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Type 2 diabetes epidemic and key risk factors in Qatar: a mathematical modeling analysis

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ABSTRACT

Introduction We aimed to characterize and forecast type 2 diabetes mellitus (T2DM) disease burden between 2021 and 2050 in Qatar where 89% of the population comprises expatriates from over 150 countries.

Research design and methods An age-structured mathematical model was used to forecast T2DM burden and the impact of key risk factors (obesity, smoking, and physical inactivity). The model was parametrized using data from T2DM natural history studies, Qatar's 2012 STEPwise survey, the Global Health Observatory, and the International Diabetes Federation Diabetes Atlas, among other data sources.

Results Between 2021 and 2050, T2DM prevalence increased from 7.0% to 14.0%, the number of people living with T2DM increased from 170 057 to 596 862, and the annual number of new T2DM cases increased from 25 007 to 45 155 among those 20–79 years of age living in Qatar. Obesity prevalence increased from 8.2% to 12.5%, smoking declined from 28.3% to 26.9%, and physical inactivity increased from 23.1% to 26.8%. The proportion of incident T2DM cases attributed to obesity increased from 21.9% to 29.9%, while the contribution of smoking and physical inactivity decreased from 7.1% to 6.0% and from 7.3% to 7.2%, respectively. The results showed substantial variability across various nationality groups residing in Qatar—for example, in Qataris and Egyptians, the T2DM burden was mainly due to obesity, while in other nationality groups, it appeared to be multifactorial.

Conclusions T2DM prevalence and incidence in Qatar were forecasted to increase sharply by 2050, highlighting the rapidly growing need of healthcare resources to address the disease burden. T2DM epidemiology varied between nationality groups, stressing the need for prevention and treatment intervention strategies tailored to each nationality.

Significance of this study

What is already known about this subject?

- ► Diabetes has high prevalence among adult Qataris.
- ► Diabetes among Qataris is projected to increase substantially within the coming decades.
- ► Diabetes burden among the expatriate resident population that constitutes 89% of the total population of Qatar is poorly characterized.

What are the new findings?

- ► By 2050, diabetes prevalence in Qatar is projected to double, while incidence is projected to increase by 80%, respectively.
- ► Diabetes burden and drivers of the epidemic varied substantially between the various nationalities residing in Qatar.
- ► While obesity is clearly the key driver of the diabetes epidemic among Qataris, this was not observed in most of the expatriate population in Qatar.

How might these results change the focus of research or clinical practice?

- ► The characterization of diabetes in Qataris and the expatriate resident population informs prevention strategies and resource allocation.
- ► The high contribution of the expatriate population to incidence, but less so to prevalence, highlights the critical need for investment in prevention strategies.
- ► The mathematical model applied in this study can be used in future studies to assess impact of targeted prevention and intervention strategies.

INTRODUCTION

Diabetes mellitus (DM) is one of the fastest growing chronic conditions globally and is a key cause of cardiovascular diseases and premature death. Based on the 2019 International Diabetes Federation's (IDF) Diabetes Atlas, 12.8% (4.8 million) of adults aged 20–79 years in the Middle East and North Africa (MENA) are estimated to be living with DM today, and this proportion is expected to reach 15.7% (25.2 million) by 2045.[1]

Type 2 DM (T2DM), which accounts for 90% of DM cases,[1] is linked to non-modifiable (age, genetics, and sociodemographic factors, etc)[1–4] and modifiable (unhealthy diet, obesity, physical inactivity, tobacco use, and alcohol consumption, etc)[3 5–7] risk factors.[8,9] The risk of onset of T2DM increases with age. Incidence of T2DM accelerates for those 40–50 years of age,[8,10] but data are increasingly showing that it is occurring at younger ages in low-to-middle income countries compared with Western countries.[10] Evidence shows that the global epidemics of obesity and T2DM are closely linked, an association that has been consistent across populations and countries.[7,8,11–13] A systematic review and meta-analysis concluded that obesity increases the risk of T2DM by 7.2-fold (95% CI 5.7 to 9.0).[7] Studies have also reported lower T2DM prevalence in populations with higher levels of habitual physical activity.[14]

Qatar is part of MENA, with a population of 2.8 million in 2019, of which only 10.8% are Qataris and the remainder are expatriates from over 150 nationalities.[15–18] The sole DM nationally representative population-based survey (2012 Qatar STEPwise Survey[19]) was conducted only among Qataris aged 18–64 years and estimated that DM, obesity, physical inactivity, and smoking prevalence were 10.4%, 41.5%, 40.0%, and 16.3%, respectively.[20] The DM burden and levels of DM risk factors among the expatriate resident population that constitutes 89.2% of the population remain poorly characterized. Although DM is recognized officially as the leading public challenge in Qatar,[21] we believe that governmental response has been challenged by the conspicuous absence of a thorough understanding of DM epidemiology, DM incidence, and drivers of incidence.

The objective of this study was to provide estimates and projections for DM prevalence among the major nationality groups residing in Qatar. Specifically, we investigated T2DM epidemiology and forecasted its evolution until 2050, by adapting and applying a published mathematical modeling approach to the total population of Qatar.[22] We provided levels and trends of T2DM prevalence and incidence, as well as of obesity, physical inactivity, and smoking prevalence between 2021 and 2050.

