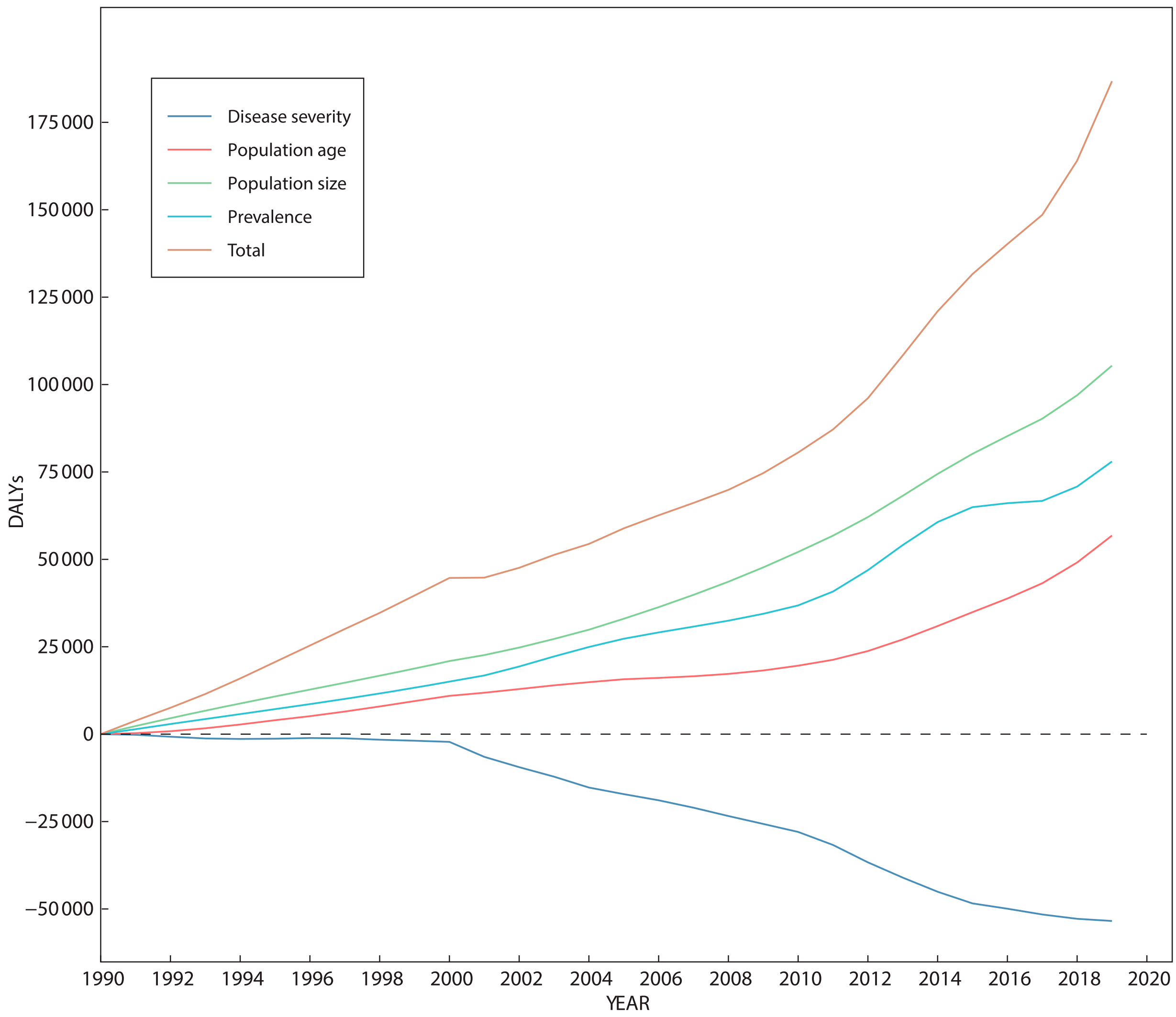


**Figure 2.** Decomposition of the type 2 diabetes burden in Saudi Arabia between 1990 and 2019.

### *Changes in T2D risk factors from 1990 to 2019*

Figure 3 shows the ranking of DALYs due to T2D risk factors, the change rate of each risk factor, and the age-standardised change rate from 1990 to 2019. High body mass index was the main risk factor for T2D in Saudi Arabia from 1990 to 2019, with the percentage of DALYs reaching 84.2% in 2019. Exposure to household air pollution from solid fuels decreased significantly (by 98.2%) in both the percentage and ranking of attributable DALYs. Exposure to ambient particulate matter pollution, second-hand smoke, and smoking increased. Exposure to ambient particulate matter pollution had the largest increase of 720.7%.

