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ORIGINAL ARTICLE

Estimating diabetes prevalence in Turkey in 2025 with and without possible interventions to reduce obesity and smoking prevalence, using a modelling approach

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Abstract

Objectives The purpose of this study is to estimate the prevalence and the number of people with type 2 diabetes (T2DM) in 2025 in Turkey and to evaluate the impact of possible policy options on T2DM prevalence.

Methods We developed a model to predict future prevalence of T2DM using trend data for adults aged 25–74 in Turkey from 1997 to 2025. The model integrates population, obesity and smoking trends to estimate the future T2DM prevalence using a Markov approach.

Results T2DM prevalence was 7.5 % (95 % CI: 6.0–9.0 %) in 1997 increasing to 16.2 % (95 % CI: 15.5–21.1 %) in 2010. The forecasted prevalence for 2025 was 31.5 % (28.6 % in men and 35.1 % in women). If obesity prevalence declines by 10 % and smoking decreases by 20 % in 10 years from 2010, a 10 % relative reduction in diabetes prevalence (1,655,213 individuals) could be achieved by 2025.

Conclusions Diabetes burden is now a significant public health challenge, and our model predicts that its burden will increase significantly over the next two decades. Tackling obesity and other diabetes risk factors needs urgent action.

Keywords Markov model · Diabetes · Projection · Intervention · Obesity

This article is part of the supplement "The rising burden of noncommunicable diseases in four Mediterranean countries and potential solutions".

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Introduction

The burden of type 2 Diabetes Mellitus (T2DM) has reached epidemic proportions, affecting 285 million people worldwide and 70 % of these live in low- and middle-income countries (Whiting et al. 2011). Contribution of diabetes (DM) to total disease burden in terms of disability-adjusted life years (DALYs) rose enormously during last two decades. Globally, the ranking of DM among all diseases increased from 21st to 16th with a 69 % increase in DALYs (Murray et al. 2012). Rapid economic transition, urbanization, increased longevity, physical inactivity, unhealthy diet and metabolic risk factors such as obesity contributed to this increase in diabetes epidemic (Hu 2011).

Turkey is in now in the epidemiological transition hence it is expected that burden of non-communicable diseases and related risk factors will be increasing in the coming period (Akgun et al. 2007). Diabetes Mellitus is one of the leading causes of death in Turkey accounting for approximately 33,000 deaths annually (Unwin et al. 2009). Earlier projections estimated the prevalence of T2DM among adults over 20 years old in Turkey as 7.4 % in 2010 (Whiting et al. 2011). However, a recent nationally representative study reported that the burden was almost double this level (13.7 %) and that awareness rates were low (Satman et al. 2013). The total prevalence of DM across Turkey ranges between 12.7 and 14.7 % according to various regional and nationwide studies (Ergor et al. 2012; Suleymanlar et al. 2011; Teo et al. 2009; Unal et al. 2012). Sampling procedures, participation rates, age groups, urban–rural representation and definitions for diabetes varied in these studies limiting direct comparison of diabetes prevalence. For example, TURDEP-II was a cross-sectional, population-based survey that included 26,499 people older than 20 from both urban and rural areas with an 89 % participation rate. This study used oral glucose tolerance test (OGTT) in addition to fasting glucose assessment after at least 10 h of overnight fasting to diagnose DM. However, the Turkish Chronic Diseases and Risk Factors Study involved 10,872 participants and OGTT was not applied.

The Turkish Ministry of Health (MoH) has prepared and started to implement action plans targeting obesity, smoking, physical inactivity and diabetes. The MoH also aims to reduce the prevalence of DM and impaired glucose tolerance by 5 % by year 2020 (Tatar 2013). Smoking rates declined especially among men with comprehensive interventions during last decade; however, obesity prevalence increased from 12.8 to 25.9 % among men and 29.2 to 41.7 % among women between 1997 and 2010 (Satman et al. 2013). According to the Turkish part of Global Adult Tobacco Survey (GATS) conducted in 2008 and 2012, smoking prevalence significantly decreased among adults from 31.2 % in 2008 to 27.1 % in 2012, representing a 13.4 % relative decline. These findings can be attributed to implementation of strict tobacco control policies and further reductions in smoking rates are expected in the future (Kostova et al. 2014).

