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## Original Article

## Lifestyle factors and macro- and micro-vascular complications among people with type 2 diabetes in Saudi Arabia



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## ABSTRACT

**Aims:** The aim of this study is to identify lifestyle factors that place people with type 2 diabetes in Saudi Arabia at a greater risk of macro- and microvascular complications.

**Methods:** A survey was conducted among adults with type 2 diabetes who attended diabetes centres in three major cities in Saudi Arabia. Participants were interviewed and their medical files were reviewed for lab test results and documented comorbidities. Associations between complication and lifestyle factors were assessed using multiple logistic regression analysis.

**Results:** A total of 1121 participants were recruited. Mean age was 57.6 ( $\pm 11.1$ ) years. The prevalence of coronary artery disease, diabetic foot, and stroke was 17.0%, 13.1% and 3.7%, and that of neuropathy, renal impairment, and retinopathy was 20.3%, 14.5%, and 42.8% respectively. Lifestyle factors associated with one or more of the complications were inadequate physical activity, longer sitting time, obesity, current or past smoking, passive smoking, hypertension, poor glycaemic control, low HDL and high triglycerides.

**Conclusions:** Diabetes complications are common among people with type 2 diabetes in Saudi Arabia. Life style factors such as inadequate physical activity, longer sitting time, obesity, smoking, hypertension, and poor control of blood glucose and lipids should be assimilated into complications prevention program.

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## 1. Introduction

Saudi Arabia has experienced enormous economic and lifestyle changes over the past few decades. Along with these changes there was a rapid increase in the prevalence of diabetes mellitus which is currently a major public health issue in the country. A recent report estimated that the prevalence of diabetes among adults in Saudi Arabia was 17.7%, which was considerably higher than the global (8.8%) and the regional (10.7%) prevalence and it places Saudi

Arabia among the countries with the highest prevalence of the disease [1].

Diabetes complications is another concerning issue in Saudi Arabia. Even though, people with diabetes in Saudi Arabia have free access to both good quality healthcare services and medications, the prevalence of microvascular (retinopathy, neuropathy, and nephropathy) and macrovascular complications (coronary artery disease (CAD), stroke, and peripheral vascular disease) were high among them [2–9]. Diabetes complications reduces the quality of life and life expectancy of the affected people and creates an economic, emotional and social disease burden. A study from Saudi Arabia estimated that in 2014 the annual cost of treating a person with diabetes with complications was US\$11,706.9 which is four-fold higher than the cost of treatment for a person without

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complications (US\$2746.7) [10]. Prevention or delay of complications can be achieved by early detection and changing of lifestyle risk factors. Thus, it is important to identify lifestyle risk factors for complications for people with type 2 diabetes in Saudi Arabia.

A number of studies from Saudi Arabia investigated traditional risk factors for macro- and micro-vascular diabetes complications [2,4–9,11,12]. The majority of these studies found that gender, older age, longer duration of diabetes, use of insulin, and poor glycaemic control were associated factors [2,4–9,11,12], while a few of them showed an association of diabetes complications with uncontrolled hypertension, smoking and dyslipidaemia [8,9,12]. Some of these studies, however, were underpowered and limited to a single centre or a small geographical location. Moreover, studies outside Saudi Arabia reported an association between complications and lifestyle factors such as physical inactivity as well as longer sitting periods [13,14]. None of the previous studies from Saudi Arabia, however, have evaluated this association.

Given that the prevalence of type 2 diabetes and its related complications are high in Saudi Arabia, do these patients have some specific traditional risk factors which could explain the observed increase in the individual macro- and microvascular complications. Thus, the aim of this study was two-fold. Firstly, to measure the prevalence of macro- and micro-vascular complications among people with Type 2 diabetes mellitus (T2DM) in Saudi Arabia. Secondly, to identify the lifestyle and other modifiable risk factors for these complications. The finding of this study will be useful for patients, healthcare providers and health policy makers in developing individual patient level management plan.