RESEARCH DESIGN AND METHODS

Mathematical model

The Awad *et al*[22] model (for Qataris only) was extended and adapted to include all major nationality groups residing in Qatar. Model details, equations, and DM natural history parametrization are in Awad *et al*.[22] Briefly, the model is a population-based deterministic model consisting of a set of differential equations describing DM dynamics in the total population of Qatar (aged 0–99; figure 1) and has been adapted and applied in several studies.[23–26]

The model stratified the population by nationality, sex, age, and T2DM status, as well as by the presence or absence of three major T2DM-related risk factors and their overlap: obesity, physical inactivity, and smoking. These risk factors were based on those identified as relevant and potentially modifiable through public health programs.[20,22,24] Data regarding these factors were available from population-level surveys.[19,20] Individuals were assumed to develop T2DM at rates that depend on their nationality, sex, age, and these risk factors.

Data sources and model fitting

Model input parameters were based on epidemiological and natural history data as listed in figure 1 and online supplemental table S1, or by fitting the model to existing data on T2DM, T2DM-related risk factors, and demographics for each nationality group. Sex-specific and age-specific T2DM incidence rate and risk factor-related transition rates were derived by obtaining the best model fit to the input data.

Eight nationalities representing the population of Qatar were included in the analysis: Bangladeshi, Egyptian, Filipino, Indian, Nepalese, Pakistani, Qatari, and Others (all remaining nationalities of Qatar residents). These eight groups each constitute >5% of Qatar's total population.[16,18] The proportion of males, mean age, and overall proportion of Qatar's total population for each expatriate resident population can be found in online supplemental table S2.

DM and related risk factors for each nationality group

Qatari nationals

Sex-specific and age-specific prevalence data for DM, obesity, smoking, and physical inactivity were obtained from the 2012 Qatar STEPwise Survey.[19,20]

Expatriate nationality groups

Given the absence of Qatar-specific data for the expatriate nationality groups, data were procured from their home countries. Sex-specific and age-specific DM prevalence in 2019 for each expatriate nationality group aged 20–79 years were assumed to be the same as those in the country of origin and were obtained from the 2019 IDF Diabetes Atlas.[1] Sex-specific obesity (between 1975 and 2016[27]), smoking (between 2007 and 2008[28]), and physical inactivity (in 2016[29]) prevalence for each nationality group were also assumed to be the same as those in the country of origin and were obtained from the Global Health Observatory data repository.

To fit the actual obesity and smoking trends in the data, the rates for onset of these outcomes were parametrized to change over time using a logistic function. Meanwhile, given the availability of only one time point,[29] the physical inactivity rate was assumed constant—the population's evolving demographic structure was the only driving factor of the temporal change in the physical inactivity prevalence.

Demographics for each nationality group in Qatar

The total population size by sex (including Qataris and expatriates) and its future projections were obtained from the database of the Population Division of the United Nations Department of Economic and Social Affairs.[30]

The proportion of Qataris out of the total population was assumed to change over time based on fitting of data reported in the Gulf Labour Markets, Migration,

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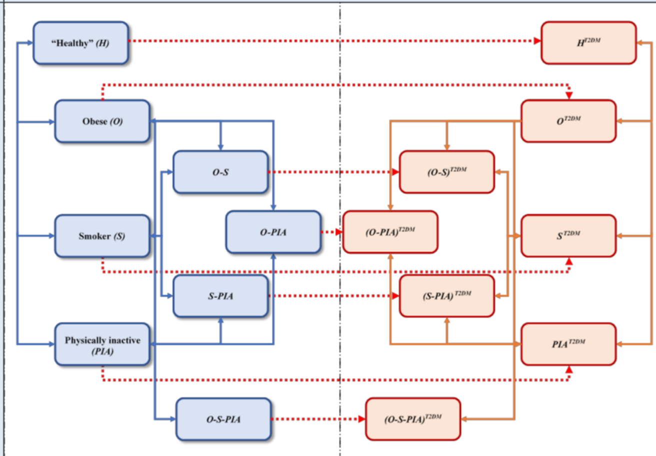
Methodology		Description
Conceptual framework		 **H**: Healthy. **O**: Obese. **S**: Smoker. **PIA**: Physically inactive. **O-S**: Obese and smoker. **O-PIA**: Obese and physically inactive. **S-PIA**: Smoker and physically inactive. **O-S-PIA**: Obese, smoker, and physically inactive. **T2DM**: Living with type 2 diabetes mellitus with status of risk factor of being obese, smoker, and physically inactive.