Estimates of the future burden of diabetes and evaluation of the possible impact of preventive measures on DM prevalence are required for allocating health resources and to help policy makers for planning future health care needs. Several modelling studies were conducted to produce estimates of diabetes prevalence mostly for the United States and other parts of the world (Boyle et al. 2010; Wild et al. 2004), but few of these have taken into account trends in major epidemiological risk factors. The aim of our study is to estimate the prevalence and the number of people with diabetes in 2025 in Turkey, taking into account both changes in demographics (population ageing) and risk factors for T2DM and to evaluate the impact of possible policy options on diabetes prevalence including smoking cessation and reducing obesity. We believe that these findings can make guidance both for planning preventive activities and future health care requirements in Turkey.

Methods

Model structure

The IMPACT Diabetes model is a Markov state-transition model which was used to estimate future T2DM prevalence in Turkey and to evaluate the impact of various intervention scenarios for policy decision making by integrating information on population, obesity and smoking trends at a given point of time (Maziak et al. 2013). The model has also been implemented in other countries (Abu-Rmeileh et al. 2013; Al-Quwaidhi et al. 2014; Al Ali et al. 2013). In total, six states are modelled: four health (starting) states (Healthy, Obese, Smoker, Diabetes and two absorbing states (Death from DM and Death from other causes). The relationships of health states are shown in the transition diagram in Fig. 1.

The healthy state is composed of individuals who are not smokers, obese or with T2DM. Initial age- and gender-specific prevalence of obesity, smoking and diabetes are incorporated with the census data to partition the Turkish adult population into the non-absorbing states. In other words, population demographic trends are used to inform the relative size of the ‘starting states’, and transition

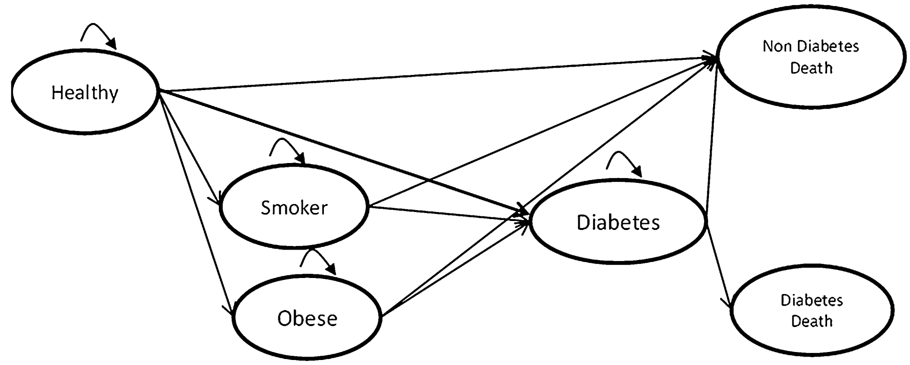

Fig. 1 Health states modelled in the Diabetes Model, Turkey, MedCHAMPS study

Table 1 Change in obesity and smoking prevalence between 1997 and 2015, Turkey, MedCHAMPS study

Years	Obesity (BMI ≥ 30 kg/m^2) %		Smoking %	
	Men	Women	Men	Women
1997	17.8	32.8	49.0	10.5
2005	23.3	38.3	38.5	10.4
2010	26.9	42.0	32.0	10.3
2015	31.2	45.7	25.2	10.4
2020	34.8	48.8	19.0	10.3
2025	38.0	50.3	13.9	10.1

probabilities are used to estimate the proportion of persons moving from the starting states to the diabetes and death states. In each annual cycle, individuals have a conditional probability of developing DM, staying in one of the four health states or dying from other causes. Individuals in the DM state can remain with diabetes or die from DM or non-DM causes at every cycle. The model requires data by 10-year age and sex groups, starting at age 25–34 and ending at age 65–74 years age band. Data needed for the initial year included population size, diabetes prevalence, obesity prevalence, smoking prevalence and total mortality. Data needed for subsequent years for forecasting purposes include population projections, obesity and smoking trends. The sources of data used for trend and validation are listed in Table 1 and described in the "data sources" section below.