## 2. Methods

### 2.1. Participants

The study population consisted of adults 18 years and above with T2DM who were followed up at diabetes centres in Hofuf, Riyadh, and Jeddah cities in Saudi Arabia. A sample size of 1082 participants was calculated for another outcome in this study [15]. Based on the reported prevalence of macro- and microvascular complications in the previous studies [2,5,7,9], a sample size of 1082 participants maintains a power higher than 90% with a significance level of 0.05. Inclusion criteria of participants includes documented diagnosis of T2DM, aged 18 years and above, and a duration of diabetes of at least one year. Pregnant women and participants who did not have haemoglobin A1c (HbA1c) test within the past one year were excluded. Both the Monash University Human Research Ethics Committee in Australia and the Research Ethics Committee of the Ministry of Health in Saudi Arabia approved this research project. All the study procedures were carried out in accordance with the principles of the Declaration of Helsinki as revised in 2013.

### 2.2. Data collection

Full description of the data collection tool and procedure were detailed in a previous article [15]. A systematic random sample of participants were recruited from the attendees of diabetes centres between May 15 and November 30, 2017. Informed consent was obtained from all participants, and they were surveyed by trained data collectors using interview administer questionnaire. The questionnaire was filled online through Research Electronic Data Capture (REDCap) application [16]. The collected data include socio-demographics, smoking, physical activity (Global Physical Activity Questionnaire (GPAQ) [17]), medical history, adherence to medication [18] and neuropathy (Michigan Neuropathy Screening Instrument [19]). The establishments' permission to use the above-

mentioned tools was obtained. After interviewing participants, their blood pressure, weight, height, waist circumference, and hip circumference were measured in a standardized way [15]. Medical records were reviewed for most recent HbA1c, creatinine, cholesterol, high density lipoprotein lipase (HDL), low density lipoprotein lipase (LDL), and triglycerides. Information regarding currently prescribed medication, and documented diagnosis of hypertension, CAD, stroke and retinopathy was also collected from medical records.

### 2.3. Data analysis

Data analysis was carried out using Stata SE version 15.0. Data were summarised and presented as a mean ( $\pm$ standard deviation) for numerical data and frequency and percentage for categorical data. T-test and chi-square test were used to examine univariate associations between potential risk factors and CAD, diabetic foot, stroke, neuropathy, retinopathy, and renal impairment. Risk factors with a p-value of 0.1 in univariate analysis were entered into multivariable logistic regression analysis with stepwise removal [20]. A p-value of 0.05 or less was considered as statistical significant. Definitions of outcomes and risk factors are available in the appendix.

## 3. Results

### 3.1. General characteristics

Out of 1121 participants, 10 (0.9%) were excluded as they had substantially incomplete records. Thus, the records of 1111 participants were used in the analysis. Mean age was 57.6 ( $\pm$ 11.1) years, and mean duration of diabetes was 13.9 ( $\pm$ 8.4) years. 65.2% (724) of the participants were female and 34.8% (387) were male. Mean body mass index was 32.9 ( $\pm$ 8.1) kg/m<sup>2</sup>. The overall prevalence of macrovascular complication was 28%, and that of microvascular complication was 54.6%. The prevalence of CAD, stroke and diabetic foot was respectively 17%, 13.1% and 3.7%, and that of diabetic neuropathy, renal impairment, and retinopathy was 20.3%, 14.5% and 42.8% respectively.

### 3.2. Univariate association between risk factors and complications

Table 1 summarises participants' demographic and lifestyle characteristics for each of the macro- and micro-vascular complications. Longer sitting time was significantly associated with higher prevalence for all complications. Similarly, physical activity less than 150 min per week was associated with all complications except CAD. Other risk factors that were associated with one or more diabetes complications include older age, male gender, lower level of education, lower household income, region of living, and active as well as passive smoking (defined as no current smoking but exposed to the smoking of others).

Clinical characteristics for each macro- and micro-vascular complications are summarised in Table 2. Longer duration of diabetes was associated with all complications. With the exception of stroke, all other complications were more prevalent among those who were taking insulin. The prevalence of CAD, stroke, renal impairment and retinopathy was higher among people with hypertension. Other risk factors that were associated with one or more of the complications include positive family history of diabetes, low adherence to medications, high body mass index, high waist-hip ratio, poor glycaemic control, low HDL, and high triglycerides. Normal cholesterol and LDL were associated with higher prevalence of CAD, stroke and renal impairment.