Type 2 diabetes mellitus (T2DM) model structure		- Expressed in terms of a set of 5,120 coupled differential equations.
		- Disaggregated the population into:
		  ○ Eight nationality groups: Bangladeshi, Egyptian, Filipino, Indian, Nepalese, Pakistani, Qatari, and Others
		  ○ Sex (female and male)
		  ○ Twenty 5-year age bands (0–4, 5–9… 95–99 years old)
		  ○ Four main susceptible classes: "healthy" (i.e., non-obese, non-smoker, non-physically inactive, and non-diabetic), obese, smoker, and physically inactive
		  ○ Four susceptible classes with overlapping risk factors
		  ○ Eight T2DM status classes based on the risk-factor status

Data Sources	Natural history and mortality data	○ Sex- and age-specific relative risks of developing T2DM for the risk factors were obtained from systematic reviews and meta-analyses of prospective cohort studies[5-7]:
		  ○ Relative risk of developing T2DM if obese[7]
		  ○ Relative risk of developing T2DM if current smoker[5]
		  ○ Relative risk of developing T2DM if physically inactive[6]
		○ Relative risk of developing T2DM if the individual has more than one risk factor was assumed to be the product of the individual risks.
		  ○ Relative risk of mortality in T2DM as compared to the general population was obtained from the DECODA (Diabetes Epidemiology: Collaborative Analysis of Diagnostic Criteria in Asia) study[38].

	Prevalence data	○ Epidemiological data for Qataris were obtained from 2012 Qatar STEPwise Survey[12 13]. Data included sex- and age-specific (by 5-years age band) prevalence for:
		  ○ T2DM
		  ○ Obesity
		  ○ Smoking
		  ○ Physical inactivity
		○ Epidemiological data for the other nationality groups were obtained from the International Diabetes Federation Atlas[1] (for T2DM), and from the Global Health Observatory data repository (for obesity[19], smoking[20], and physical inactivity[21]).

	Demographic data	○ Total and sex-specific population size was obtained from the database of the Population Division of the United Nations Department of Economic and Social Affairs[22]. ○ Age-specific population size and/or distribution by age group were obtained from Qatar's Planning and Statistics Authority[9 11]. ○ Nationality-specific proportion of the population was obtained from Qatar's Planning and Statistics Authority[9 11].

Fitting method		○ The model was fitted to all available country-specific data using a nonlinear least-square fitting method[39].
		○ Parameters quantified through best fit included sex- and age-specific:
		  ○ T2DM baseline incidence rate (i.e., incidence rate from "healthy" to T2DM)
		  ○ Transition rate from healthy to obese
		  ○ Transition rate from obese to healthy
		  ○ Transition rate from healthy to smoker
		  ○ Transition rate from smoker to healthy
		  ○ Transition rate from healthy to physically inactive
		  ○ Transition rate from physically inactive to healthy

Uncertainty-analysis		- Multivariable uncertainty analysis was conducted using Latin Hypercube sampling[25 26] to specify the ranges of uncertainty in projected T2DM outcomes, with respect to variations in the key structural model parameters.
		- 1,000 model runs were generated in this analysis.
		- Parameters varied in the uncertainty analysis were relative risks of:
		  ○ Developing T2DM if obese
		  ○ Developing T2DM if smoker
		  ○ Developing T2DM if physically inactive
		  ○ Mortality in T2DM as compared to the general population

T2DM: Type 2 diabetes mellitus

Figure 1 Description of the mathematical modeling methodology applied in this study. A detailed description can be found in Awad *et al*.[22]

and Population Programme[31] and Qatar's Planning and Statistics Authority[16 18] (online supplemental figure S1).

The proportion of each expatriate nationality group out of the total expatriate population was based on data from Qatar's Planning and Statistics Authority,[16 18] and was assumed stable throughout the projected time horizon (online supplemental table S2). The age-specific population distribution for each nationality group (including Qataris) in 2019 was based on data of Qatar's Planning and Statistics Authority.[16] Immigration and emigration were incorporated through age-dependent and time-dependent rates that were derived by fitting the age-specific population size for each nationality group in 2019 and the total population by sex over time (online supplemental text S1 and figure S2).

Projecting the burden of T2DM and risk factors

Using the best-fit parameters, sex-specific and age-specific prevalence of T2DM, obesity, smoking, and physical inactivity were projected between 2021 and 2050 in the population aged 20–79 years. Total numbers of prevalent and incident T2DM cases (ie, the annual number of new cases) were also predicted. The effect of each risk factor on T2DM was also estimated through a population attributable fraction approach.[22 32] These estimates where reported for Qatar as a whole and for each nationality group.

Sensitivity analyses

To investigate the impact of population aging on projected T2DM burden (as opposed to other factors such as obesity), a sensitivity analysis was conducted where, from 2020 onward, first, T2DM incidence rate was assumed independent of age (ie, to control the effect of aging by using a uniform incidence rate for all ages). Second, to control the effect of obesity on the prevalence of T2DM, another sensitivity analysis was conducted. Here, as opposed to the predicted increase in obesity trend, the impact of a stable obesity prevalence between the years 2020 and 2050 was assessed. These analyses were only conducted for the Qatari population as the T2DM burden in this population is mainly driven by aging and obesity.[22]

Uncertainty analysis

The 95% uncertainty intervals (UIs) around the projected T2DM outcomes were estimated with a multivariable uncertainty analysis of 1000 model runs, applying Latin Hypercube sampling from a multidimensional distribution of the parameters.[33 34] In each run, we varied simultaneously the relative risk (RR) of mortality and of developing T2DM for individuals who are obese, smoker, and physically inactive. We used a ±30% uncertainty around the age-specific and sex-specific RRs of the mortality point estimates and a 95% CI for the remaining parameters (online supplemental table S1). The T2DM model was refitted for each set of new input parameter values, and the 95% UIs were derived from the distribution of outcomes over the 1000 model runs.