The transition probability for moving from the healthy state to DM is based on age- and gender-specific incidence of DM. DM incidence cannot generally be estimated directly from population surveys anywhere in the world and this is also the case in Turkey. We therefore estimated incidence using DISMOD II software (Barendregt et al. 2003). DISMOD II calculates incidence, case fatality and total mortality rates needed for the DM model using data on age- and gender-specific prevalence, remission (assumed to be zero) and relative risk for mortality among people with DM. We also defined transition probabilities of developing DM for the obese and smoker states. Potential overlaps between the healthy, obese and smoking group are estimated by calculating the conditional probabilities of membership, thereby estimating the proportion of new cases of diabetes that can be attributed to smoking and obesity at each cycle. The time horizon of the model extends to the age of 75, and the cycle length is 1 year. The model was implemented using the Microsoft Excel™ spreadsheet package.

Key assumptions in the model are that the risks of death for the health states and the transition rates to diabetes from healthy groups are constant over time. However, the model uses time-dependent incidence values, which means that within each age cohort, as the individuals age, the incidence changes to reflect that. A detailed description of the model, including all assumptions, references for key parameter estimates, and algebraic derivations is presented in Electronic supplementary material.

Data sources

We used the most reliable data after critical appraisal of available data sources in local settings. Population data were obtained from Turkish national census data (TUIK 2013). Population trends after 2010 were obtained from projections provided by Turkish Statistical Institute (TURKSTAT) for the years 2013–2020 (TURKSTAT 2013). Linearly interpolated data were used for missing years. Diabetes prevalence values for the initial year were obtained from the nationwide cross-sectional Turkish Diabetes Epidemiology Study (TURDEP-I) (Satman et al. 2002). We used adjusted prevalences generated by DISMOD II from the TURDEP-I study. The prevalence estimates input to model are given in Table 4 of the Supplementary Appendix. Obesity was defined as body mass index (BMI) ≥ 30 kg/m^2 for both men and women. Data for obesity came from national population-based surveys; The Turkish Adult Risk Factor Survey (TEKHARF-1990), TURDEP-I (1997) and TURDEP-II (2010) (Satman et al. 2002, 2013; Yumuk 2005). Obesity trends were estimated by extrapolating the available data for future years assuming that the same trend will continue in the coming period. The assumed projections in obesity prevalence were also supported by recent estimates of trends in mean BMI by the WHO Global Burden of Disease Study, 2011, which also showed a linear increasing trend in mean BMI in Turkey (Finucane et al. 2011) We set upper limits to the obesity trends in the model if the projected prevalence in any age-gender group exceeded 60 %, because the evidence suggests that in some populations plateauing of the obesity prevalence rates has already been observed, see the Electronic supplementary material for details (Schneider et al. 2010; Stevens et al. 2012). Smoking was defined as current daily cigarette smoking. Smoking rates were obtained from two studies; TURDEP-I (1997) and TURDEP-II (2010) (Satman et al. 2002, 2013). Total mortality rates were obtained from the life tables generated by World Health Organization for Turkey (WHO 2013). The model provided estimates using the analysis of extremes method (Briggs et al. 1994), consisting in running the model with all parameters set to minimum and maximum realistic values. The sensitivity analyses are updated by running a macro implemented in the Excel sheet.

Scenario analysis

Besides estimating the prevalence of DM in 2025, we additionally evaluated five "what if" scenarios based on the health policy options available in national and international documents targeting obesity and smoking. The first scenario was based on a target for specific reductions in the prevalence of adult obesity as set out by the obesity prevention and control plan of Ministry of Health of Turkey. This target is to reduce the prevalence of obesity by 5 % over a 5-year time period (MoH 2010). The second scenario was to halt the rise in obesity prevalence at 2010 levels until the year 2015 (WHO 2011). The third scenario was to halt the rise in obesity prevalence and also to achieve a 40 % reduction in smoking prevalence by 2025 compared to year 2010 (WHO 2011). The last two scenarios assessed the impact of a 10 % relative reduction in obesity prevalence and a 20–40 % reduction in smoking prevalence by 2025 starting in 2010 on diabetes burden in Turkey. All scenarios are based on population-wide reductions in future obesity prevalence.

Results

Population characteristics at starting point and risk factor trends during 1997–2025

The changes in obesity and smoking prevalence were assumed to be linear in men and women and within the different age groups. The obesity prevalence increased in both men and women while smoking prevalence decreased over the period 1997–2010. Obesity prevalence has increased from 17.8 % in men and 32.8 % in women in 1997 to 26.9 % in men and 42.0 % women in 2010.