**Table 1**  
Demographic characteristics by type of macro- and micro-vascular complications.

| Variables                   | CAD<br>17.0% (n = 189) |         | Diabetic foot<br>13.1 (n = 145) |        | Stroke<br>3.7% (n = 41) |       | Neuropathy<br>20.3% (n = 202) |         | Renal impairment<br>14.5% (n = 161) |         | Retinopathy<br>42.8% (n = 476) |         |
|-----------------------------|------------------------|---------|---------------------------------|--------|-------------------------|-------|-------------------------------|---------|-------------------------------------|---------|--------------------------------|---------|
|                             | %                      | p-value | %                               | %      | %                       | %     | p-value                       | p-value | p-value                             | p-value | %                              | p-value |
| Age % (n)                   |                        |         |                                 |        |                         |       |                               |         |                                     |         |                                |         |
| ≤60 years                   | 13.0                   | <0.001  | 12.8                            | 0.847  | 2.8                     | 0.146 | 20.5                          | 0.995   | 8.8                                 | <0.001  | 38.5                           | <0.001  |
| 61–70 years                 | 23.9                   |         | 14.0                            |        | 4.7                     |       | 19.9                          |         | 20.3                                |         | 46.8                           |         |
| ≥71 years                   | 21.6                   |         | 12.2                            |        | 5.8                     |       | 20.3                          |         | 29.5                                |         | 55.4                           |         |
| Gender: % (n)               |                        |         |                                 |        |                         |       |                               |         |                                     |         |                                |         |
| Female                      | 15.6                   | 0.088   | 13.1                            | 0.924  | 4.1                     | 0.566 | 12.8                          | <0.001  | 14.2                                | 0.732   | 44.6                           | 0.103   |
| Male                        | 19.6                   |         | 12.9                            |        | 3.5                     |       | 25.0                          |         | 15.0                                |         | 39.5                           |         |
| Education level % (n)       |                        |         |                                 |        |                         |       |                               |         |                                     |         |                                |         |
| University/college          | 13.1                   | 0.064   | 10.6                            | 0.111  | 1.5                     | 0.031 | 9.9                           | <0.001  | 13.1                                | 0.037   | 30.8                           | <0.001  |
| Intermediate/secondary      | 15.1                   |         | 11.1                            |        | 2.6                     |       | 16.2                          |         | 11.1                                |         | 39.0                           |         |
| Illiterate/primary          | 19.5                   |         | 15.1                            |        | 5.1                     |       | 26.8                          |         | 17.1                                |         | 49.4                           |         |
| Region                      |                        |         |                                 |        |                         |       |                               |         |                                     |         |                                |         |
| Hofuf                       | 30.5                   | <0.001  | 23.9                            | <0.001 | 5.9                     | 0.107 | 28.3                          | 0.003   | 20.9                                | 0.006   | 46.4                           | 0.397   |
| Jeddah                      | 10.5                   |         | 12.9                            |        | 2.4                     |       | 17.8                          |         | 12.9                                |         | 43.2                           |         |
| Riyadh                      | 14.4                   |         | 9.0                             |        | 3.4                     |       | 17.9                          |         | 12.7                                |         | 41.4                           |         |
| Location of residence % (n) |                        |         |                                 |        |                         |       |                               |         |                                     |         |                                |         |
| Urban                       | 16.1                   | 0.154   | 12.3                            | 0.102  | 3.9                     | 0.280 | 19.4                          | 0.086   | 14.6                                | 0.973   | 42.1                           | 0.231   |
| Rural                       | 23.2                   |         | 15.8                            |        | 4.2                     |       | 22.6                          |         | 13.7                                |         | 43.2                           |         |
| Remote                      | 21.0                   |         | 21.0                            |        | 0.0                     |       | 31.5                          |         | 14.5                                |         | 53.2                           |         |
| Household income % (n)      |                        |         |                                 |        |                         |       |                               |         |                                     |         |                                |         |
| 6000 SAR and less           | 19.1                   | 0.115   | 17.5                            | <0.001 | 4.5                     | 0.381 | 29.3                          | <0.001  | 11.0                                | 0.085   | 36.1                           | 0.003   |
| 6001–9000 SAR               | 17.4                   |         | 7.7                             |        | 3.5                     |       | 14.6                          |         | 16.2                                |         | 41.7                           |         |
| 9001 SAR and over           | 13.6                   |         | 10.4                            |        | 2.7                     |       | 11.6                          |         | 16.0                                |         | 47.9                           |         |
| Active smoking % (n)        |                        |         |                                 |        |                         |       |                               |         |                                     |         |                                |         |
| Never                       | 15.8                   | 0.013   | 12.0                            | 0.006  | 3.6                     | 0.507 | 21.0                          | 0.080   | 14.1                                | 0.409   | 43.2                           | 0.573   |
| In the past (>one year)     | 27.7                   |         | 16.0                            |        | 3.2                     |       | 11.7                          |         | 19.2                                |         | 43.6                           |         |
| Current smoker              | 19.1                   |         | 25.4                            |        | 6.4                     |       | 23.8                          |         | 14.3                                |         | 36.5                           |         |
| Passive smoking % (n)       |                        |         |                                 |        |                         |       |                               |         |                                     |         |                                |         |
| No                          | 17.0                   | 0.915   | 12.2                            | 0.027  | 3.7                     | 0.569 | 19.1                          | 0.020   | 14.9                                | 0.376   | 42.5                           | 0.581   |
| Yes                         | 17.3                   |         | 18.6                            |        | 44.5                    |       | 27.7                          |         | 12.2                                |         | 44.9                           |         |
| Physical Activity % (n)     |                        |         |                                 |        |                         |       |                               |         |                                     |         |                                |         |
| Active (≥150 min/week)      | 13.7                   | 0.059   | 8.5                             | 0.004  | 1.8                     | 0.033 | 12.5                          | <0.001  | 10.1                                | 0.007   | 31.4                           | <0.001  |
| Inactive (<150 min/week)    | 18.4                   |         | 14.9                            |        | 4.5                     |       | 23.7                          |         | 16.4                                |         | 47.6                           |         |
| Sitting hours (mean ± SD)   | No: 5.8 ± 3.4          | <0.001  | No: 5.9 ± 3.4                   | <0.001 | No: 6.0 ± 3.5           | 0.004 | No: 5.7 ± 3.2                 | <0.001  | No: 5.8 ± 3.4                       | <0.001  | No: 5.8 ± 3.4                  | 0.001   |
|                             | Yes: 7.3 ± 3.6         |         | Yes: 7.2 ± 4.7                  |        | Yes: 7.7 ± 5.5          |       | Yes: 6.6 ± 4.4                |         | Yes: 7.7 ± 4.4                      |         | Yes: 6.5 ± 3.9                 |         |

