Contents available at ScienceDirect

Diabetes Research and Clinical Practice

journal homepage: www.elsevier.com/locate/diabres

International Diabetes Federation

Comparison of type 2 diabetes prevalence estimates in Saudi Arabia from a validated Markov model against the International Diabetes Federation and other modelling studies☆

Abdulkareem J. Al-Quwaidhi [a,b,*], *Mark S. Pearce* [a], *Eugene Sobngwi* [a], *Julia A. Critchley* [c], *Martin O'Flaherty* [d]

[a] *Newcastle University, United Kingdom*
[b] *Ministry of Health, Saudi Arabia*
[c] *St. George's University of London, United Kingdom*
[d] *University of Liverpool, United Kingdom*

ARTICLE INFO

Article history:
Received 5 March 2013
Received in revised form
29 September 2013
Accepted 20 December 2013
Available online 3 January 2014

Keywords:
Modelling
Diabetes
Prevalence
Saudi Arabia

ABSTRACT

Aims: To compare the estimates and projections of type 2 diabetes mellitus (T2DM) prevalence in Saudi Arabia from a validated Markov model against other modelling estimates, such as those produced by the International Diabetes Federation (IDF) Diabetes Atlas and the Global Burden of Disease (GBD) project.

Methods: A discrete-state Markov model was developed and validated that integrates data on population, obesity and smoking prevalence trends in adult Saudis aged ≥25 years to estimate the trends in T2DM prevalence (annually from 1992 to 2022). The model was validated by comparing the age- and sex-specific prevalence estimates against a national survey conducted in 2005.

Results: Prevalence estimates from this new Markov model were consistent with the 2005 national survey and very similar to the GBD study estimates. Prevalence in men and women in 2000 was estimated by the GBD model respectively at 17.5% and 17.7%, compared to 17.7% and 16.4% in this study. The IDF estimates of the total diabetes prevalence were considerably lower at 16.7% in 2011 and 20.8% in 2030, compared with 29.2% in 2011 and 44.1% in 2022 in this study.

Conclusion: In contrast to other modelling studies, both the Saudi IMPACT Diabetes Forecast Model and the GBD model directly incorporated the trends in obesity prevalence and/or body mass index (BMI) to inform T2DM prevalence estimates. It appears that such a direct incorporation of obesity trends in modelling studies results in higher estimates of the future prevalence of T2DM, at least in countries where obesity has been rapidly increasing.

* *Corresponding author at*: PO Box: 35515, Al-Ahssa 31982, Saudi Arabia. Tel.: +966 50 492 5650.
E-mail addresses: aal-qwidi@moh.gov.sa (A.J. Al-Quwaidhi), mark.pearce@ncl.ac.uk (M.S. Pearce), Eugene.sobngwi@ncl.ac.uk (E. Sobngwi), jcritchl@sgul.ac.uk (J.A. Critchley), M.OFlaherty@liverpool.ac.uk (M. O'Flaherty).

0168-8227/$ – see front matter © 2013 Elsevier Ireland Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.diabres.2013.12.036

1. Introduction

T2DM is one of the most common non-communicable diseases in the world, and its levels are progressively increasing, particularly in developing countries [1]. It imposes a heavy burden on individuals and health care systems. The disease is associated with severe complications (e.g. blindness, lower limb amputations, and chronic renal failure) which affect health and productivity [2]. In 2011, diabetes caused around 4.6 million deaths globally in the 20–79 age group, and at least US$ 465 billion in healthcare expenditures, which was equivalent to 11% of total healthcare expenditures in adults [3]. Therefore, it is important for countries to have credible data on the trends in T2DM prevalence and its likely future projections. These data are required for proper health policy planning and resource allocation for the prevention and control of T2DM.

The Kingdom of Saudi Arabia (KSA) is one of the largest and wealthiest countries in the region of Middle East and North Africa (MENA). It is a leading oil-producing country, and has witnessed massive socioeconomic developments in the past five decades with rapid urbanisation and changes in the population lifestyles. KSA is now classified by the IDF to be among the top 10 countries globally with the highest projected prevalence of diabetes in 2011 (16.2%) and 2030 (20.8%) [1]. Furthermore, the prevalence of some risk factors for T2DM in KSA (e.g. obesity) has also been estimated to be among the highest in the world [4].