The mathematical model was implemented in, and all analyses were conducted using, MATLAB V.2019a.[35]

RESULTS

The model fitted population size, sex-speciic and age-specific T2DM prevalence data, and data for the risk factors, obesity, smoking, and physical inactivity for each nationality. Online supplemental figure S3 shows the model fits for Qataris and 0nline supplemental figure S4 shows the model fits for the Indian nationality group as an example of one expatriate group.

T2DM burden between 2021 and 2050

T2DM prevalence among 20–79 years old living in Qatar was projected to increase from 7.0% currently to 14.0% in 2050 (figure 2A). That among Qataris increased from

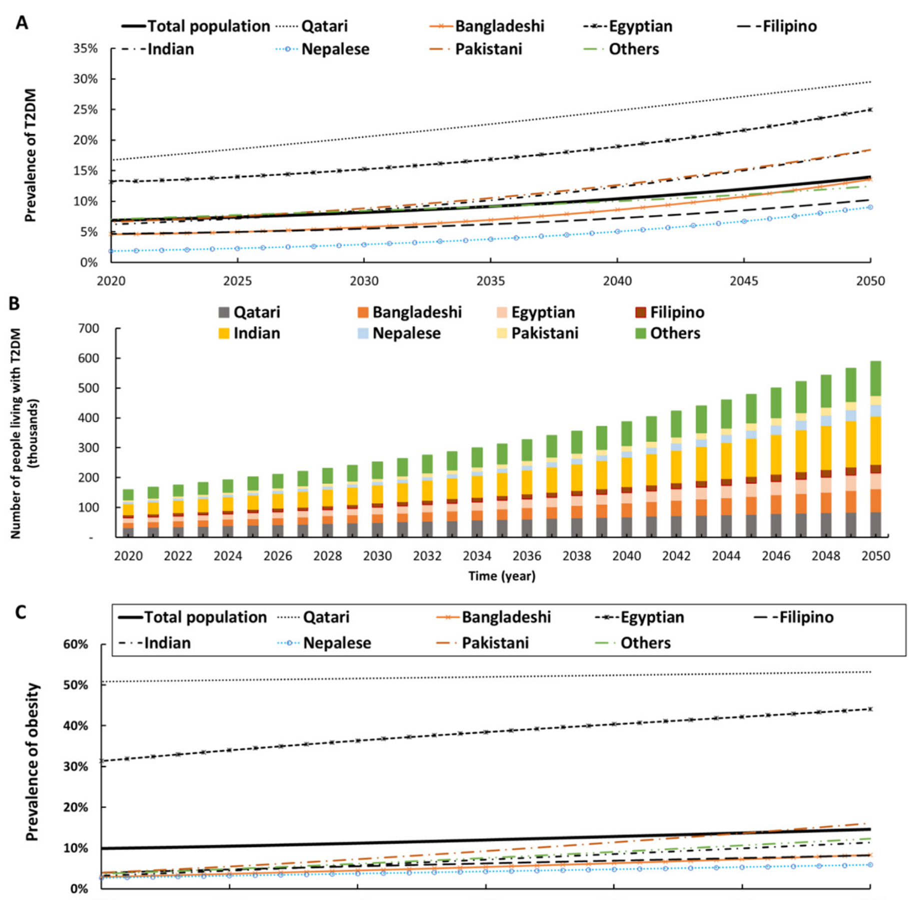


Figure 2 Projected type 2 diabetes mellitus (T2DM) prevalence for various nationality groups in Qatar between 2020 and 2050: (A) T2DM prevalence (proportion) and (B) total number of people living with T2DM, among persons aged 20–79 years. (C) Model projections for obesity prevalence among the various nationality groups in Qatar between 2020 and 2050.