Smoking rates significantly decreased from 49.0 % in 1997 to 32.0 % in 2010. Smoking prevalence was around 10 % for women in the same time period, falling slightly.

Diabetes incidence and total mortality

According to the DISMOD II outputs, the estimated annual diabetes incidence was higher in women than in men (1144 per 100,000 vs. 940 per 100,000). The estimated diabetes mellitus related case fatality rate was also higher among women (594 per 100,000) compared to men (367 per 100,000) for the year 1997. The rates showed an increasing trend with age for both diabetes incidence (from 254 per 100,000 in the 25–34 year age group to 2336 per 100,000 in the 65–74 year age group), and diabetes case fatality rate (from 181 to 6051 per 100,000 in the 25–34 year and the 65–74 year age groups, respectively).

Model diabetes prevalence estimates

Model estimates of Diabetes Mellitus projected a substantial increase in diabetes prevalence in Turkey from 7.5 to 31.5 %, and in the number of patients with diabetes (from 2,193,508 to 16,143,941) between 1997 and 2025. In women, the prevalence and number of patients with diabetes were estimated to be 8.7 % and 1,262,175, respectively, in 1997 and 34.7 % and 8,929,164, respectively, in 2025. In men, the numbers are slightly lower than women; 6.3 % (931,333) in 1997 and 28.2 % (7,214,777) in 2025. However, the relative increase in the prevalence of diabetes and number of people with diabetes is higher in men than in women (347.6 and 674.7 % in men vs. 298.7 and 607.4 % in women) during the same period.

Most of the increase in the prevalence of diabetes is projected to occur in younger age groups, where diabetes prevalence is estimated to increase by 6.9 % and 3.3-fold among the age groups of 25–34 years and 35–44 years, respectively, from 1997 to 2010 (Table 2). Among people 25–74 years of age, and between 1997 and 2020, the model predicts an increase in diabetes prevalence from 7.5 to 26.2 %, and increase in the number of people with diabetes from 2,193,509 to 12,577,714.

Scenario analysis

Table 3 summarizes the impact of applying different 'what if' assumptions on the diabetes burden in the total Turkish population, as estimated by the model. The Turkish IMPACT Diabetes Forecast Model estimated that a 7.6 % relative reduction in diabetes prevalence resulting in 1,217,648 fewer individuals with diabetes could be achieved by 2025 if the rise in obesity could be halted. Adding the 40 % reduction target for smoking resulted in a 7.9 % relative reduction in diabetes prevalence, preventing an additional 35,275 cases in 2025. If the scenario of 10 % reduction in obesity and 40 % reduction in smoking could be realized, the estimated relative reduction in diabetes prevalence by 2025 would be 12.6 % (2,034,635 individuals). Meeting the target of a 10 % relative reduction in obesity prevalence and 20 % relative reduction in smoking prevalence by 2025 would reduce diabetes prevalence by 10.5 % (1,655,213 individuals).

Discussion

Our projections showed a dramatic increase in the number of people with type 2 diabetes, especially in middle age groups (45–54) by 2025. It is estimated that there will be 13 million excess people with diabetes in 2025 compared to the reference year 1997 and diabetes prevalence is projected to increase to 31.5 % in the Turkish adult population over 25 years of age.

Table 2 Projected prevalence and number of people with type 2 diabetes for selected years among adults 25 years of age and over in Turkey, 1997–2025, MedCHAMPS study