### 3.3. Multivariable association between risk factors and macrovascular complications

Table 3 shows the results of the multivariable logistic regression analysis with stepwise selection for the association between each of the macrovascular complications and different risk factors. Hypertension and obesity increased the odds of CAD by 3.4-fold and 1.7-fold respectively, while every one hour of sitting per day increased the odds by 10%. The odds of CAD was also higher for male gender, older age, longer duration of diabetes, while using insulin alone or insulin with oral tablets increased the odds by 2.2-fold and 1.9-fold respectively. The adjusted odds of diabetic foot was 2.7-fold and 2-fold higher for current smoking and past smoking respectively, while passive smoking increased the odds by 1.9-fold. Low level of physical activity was associated with 90% increased odds of diabetic foot. Other risk factors of diabetic foot include use of insulin, and low household income. For both CAD and Diabetic foot, increased odds was observed among people living in the Hofuf region. In regards to stroke, hypertension increased the odds by 4.9-fold, while lower level of education was associated with 2.6-fold higher odds. The odds of stroke was also 2.2-fold higher for male gender, while for every one hour of sitting per day the risk increased by 10%.

### 3.4. Multivariable association between risk factors and microvascular complications

The results of the multivariable logistic regression analysis for

microvascular complications of neuropathy, retinopathy and renal impairment and various risk factors are presented in Table 4. The adjusted odds of neuropathy was 2.7-fold higher for current smokers, 1.5-fold higher for low physical activity, and 1.1-fold higher for every one hour of sitting. Both obesity and very poor glycaemic control (HbA1c ≥ 9%) were associated with 50% increase in the odds of neuropathy, while Low household income increased the odds by 2.4-fold. Other risk factors of neuropathy include male gender, family history of diabetes and use of insulin. In regards to renal impairment, hypertension increased the odds by 2.2-fold, while low HDL and high triglycerides increased the odds by 1.9-fold and 1.8-fold respectively. Every one hour of sitting increased the risk of renal impairment by 10% and use of insulin alone increased the odds by 80%. Older age was also a strong predictor of renal impairment and patients living in Hofuf region and with household income between 6001 and 9000 Saudi Riyals had higher odds. Longer duration of diabetes increased the odds of retinopathy by 2.3-fold, and the risk was 1.5-fold higher for age above 70 years. The odds of retinopathy was also increased by 40% for patients with hypertension, 60% for low level of physical activity, and 90% for insulin users. Other risk factors of retinopathy were lower level of education, and family history of diabetes.