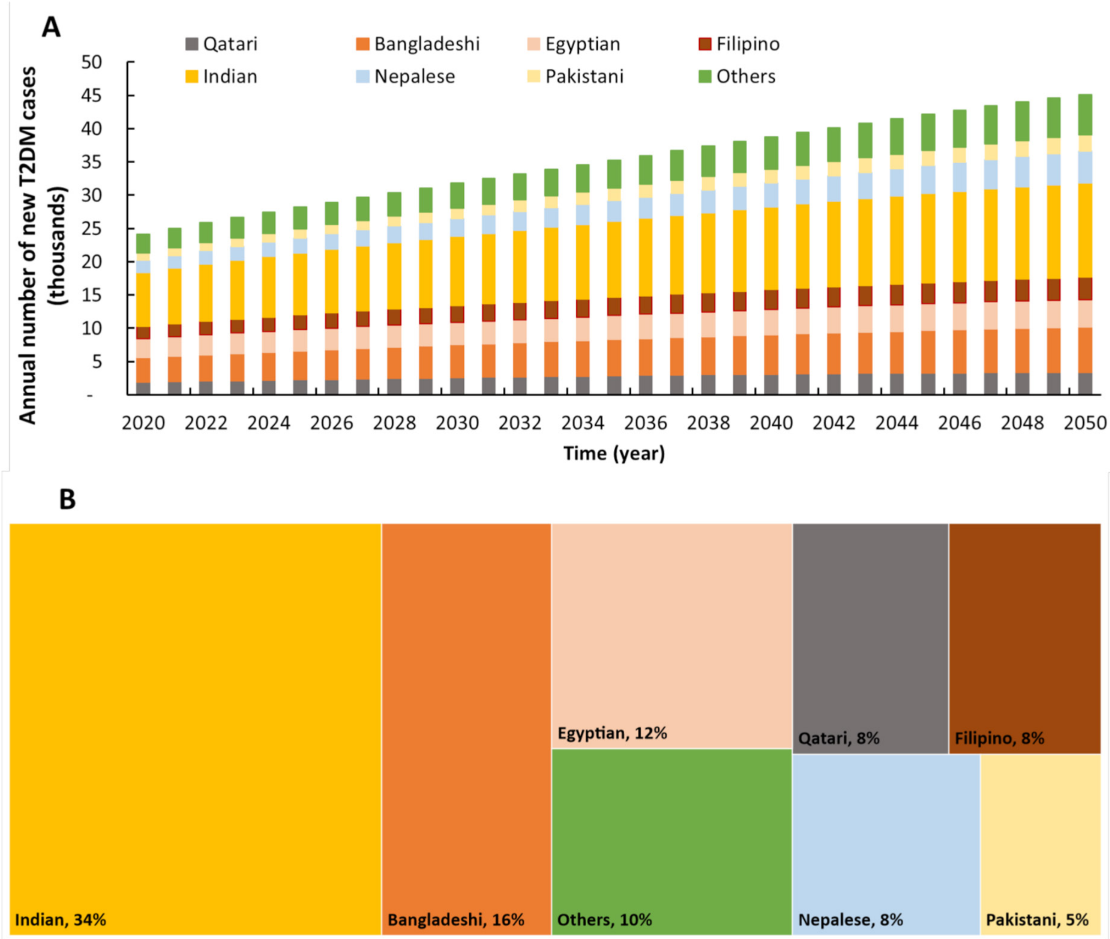


Figure 3 Projected type 2 diabetes mellitus (T2DM) incidence among the various nationality groups in Qatar between 2020 and 2050. (A) The annual number of new T2DM cases and (B) the proportion of new T2DM cases by nationality group, among persons aged 20–79 years.

17.1% to 29.5% in 2050. For expatriate groups, T2DM prevalence is lowest among Nepalese at 1.9% and highest among Egyptians at 13.2%, projected to reach 9.1% and 25.0% in those groups, respectively, in 2050 (figure 2A and online supplemental table S3).

The number of T2DM cases in Qatar will increase from 170 057 to 596 862 in 2050 (figure 2B). Most present cases were estimated among Indians (27% of all cases) followed by Qataris (14%), Bangladeshis (13%), Egyptians (10%), Nepalese (6%), and Pakistanis and Filipinos (5% each; figure 2B). Other nationalities combined comprised 19% of cases (figure 2B).

The annual number of new T2DM cases is expected to increase from 25 007 in 2021 to 45 155 in 2050 (figure 3A). Throughout the next three decades, Indians are projected to comprise the largest number of new cases (34% of new cases), followed by Bangladeshis (16%), Egyptians (12%), Qataris (8%), Nepalese (8%), Filipinos (8%), and Pakistanis (5%; figure 3B). Other nationalities combined comprised 10% of new cases (figure 3B).

Obesity, smoking, and physical inactivity from 2021 to 2050

Obesity prevalence among persons 20–79 years old living in Qatar increased from 8.2% in 2021 to 12.5% in 2050 (figure 2C). Obesity prevalence among Qataris is substantially higher than that for other nationalities, 50.9% today and expected to reach 53.2% in 2050. In other groups, obesity prevalence was lowest among Bangladeshis at 3.0% in 2021 and 8.4% in 2050, and highest among Egyptians at 31.9% and 44.1%, respectively (figure 2C).

Smoking prevalence among persons 20–79 years old living in Qatar is expected to decline slightly from 28.3% in 2021 to 26.9% in 2050 (figure 4A). Smoking prevalence among Qataris is lower than that of other groups, 17.6% at present, but increasing to 20.2% in 2050. In other nationality groups, smoking prevalence was lowest among Indians at 20.4% currently and 18.5% in 2050, and highest among Bangladeshis at 43.7% and 42.2%, respectively (figure 4A).

Physical inactivity prevalence among those 20–79 years old living in Qatar slightly increased from 23.1% today to 26.8% in 2050 (figure 4B). Physical inactivity prevalence was highest for Qataris at 40.1%, rising to 45.3% by 2050. In other groups, physical inactivity prevalence was lowest among Nepalese at 12.2% in 2021 and expected to reach 17.7% in 2050. It was highest among Filipinos at 39.9% in 2021 and 44.0% in 2050 (figure 4B).