Gender	Age groups	Years				
		1997 n (%)	2010 n (%)	2015 n (%)	2020 n (%)	2025 n (%)
Men						
	25–34	41,250 (0.8)	434,635 (6.8)	708,453 (11.1)	1,001,589 (15.6)	1,288,439 (19.7)
	35–44	135,260 (3.4)	697,049 (13.3)	1,053,288 (16.7)	1,461,956 (22.9)	1,883,181 (29.2)
	45–54	266,301 (10.0)	823,807 (20.0)	1,128,920 (22.7)	1,474,807 (28.9)	1,851,662 (32.6)
	55–64	270,286 (14.6)	625,201 (23.4)	845,632 (25.9)	1,119,214 (29.3)	1,402,766 (32.9)
	65–74	218,237 (19.7)	402,171 (28.4)	478,391 (28.9)	600,879 (28.3)	788,729 (30.0)
	Total	931,334 (6.3)	2,982,863 (15.1)	4,214,684 (19.3)	5,658,445 (23.7)	7,214,777 (28.2)
Women						
	25–34	64,091 (1.3)	361,019 (5.8)	526,483 (8.3)	702,806 (11.4)	907,616 (14.5)
	35–44	192,342 (5.1)	677,888 (13.2)	972,359 (16.9)	1,361,400 (21.6)	1,830,126 (28.9)
	45–54	351,777 (13.4)	909,520 (21.8)	1,280,898 (27.9)	1,800,820 (35.3)	2,517,063 (44.3)
	55–64	392,406 (20.5)	861,844 (29.2)	1,339,308 (39.6)	1,860,183 (47.1)	2,236,285 (50.1)
	65–74	261,559 (21.5)	701,626 (40.2)	885,411 (44.2)	1,136,489 (46.1)	1,438,074 (47.8)
	Total	1,262,175 (8.7)	3,511,897 (17.3)	5,004,459 (22.7)	6,861,698 (28.6)	8,929,164 (34.7)
Total						
	25–34	105,341 (1.0)	795,654 (6.3)	1,234,936 (9.7)	1,704,395 (13.5)	2,196,055 (17.1)
	35–44	327,602 (4.2)	1,374,937 (13.3)	2,025,647 (17.5)	2,823,356 (22.3)	3,713,307 (29.1)
	45–54	618,078 (11.6)	1,733,327 (20.8)	2,409,818 (26.1)	3,275,627 (32.1)	4,368,725 (38.5)
	55–64	662,692 (17.6)	1,487,045 (26.4)	2,184,940 (32.9)	2,979,397 (38.3)	3,639,051 (41.9)
	65–74	479,796 (20.6)	1,103,797 (34.9)	1,363,802 (37.3)	1,737,368 (37.8)	2,226,803 (39.6)
	Total	2,193,509 (7.5)	6,494,760 (16.2)	9,219,143 (21.0)	12,577,714 (26.2)	16,143,941 (31.5)

Table 3 Results of the impact of reducing obesity (or obesity and smoking) on the diabetes burden in Turkey (total population) using different policy scenarios for year 2025, MedCHAMPS study

Baseline burden of T2DM[a] (2025)		Burden of T2DM (2025) with the "What if" policy assumption		Reduction of burden of T2DM (2025)		Target (What if assumption)[b]
Prevalence (%)[c]	Number (T2DM cases)	Prevalence (%)	Number (T2DM cases)	Relative change in Prevalence (%)	Number (T2DM cases)	
Scenarios						
31.5	16,143,941	27.6	14,146,490	−12.3	−1,997,451	5 % O in 5 years
		29.1	14,926,293	−7.6	−1,217,648	Halt O
		29.0	14,891,018	−7.9	−1,252,923	Halt O + 40 % S
		27.5	14,109,306	−12.6	−2,034,635	10 % O + 40 % S
		28.2	14,488,728	−10.5	−1,655,213	10 % O + 20 % S

[a] *T2DM* Type 2 diabetes mellitus

[b] *10 % O* 10 % relative reduction of obesity prevalence by 2020, *10 % O + 40 % S* 10 % relative reduction in obesity prevalence and 40 % relative reduction in smoking prevalence by 2020, *Halt O* halt the rise in obesity prevalence by 2020, *Halt O + 40 % S* halt the rise in obesity prevalence and 40 % relative reduction in smoking prevalence by 2020, *5 % O* 5 % relative reduction of obesity prevalence by 2015, 10 % *O + 20 % S* 10 % relative reduction in obesity prevalence and 20 % relative reduction in smoking prevalence by 2020

[c] Projected population of Turkey for year 2025 is 51,292,000 (Age group 25–74). (baseline for all targets: 2010)

A recent study which generated projections of DM prevalence for the years 2010 and 2030 for 216 different countries estimated that overall the DM prevalence for the population aged 20–79 years would be 7.4 % in 2010 and 9.4 % in 2030 (Shaw et al. 2010). Same study predicted a relative increase of 28.3 % (from 7.4 to 9.5 %) in diabetes prevalence, and 69.1 % increase (from 3,502,000 to 5,921,000) in the number of people with diabetes among Turkish adults 20–79 years of age between 2011 and 2030. These figures are substantially lower than our model predictions. Between 2010 and 2020 alone, our model predicted a 197.4 % increase in diabetes prevalence and 192.4 % increase in the number of people with diabetes.