## Discussion

The age-standardised mortality and YLL rates of T2D in Saudi Arabia decreased, while the age-standardised incidence and prevalence of T2D increased during the study period. From 1990 to 2019, the proportion of T2D DALYs increased gradually in the age group below 40 years, although the age group above 50 years remained the main prevalent population of T2D in Saudi Arabia. Population size, increasing prevalence, and ageing have led to an increased burden of T2D, while disease severity has decreased. High BMI remains the most critical risk factor for T2D, and the burden of T2D from particulate pollution exposure has increased sharply.

Our study found a decreasing trend in age-standardised mortality rates for T2D in Saudi Arabia over the past three decades, and these decreases may be related to the improvement in health care in Saudi Arabia over the past few years.[19] Since the primary health care system reform was carried out in 2016 until mid-2019, Saudi Arabia has seen a 37.5% increase in primary health care visits and an increase in coverage of rural community health posts from 78% to 83%.[20] However, the age-standardised prevalence of T2D in Saudi Arabia (462.1/100 000) is still much higher than the global average (295.4/100 000). The age-standardised incidence and prevalence of T2D in Saudi Arabia showed an increasing trend, increasing by more than 60% between 1990 and 2019. This may be due to socioeconomic transition and major lifestyle changes, with Saudis gradually abandoning the more active tribal and nomadic lifestyle in favour of a Western one.[21] Poor diets, such as those high in animal fats and refined sugars, have contributed to a serious obesity problem in Saudi Arabia.[22] Al-Nuaim[23] pointed out that obesity can cause impaired glucose tolerance, making obese patients more likely to develop diabetes. The high rate of consanguinity among Saudis may be one of the reasons for the rapid increase in prevalence.[21,24] In April 2021, the WHO launched the Global Diabetes Compact, a global initiative to reduce the risk of diabetes and ensure equitable access to comprehensive, affordable care and prevention

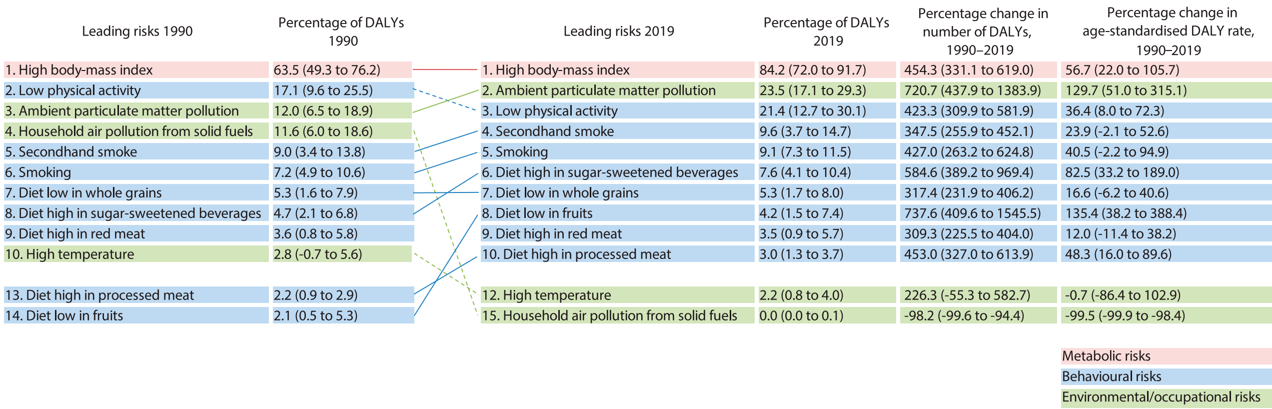


**Figure 3.** DALYs due to type 2 diabetes risk factors in Saudi Arabia 1990–2019. DALY: Disability-adjusted life years. The line connecting the boxes refers to changes in the ranking of risk factors, with the solid line indicating an increase in the ranking of the burden of disease due to risk factors and the dashed line indicating a decrease in the ranking of the burden of disease due to risk factors.

for people with diabetes.[25] As Saudi Arabia has a high burden of diabetes, reducing the burden of diabetes may bring more health benefits.