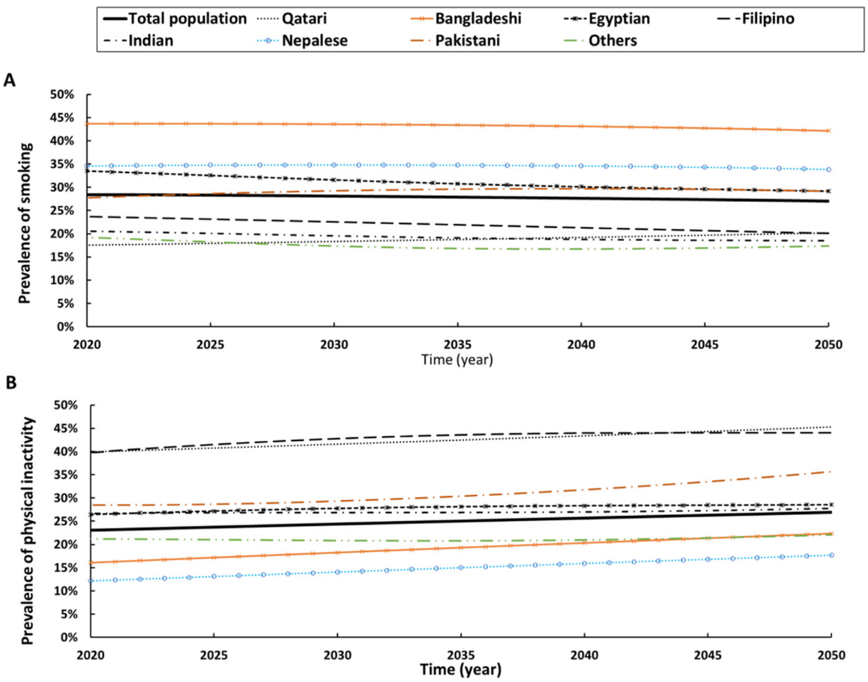


Figure 4 Model projections for key type 2 diabetes mellitus (T2DM) risk factors among the various nationality groups in Qatar between 2020 and 2050. The figure shows the projected prevalence of (A) smoking and (B) physical inactivity, for persons aged 20–79 years.

T2DM attributed to each risk factor between 2021 and 2050

The proportion of incident T2DM cases attributed to obesity among those 20–79 years old living in Qatar is expected to increase from 21.9% now to 29.9% in 2050. Among Qataris, the proportion of incident T2DM cases attributed to obesity should decrease slightly from 68.3% to 65.3% in 2050 (figure 5). In other nationality groups in 2021, this proportion was lowest among Indians at 10.5% and highest among Egyptians at 56.9%. In 2050, this proportion is expected to be lowest among Nepalese at 14.9% and highest in Egyptians at 60.3% (figure 5).

The proportion of incident T2DM cases attributed to smoking among those 20–79 years-old living in Qatar is anticipated to slightly decrease from 7.1% to 6.0% by 2050. For Qataris, the proportion of incident T2DM cases attributed to smoking may increase very slightly from 1.9% to 2.1% in 2050 (figure 5). For other nationality groups in 2021, this proportion was lowest among Pakistanis at 4.8% and highest among Bangladeshis at 12.6%. In 2050, this proportion is projected to be lowest among Filipinos at 3.6% and highest among Bangladeshis at 10.7% (figure 5).

The proportion of incident T2DM cases attributed to physical inactivity among those 20–79 years old living in Qatar hovered around 7% between 2021 and 2050. In Qataris, the proportion of incident T2DM cases attributed to physical inactivity may increase very slightly from 4.2% in 2021 to 4.7% in 2050 (figure 5). In other groups, this proportion at present is lowest among Nepalese at 4.2% and highest among Filipinos at 12.7%. In 2050, this proportion will be lowest among Egyptians at 4.0% and highest among Filipinos at 12.9% (figure 5).

Sensitivity analyses

The two sensitivity analyses, conducted to investigate the impact of an aging population and obesity on the estimated T2DM trends, highlighted the role of aging on the increasing prevalence of T2DM. After the year 2020, when the T2DM incidence rate was assumed independent of age (to control the effect of aging), the prevalence of T2DM among Qataris increased only modestly from 17.1% to 19.3% (online supplemental figure S6A). However, when the obesity prevalence was held constant between the years 2020 and 2050 (to control the effect of obesity; online supplemental figure S6B), the prevalence of T2DM among Qataris increased substantially from 17.1% to 28.1% (online supplemental figure S6A). This outcome reflects the future role of aging on the growing prevalence of T2DM in Qatar.

Uncertainty analysis

The uncertainty analysis results for the trend in T2DM prevalence between 2021 and 2050 in the 20–79 year old population living in Qatar is shown in online supplemental figure S7. Despite the uncertainty in input parameters, the uncertainty range of the predicted T2DM prevalence was relatively small, supporting the consistency of the above estimates.