Our results are also consistent with other studies using the same model. One from Syria predicted a relative increase of 113.8 % in diabetes prevalence (from 10 to 21.3 %), and of 329.2 % in number of people with diabetes (from 686,195 to 2,944,813) between 2003 and 2022 (Al Ali et al. 2013). In Palestine, the model predicted that DM prevalence would increase from 9.7 to 20.6 % between 2000 and 2020 (Abu-Rmeileh et al. 2013). This model may predict bigger increases in DM prevalence than International Diabetes Federation (IDF) based estimates (Al-Quwaidhi et al. 2014; Al Ali et al. 2013). However, other studies, e.g. from the United States using a Markov model projected substantial increases, such as an approximate doubling in US prevalence by 2050 (Narayan et al. 2006). A study from Australia also projected increases from 10.1 % in 2010 to 17.0 % in 2025 (Magliano et al. 2008).

There may be several reasons why our estimates differ from other modelling studies. First, we used more recent country-specific data. Second, discrepancies might result from the use of different statistical methods and modelling approaches. The IDF prevalence estimates were generated using an average of available data from countries matched by IDF region, geography and World Bank's income classification. Another reason for this discrepancy could be due to differences in diabetes-related mortality estimates. Deaths attributed to diabetes in Turkey were estimated by the IDF at 31,931 in 2011, while a lower estimate (23,878) of diabetes mortality for the same year was found in our study using the DISMOD II model. Our model also accounted explicitly for the effects of changes in epidemiological risk factors such as obesity and smoking, which might provide better estimates than the other models. The IDF estimates, for example, were derived from logistic regression models and based only on changes in urbanization. In regions where obesity is increasing rapidly, this may lead to an underestimate in future projections of disease.

Compared to the TURDEP-I study conducted during 1997, waist circumference increased by approximately 6 cm among men and 7 cm among women over a 12-year time period (Satman et al. 2013). The TURDEP studies suggested that diabetes prevalence has increased by 90 % and obesity has increased by 44 % between years 1997 and 2010 (Satman et al. 2013). Several factors contributed to increasing trends in obesity in Turkey. Overweight and obesity are more prevalent in urban compared to rural areas because of the easy availability of public transportation and prevalence of sedentary lifestyles. This is particularly important in women, who tend to have a more sedentary lifestyle because of their low participation in the workforce and due to cultural attitudes. Changing lifestyles as a result of rapid urbanization and longer survival of individuals with obesity and DM also contribute to increases in DM burden (Bagriacik et al. 2009; Satman et al. 2013). Recently, the Turkish Ministry of Health (MoH) prepared action plans named "Obesity Prevention and Control Program of Turkey" and "Diabetes Prevention and Control Program". These programs target increasing awareness for diabetes and risk factors, promoting healthy life styles, controlling diabetes through early diagnosis, improving treatment and monitoring of diabetes in line with current standards, and decreasing diabetes-related complications (MoH 2011; Tatar 2013).

We evaluated the impact of five population-based intervention policy options on future diabetes prevalence. The ambitious targets set by the WHO (10 % relative reduction in obesity and 40 % reduction in smoking prevalence) and by the Turkish Ministry of Health (5 % reduction in obesity in 5 years) would achieve the highest reductions in diabetes prevalence. However, these targets may not be achievable. Halting the increase in obesity prevalence would be a more realistic target initially followed by a higher target for longer term reduction. The implementation of the proposed interventions needs to be investigated thoroughly in local settings. The greatest increase in diabetes prevalence is projected to occur in younger people. This is related to higher increases in obesity rates predicted among younger age groups. Hence, population-wide preventive measures that support and facilitate healthy eating and physical activity not only among adults but also in children are needed. Evidence in other countries suggests that diabetes and obesity are more concentrated among lower socioeconomic groups, so vulnerable subgroups should also be given priority to tackle with these problems (Siegel et al. 2013).

As part of the obesity control program, MoH started establishing weight management clinics in community health centres located in each district of Turkey. These clinics will give counselling to overweight and obese individuals which might have an impact on increasing awareness level for individuals with obesity. These clinics can also refer individuals to a secondary care centre if necessary. However, the evidence suggests that the effectiveness of similar weight-loss interventions among adults is limited (Loveman et al. 2011).