Epidemiological modelling is a valuable tool for estimation and future prediction of T2DM prevalence. The IDF [1] and other international modelling studies [5–9] have generated estimates of the prevalence of diabetes in different countries of the world, including KSA, at different time points. However, for KSA, most of such estimates appear to noticeably underestimate the true situation, as they have been well surpassed by the local 'observed' data.

We developed the 'Saudi IMPACT Diabetes Forecast Model' to estimate the trends and likely future projections of T2DM in KSA, based primarily on the trends in the prevalence of obesity and smoking as risk factors. Obesity has been well recognised as one of the most important risk factors for T2DM [10]. In addition, smoking is not only a reflection of unhealthy lifestyle (with low physical activity and unhealthy diet), but it has also been recognised as an independent risk factor for T2DM in several large prospective studies that have adjusted their results for many potential covariates (e.g. obesity, physical activity, age, etc.) [11]. We validated our model against local observed data from the STEPS (STEPwise approach to non-communicable diseases Surveillance) survey [12] in 2005. This study aims to provide a detailed comparison of the estimates of T2DM prevalence in KSA by the Saudi IMPACT Diabetes Forecast Model against the estimates of the IDF Diabetes Atlas [1] and the GBD study [5].

2. Methods

2.1. *The model*

The Saudi IMPACT Diabetes Forecast Model is a discrete-state Markov model, implemented in Microsoft Excel spreadsheets. It was originally designed for the MedCHAMPS project [13,14] for use in middle and low income countries, where extensive data on T2DM risk factors, prevalence, and complications may not be available. It integrates information on the trends in the adult Saudi population structure by age group and sex (obtained from the Central Department of Statistics and Information (CDSI) [15] and the United Nations (UN) population estimates [16]), and the trends in the prevalence of two risk factors for T2DM: obesity (BMI $\geq$ 30 kg/m^2) and current active smoking (obtained from local population-based surveys). The model estimates the trends in prevalence of T2DM in the Saudi adults aged $\geq$25 years during the 30-year period of 1992–2022. The age- and sex-specific prevalence of T2DM in the starting year of modelling (1992) was obtained from a nationwide population-based study, which used the WHO 1985 diagnostic criteria and oral glucose tolerance test (OGTT) for diagnosis of T2DM [17].

Fig. 1 shows a simple illustration of the model structure. The model assumes that the population is divided into three discrete pools (health states): those who are obese, those who are smokers, and those who are 'healthy' (i.e. non-obese, non-smokers, and not having T2DM). Individuals can make transitions from the three main health states or remain in the same state during each modelling cycle (one year). Individuals can make transitions to the (Diabetes) state (i.e. they develop T2DM), or die due to other causes. Individuals in the (Diabetes) state can die as a result of T2DM or due to other causes. Individuals with T2DM cannot make transition back to the three main states, assuming a zero remission rate.

The size of the (Obese) and (Smokers) states were determined by the age- and sex-specific prevalence of obesity and active smoking, as obtained from nationally-representative local surveys. Three surveys were used to obtain the prevalence of obesity in 1992 [17], 1997 [18], and 2005 [12]. In addition, two surveys were used to derive the prevalence of active smoking in 1992 [19] and 2005 [12]. Data for missing years were estimated through linear interpolation, while data for future trends were estimated through linear extrapolation, assuming similar rates of increase as that observed from surveys. Fig. 2 demonstrates the trends in prevalence of obesity and smoking in the adult Saudi men and women over the modelling period (1992–2022), assuming a linear increasing trends.

The potential overlaps between the model health states were handled in three different ways. First, smoking prevalence was multiplied by obesity prevalence in order to estimate the proportion of population who were both obese and smokers. Then, such a proportion was subtracted from the 'original' smoking prevalence, to leave in the (Smokers) state only those individuals who were smokers but not obese. Second, we estimated the number of individuals with T2DM (in the Diabetes state) in whom the disease was assumed to be 'caused' by obesity as an exposure, through multiplying the '*population attributable risk*' [20] by the size of (Diabetes) state. Then, the number of such individuals was subtracted from the total obese individuals in population, to leave in the (Obese) state only those obese individuals who do not have T2DM. Finally, we applied the same previous approach of the *population attributable risk*, to leave in the (Smokers) states only those people who are smokers, but not having T2DM.