## 4. Discussion

This multicentre study provided an update regarding the prevalence of diabetes macro- and micro-vascular complications and the factors related to them in Saudi Arabia. Our results showed that

**Table 2**  
Clinical characteristics by type of macro- and micro-vascular complications.

| Variables                        | CAD<br>17.0% (n = 189) |         | Diabetic foot<br>13.1 (n = 145) |         | Stroke<br>3.7% (n = 41) |         | Neuropathy<br>20.3% (n = 202) |         | Renal<br>impairment<br>14.5% (n = 161) |         | Retinopathy<br>42.8% (n = 476) |         |
|----------------------------------|------------------------|---------|---------------------------------|---------|-------------------------|---------|-------------------------------|---------|--|---------|--------------------------------|---------|
|                                  | %                      | p-value | %                               | p-value | %                       | p-value | %                             | p-value | %                                      | p-value | %                              | p-value |
| DM Duration % (n)                |                        |         |                                 |         |                         |         |                               |         |  |         |                                |         |
| ≤10 years                        | 10.7                   | <0.001  | 9.5                             | 0.001   | 2.1                     | 0.033   | 15.0                          | 0.001   | 8.6                                    | <0.001  | 26.4                           | <0.001  |
| >10 years                        | 20.9                   |         | 15.1                            |         | 4.6                     |         | 23.7                          |         | 18.0                                   |         | 52.9                           |         |
| Family history of diabetes % (n) |                        |         |                                 |         |                         |         |                               |         |  |         |                                |         |
| No                               | 14.3                   | 0.158   | 11.4                            | 0.374   | 2.9                     | 0.391   | 15.6                          | 0.028   | 14.6                                   | 0.900   | 38.2                           | 0.068   |
| Yes                              | 18.0                   |         | 13.5                            |         | 4.0                     |         | 22.0                          |         | 14.3                                   |         | 44.5                           |         |
| Modality of treatment            |                        |         |                                 |         |                         |         |                               |         |  |         |                                |         |
| Oral tablet                      | 11.0                   | <0.001  | 8.3                             | <0.001  | 3.1                     | 0.170   | 14.0                          | <0.001  | 10.1                                   | <0.001  | 32.6                           | <0.001  |
| Insulin                          | 25.9                   |         | 18.8                            |         | 5.8                     |         | 26.4                          |         | 22.8                                   |         | 54.5                           |         |
| Oral and insulin                 | 23.3                   |         | 18.9                            |         | 3.3                     |         | 29.8                          |         | 17.4                                   |         | 56.7                           |         |
| Medication adherence             |                        |         |                                 |         |                         |         |                               |         |  |         |                                |         |
| Good adherence                   | 18.8                   | 0.119   | 10.9                            | 0.023   | 4.0                     | 0.761   | 18.5                          | 0.258   | 14.4                                   | 0.894   | 43.6                           | 0.871   |
| Moderate adherence               | 13.7                   |         | 15.4                            |         | 3.4                     |         | 22.5                          |         | 14.3                                   |         | 42.2                           |         |
| Poor adherence                   | 17.9                   |         | 18.9                            |         | 2.8                     |         | 23.3                          |         | 16.0                                   |         | 41.5                           |         |
| Hypertension                     |                        |         |                                 |         |                         |         |                               |         |  |         |                                |         |
| No                               | 6.3                    | <0.001  | 10.8                            | 0.147   | 0.9                     | 0.001   | 17.2                          | 0.097   | 6.0                                    | <0.001  | 33.9                           | <0.001  |
| Yes                              | 21.6                   |         | 14.0                            |         | 4.9                     |         | 21.7                          |         | 18.1                                   |         | 46.7                           |         |
| Body mass index % (n)            |                        |         |                                 |         |                         |         |                               |         |  |         |                                |         |
| Underweight/normal               | 11.5                   | 0.014   | 13.3                            | 0.075   | 0.9                     | 0.244   | 14.0                          | 0.001   | 11.5                                   | 0.654   | 43.4                           | 0.402   |