The massive increases in obesity prevalence suggest that structural measures will be needed to achieve the targets set by the Ministry of Health. In recent years, curbing the intake of sugar and sugar-sweetened beverages has been increasingly advocated as an appropriate and effective strategy to control the obesity and diabetes epidemic. Some countries, such as Mexico, have recently passed legislation to increase taxes on sugar-containing products (Brownell et al. 2009). In 2011, Turkey banned sale of drinks with high calorie ingredients and foods such as fries in elementary schools. These unhealthy products were replaced with milk, yoghurt, fresh fruit juice and fruit.

Strengths and limitations

The Turkish IMPACT Diabetes Forecast Model has several strengths. The model may be most appropriate for most of the developing countries since it requires a relatively limited number of data inputs and does not need sophisticated statistical software. The model can provide estimates for future diabetes prevalence which can inform policy using different intervention scenarios to target the specific risk factors. The model results were validated against local observed data. A number of reduction targets set by local and leading international authorities were incorporated into the 'what if policy analyses' in the model. The 'what if' analyses in this model can, therefore, form a useful platform for policy planning and decision making. The model directly incorporates data on trends in adult obesity and smoking to inform the projections of future T2DM prevalence in Turkey using national data. This is a big advantage over other models, and is the most likely reason for the large differences in the estimates and projections of T2DM compared with IDF estimates. The IDF model did not take into account the changes in T2DM risk factors (e.g. obesity) which are likely to result in underestimation of T2DM prevalence if the levels of obesity and other risk factors continue to rise (Whiting et al. 2011).

The projections we report suffer from several limitations. Our projections do not take the effect of advances in diabetes prevention into account which may reduce the number of new cases with DM. On the other hand, the advances in DM treatment could decrease the case fatality rates which might increase longevity but also the number of people with DM.

We have assumed a linear increase in risk factors. However, trends for obesity prevalence may follow less than linear or nonlinear patterns and thus our projections of obesity prevalence may not be accurate. The DISMOD-derived transition parameters (DM incidence, case fatality, and total mortality) were assumed to be constant over the whole modelling period (1997–2025), but these parameters might change over time.

We used BMI for assessing obesity trends; however, this measure is now considered as an imperfect indicator of visceral obesity. We could use superior measures other than BMI such as waist to height ratio (WHR) but the availability of these measures is not as widespread as height and weight in surveys conducted in Turkish settings. The reported projections seem reasonable if things continue as in the past, with no major changes occurring. However, recently, plateauing of obesity prevalence has been reported in some populations such as the United States, but not other populations (Flegal et al. 2012). Thus, if the rise in prevalence of obesity halts then our estimates will be higher than reality. The model does not take into account other factors that might have an impact on T2DM prevalence such as immigration, emigration, changes in detection and treatment of diabetes.

Our diabetes model made predictions only based on trends in two main risk factors such as obesity and smoking. The diabetes model did not explicitly take into account any other risk factors such as physical activity and dietary patterns because of scarcity of reliable trend data. For example, there is only one published national study (Turkish National Nutrition and Health Survey-2014) measuring these two conditions at population level. In addition, recent findings suggest that secular trends in physical activity levels are not consistent with trends in obesity prevalence. Evidence from trials also does not support a direct relationship between physical activity and excess weight gain (Luke and Cooper 2013). However, it is evident that physical activity is an important mediator of glycemic control and diabetes, hence physical activity should be promoted even among health individuals (Mikus et al. 2012).

Conclusion

In conclusion, our model based on the most recent national data about the epidemiology and demography of T2DM shows that the number of people with DM in Turkey will increase substantially. Over the next 10 years, the prevalence of total diabetes in the Turkey will increase from its current level of about 1 in 10 adults to between 1 in 5 and 1 in 3 adults by 2025. Effective strategies will need to be undertaken to reduce the impact of DM risk factors such as obesity on the national diabetes burden and these efforts should be directed towards younger age groups which might benefit more from these interventions. Our analysis suggests that successful implementation of effective preventive interventions focused on obesity and smoking will need substantial population-wide reductions in obesity prevalence, and most likely the result of structural interventions rather than those acting on individual patients. Such intervention has significant impact on future increases in diabetes prevalence.

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Conflict of interest We declare that we have no conflicts of interest.

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