DISCUSSION

T2DM prevalence in Qatar is currently estimated in this study at 7%, just below the global average of 9%,[1] but is projected to double by 2050, mainly due to population aging[9] (online supplemental figure S6A), especially

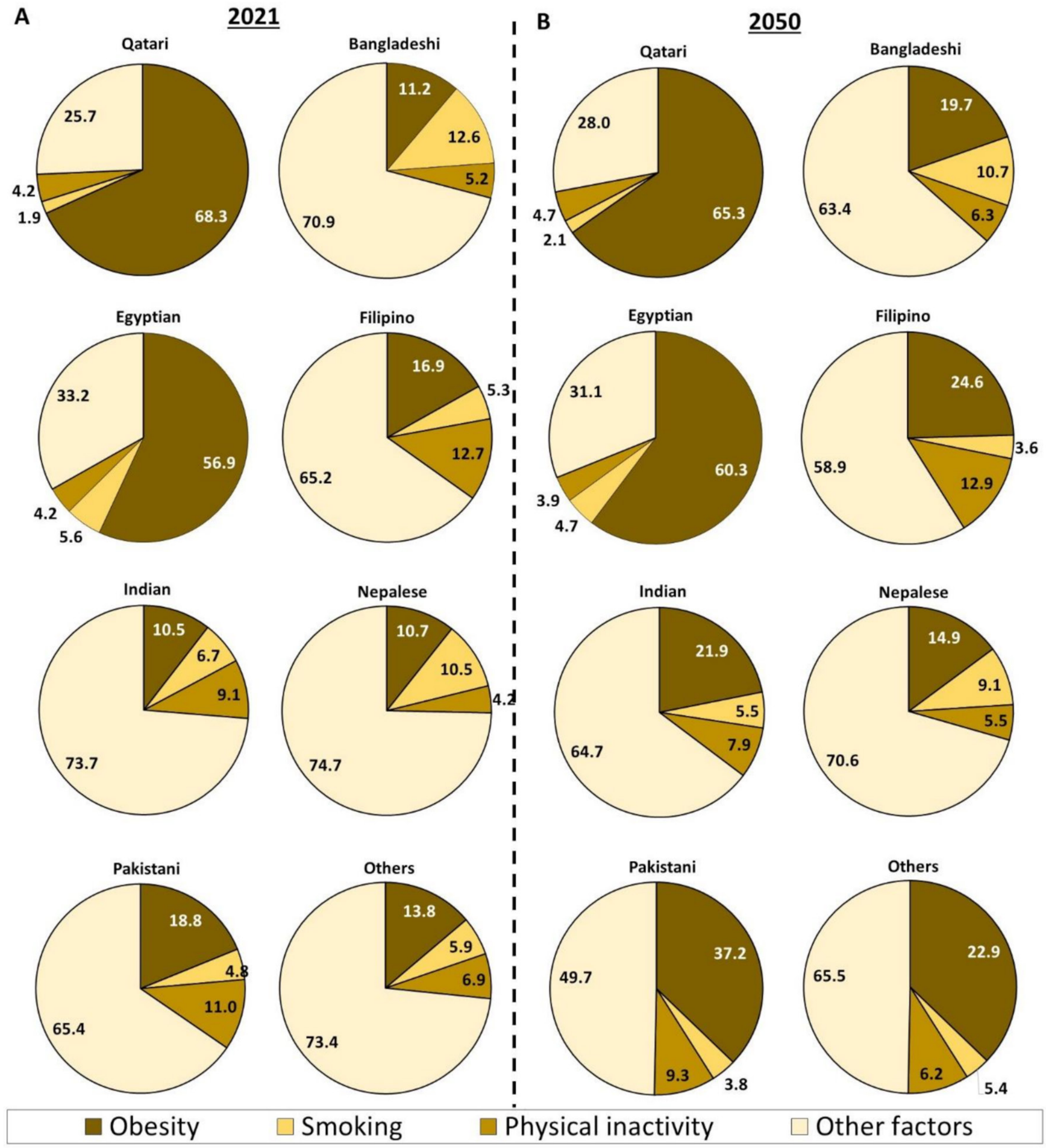


Figure 5 Model projections for the proportions of type 2 diabetes mellitus incidence attributed to obesity, smoking, and physical inactivity among the various nationality groups in Qatar in (A) 2021 and (B) 2050.

for Qataris who constitute the permanent population of this country (online supplemental figure S5 shows the increase in mean age for each nationality group in Qatar). Increasing T2DM prevalence coupled with population growth forecast a sharp increase of people living with T2DM from just over 170 000 at present to nearly 600 000 in 2050 highlighting the rapidly growing need for healthcare resources to address the diabetes disease burden in this country. Obesity was the leading driver of T2DM incident cases with a projected increase from 19% today to 28% by 2050. Smoking and physical inactivity contributed to this incidence at around 8% each between 2021 and 2050.

This study is the first to estimate the burden of T2DM in the total population of Qatar, and its variation by nationality in this unique country where 89% of the resident population comprises expatriates (mainly males) from over 150 countries.[15–18] We found that the T2DM burden and drivers of the epidemic varied substantially by nationality. For instance, T2DM prevalence among Qataris and Egyptians was much higher than that among Nepalese and Filipinos, among others (figure 2).