T2D can occur at any age but usually peaks in adults aged 65 years and older;[26] however, recent studies have found that T2D is becoming more prevalent in younger adults (aged < 40 years). Young-onset T2D is expected to become a more common feature of the broader diabetes population in both developing and developed countries,[27,28] which is consistent with the results of our study. The percentage of T2D DALYs in Saudi Arabia rose from 12.13% versus 14.85% in 1990 to 16.49% versus 18.73% in 2019 for men and women in the under-40 age group. Risk factors such as unhealthy eating habits and sedentary lifestyles are prevalent among young Saudis,[29] with an increase in the prevalence of T2D among Saudi youth.[30] This may be an essential cause of the increased burden in young people, and there is a need to enhance early and targeted screening for T2D in Saudi adolescents to control the growth of the T2D disease burden in young people. However, the proportion of T2D DALYs in people over 50 years of age remains predominant in both male and female individuals, and improving the health status of older adults remains an important measure to reduce the burden of T2D. The higher rate of DALYs caused by T2D in women under the age of 50 compared with that of men may be attributed to women's greater risk of developing T2D after childbirth.[31]

Our study refers to Gupta's decomposition method[17,18] to further decompose the T2D DALY changes. The decomposition results showed that population size, ageing, and prevalence all contributed to the increase in the burden of T2D. The burden of disease caused by ageing is not as severe as population size, but this does not mean that the effects of ageing can be ignored. Saudi Arabia is in transition to an ageing society with a steady and slow decline in the birth rate combined with a low death rate.[32] Population ageing may be an additional reason for the continued increase in total T2D deaths.[33] With the advent of an ageing society, the burden of T2D in Saudi Arabia is likely to grow as well. One positive note is that although the prevalence of T2D in Saudi Arabia has increased year by year, the severity of the disease has decreased, which may be related to Saudi achievements in the healthcare sector, such as the improvement in the level of medical care and the increase in the accessibility of health resources.[34]

In 2019, high BMI remained the most significant cause of T2D disease burden in Saudi Arabia among the 10 major T2D risk factors. High BMI is a significant risk factor for diabetes.[35] No country or region has seen a significant decrease in the proportion of people with a high BMI between 1990 and 2019 or in the past decade,[14,36] and the complete failure to reduce BMI levels at the national level means that changing physical inactivity and controlling diet quality and excessive energy intake can be very challenging but can have broad health benefits for people with diabetes.[14] Notably, reductions in household air pollution from solid fuels have led to significant reductions in disease burden, but these reductions may be offset by increases in ambient particulate matter pollution. Over three decades, the DALYs figure from ambient particulate matter pollution has risen by more than 700%, and in 2019 it became the second leading risk factor for T2D. Air pollution abatement may play an important role in reducing the disease burden caused by T2D in Saudi Arabia.[6]

There are some limitations that should be addressed in this study. First, GBD 2019 estimated incidence, prevalence, mortality, YLLs, YLDs, and DALYs for 369 countries and territories but did not separately assess the burden of disease in urban and rural areas. Some studies suggest that T2D is more prevalent in urban populations,[37] and future assessments of the urban–rural burden of T2D in Saudi Arabia could better improve the understanding of the Saudi T2D problem. Second, this is an ecological study, and the data for T2D are national-level estimates that inevitably suffer from ecological fallacies, thus the findings do not necessarily apply to individuals. Third, our estimates of the burden of disease and its changes are based on the Gupta decomposition method, and the results of the analysis are subject to the limitations of the method itself. For example, the method is not yet able to account for possible two-way and higher-order interactions between the factors of interest when decomposing their contributions.[38]

## Conclusion

In conclusion, the burden of T2D in Saudi Arabia has continued to rise over the past 30 years, and the decline in disease burden due to disease severity has been partially offset by factors such as population size and ageing; in addition, adverse trends in many risk factors in all aspects of metabolism, behaviour, and the environment have brought about an increase in disease burden. Saudi Arabia should continue to make T2D a public health priority to curb the growth of the T2D disease burden by controlling T2D risk factors.

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*Author contributions* – The authors' responsibilities were as follows: ZS designed the research; JH performed the data analysis; JH drafted the original manuscript; JH, ZS, BH, and SL critically revised the manuscript; ZS provided administrative support for the project and had primary responsibility for the final manuscript; JH, BH, and SL accessed and verified the data; all authors read and approved the final manuscript.

*Availability of data and materials* – Publicly available datasets were analysed in this study. This data can be found here: http://ghdx.healthdata.org/gbd-2019. The programmes used during the current study are available from the corresponding author on reasonable request.

*Supplementary data* – Supplementary data for this article can be accessed online at https://doi.org/10.1080/16089677.2024.2311494.

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