While obesity is clearly the key driver of the T2DM epidemic among Qataris, this was not observed in most of the expatriate population in Qatar (figure 5). One quarter of T2DM cases among expats were related to obesity, while more than half of the cases appeared to be related to other factors. Since the majority of expats are of Asian ethnicity, these factors could include reduced insulin secretory function/increased insulin resistance, increased visceral fat in people with low body mass index (BMI), and young onset of DM.[36–39] Evidence suggests that people of Asian ancestry have about five to six times higher risk of developing DM than white Europeans.[38 40] Further research within Qatar is needed to understand the drivers behind the T2DM burden in the country, specifically in the expatriate population groups.

One key finding of this study is that, unlike in other permanent populations, the contribution of incidence versus prevalence is remarkably different and varies by nationality, as most expatriates do not typically reside more than two decades in Qatar.[16 18] This means that different contributions of individual nationality groups to incidence versus prevalence result from the interplay of immigration, emigration, and aging for each nationality. As illustrated in online supplemental figure S5, the mean age among the expatriates ranged within a small interval of 30–40 years between 2021 and 2050, as a consequence of expatriates staying for only a decade or so in Qatar, and thus the lower overall prevalence of T2DM in Qatar. For example, Qataris contributed only 8% of incident cases vs 14% of prevalent cases. Meanwhile, Indians contributed 34% of incident cases vs only 28% of prevalent cases, due to emigration at older ages (figures 2B and 3). This is especially true for the expatriate craft and manual workers who comprise 60% of the population in Qatar.[41] These workers are typically single men, aged 20–49 years, recruited to work in development projects, and mostly of Bangladeshi, Indian, Nepalese, and Pakistani nationalities.[18 41] The high contribution of these expatriate groups to incidence, but less so to prevalence, highlights the critical need for investment in prevention strategies. Many will develop DM and be diagnosed in Qatar, but may live the rest of their life with DM elsewhere after the end of their employment in Qatar.

Based on the 2019 IDF Diabetes Atlas,[1] 15.5% of adults in Qatar were estimated to be living with T2DM, which is substantially higher than that estimated in the present study. Differences in the T2DM levels and projections are in part due to differences in input data and the modeling methodology used for the projections—IDF based their estimates and projections on data from Qatar's neighboring countries and using a logistic regression method for projection as opposed to a dynamical population-level model for T2DM and its key risk factors.[1] Also of note, compared with previous projections for T2DM among Qataris,[22] the T2DM epidemic among Qataris in the present study was forecasted to progress faster reaching higher T2DM prevalence by 2050 (figure 2A). The main reason for this increase is the higher mean age of Qataris projected by 2050 (online supplemental figure S5). While the previous study projected a mean age of 38 years by 2050,[22] the present study projected a mean age of 48 years, based on updated demographic data from Qatar[9 11 31] (online supplemental figure S5).

Predictions in this study may be limited by the representativeness of the model input data for each nationality, particularly the data on current levels of DM, obesity, smoking, and physical inactivity. We had to procure data from home countries for the expatriate nationality groups, as we did not have Qatar-specific data for these populations. Living in Qatar, behavioral factors impacting T2DM among expats may differ from their home countries. This highlights the need for nationally representative surveys in Qatar that include all national groups in the country.

BMI $\geq 30\,kg/m^2$ was used to define obesity for all nationalities because it is standard to obtain from existing data.[42] However, the application of current BMI cut-off points for Asians may underestimate the level and impact of obesity on T2DM in these groups.[36 37 43 44] Current data do not indicate a clear BMI cut-off point for obesity among Asians. However, the WHO has recommended a BMI cut-off point of 27.5 kg/m^2 to potentially represent obesity among Asian populations.[37] Other studies on Asian populations have shown that even lower values might be compatible with a BMI of 30 in white European populations.[44] Another limitation could be the representativeness of the RR estimates of T2DM with respect to risk factors and disease-related mortality for the various population groups in Qatar. However, given that these RRs were pooled from multiple settings worldwide,[5–7] they should represent biological mechanisms that are probably universal in effect. The data on physical inactivity levels were self-reported and potentially inflated relative to objective biomarkers.[45] We conducted a multivariable uncertainty analysis to factor these uncertainties in the parameters. The analysis indicated rather narrow uncertainty intervals around point estimates, affirming our predictions (online supplemental figure S7).

In conclusion, T2DM burden in Qatar is projected to increase substantially over the next three decades with obesity being a leading driver of the epidemic. Among Qataris specifically, population aging is also a main driver of the increasing burden. Given the unique demographics of Qatar, T2DM incidence, prevalence, and attributed risk factors varied substantially between different nationality groups highlighting the need to investigate drivers of T2DM in each group. The contribution of incidence versus prevalence also varied by group, reflecting the interplay of immigration, emigration, and aging for the various groups. These findings stress the need for prevention and treatment intervention strategies tailored to each group's needs. Given these ongoing demographic and epidemiological health transitions, ensuring long-run financial sustainability for a T2DM response in Qatar could be challenging. Therefore, population-level prevention and intervention strategies should be a priority to alleviate the growing T2DM burden.

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