| Pre-obesity                      | 13.3                   |         | 9.3                             |         | 4.0                     |         | 14.5                          |         | 14.3                                   |         | 39.3                           |         |
| Obesity (class I – III)          | 19.6                   |         | 14.6                            |         | 4.1                     |         | 23.9                          |         | 14.7                                   |         | 43.9                           |         |
| Waist/hip ratio % (n)            |                        |         |                                 |         |                         |         |                               |         |  |         |                                |         |
| Normal                           | 15.9                   | 0.412   | 12.3                            | 0.284   | 2.7                     | 0.074   | 20.3                          | 0.924   | 11.6                                   | 0.034   | 41.1                           | 0.536   |
| High                             | 17.9                   |         | 14.7                            |         | 4.8                     |         | 20.1                          |         | 16.3                                   |         | 43.0                           |         |
| Glycaemic control (HbA1c)        |                        |         |                                 |         |                         |         |                               |         |  |         |                                |         |
| Good Control (<7%)               | 15.6                   | 0.768   | 10.3                            | 0.031   | 3.0                     | 0.820   | 14.7                          | <0.001  | 16.0                                   | 0.672   | 33.1                           | <0.001  |
| Poor control (7%–8.9%)           | 17.3                   |         | 11.7                            |         | 3.8                     |         | 17.2                          |         | 13.6                                   |         | 43.8                           |         |
| Very poor control (≥9%)          | 17.7                   |         | 16.6                            |         | 4.0                     |         | 27.9                          |         | 14.3                                   |         | 48.8                           |         |
| Total cholesterol % (n)          |                        |         |                                 |         |                         |         |                               |         |  |         |                                |         |
| Normal                           | 23.3                   | <0.001  | 13.9                            | 0.604   | 5.7                     | 0.026   | 18.6                          | 0.379   | 18.2                                   | 0.025   | 47.2                           | 0.065   |
| High                             | 14.5                   |         | 12.7                            |         | 2.9                     |         | 21.0                          |         | 13.0                                   |         | 41.1                           |         |
| LDL % (n)                        |                        |         |                                 |         |                         |         |                               |         |  |         |                                |         |
| Normal                           | 21.5                   | <0.001  | 13.0                            | 0.152   | 4.9                     | 0.045   | 14.7                          | 0.205   | 20.2                                   | 0.001   | 45.3                           | 0.293   |
| High                             | 11.9                   |         | 9.6                             |         | 2.3                     |         | 18.7                          |         | 11.0                                   |         | 41.2                           |         |
| HDL % (n)                        |                        |         |                                 |         |                         |         |                               |         |  |         |                                |         |
| Normal                           | 12.8                   | 0.004   | 10.1                            | 0.007   | 2.6                     | 0.254   | 19.9                          | 0.375   | 11.3                                   | <0.001  | 41.0                           | 0.459   |
| Low                              | 20.2                   |         | 16.6                            |         | 4.1                     |         | 17.2                          |         | 20.7                                   |         | 43.7                           |         |
| Triglycerides % (n)              |                        |         |                                 |         |                         |         |                               |         |  |         |                                |         |
| Normal                           | 15.0                   | 0.005   | 12.1                            | 0.174   | 3.3                     | 0.586   | 18.7                          | 0.044   | 12.9                                   | 0.019   | 42.4                           | 0.499   |
| High                             | 22.2                   |         | 15.2                            |         | 4.0                     |         | 24.5                          |         | 18.5                                   |         | 44.7                           |         |

among people with T2DM, 28% had macrovascular complications, and 54.6% had microvascular complications and these complications were associated with a number of modifiable lifestyle factors.

The prevalence of CAD and stroke in this study was within the reported range in high- and middle-income countries [21]. Previous studies from Saudi Arabia, however, reported slightly higher prevalence of these complications [2,3,11]. The lower prevalence in our study could be explained that they were measured from people attending diabetic centres which are secondary level healthcare facilities in the country. In contrast, the previous studies assessed the prevalence of these complications using hospital level data, where the prevalence is likely to be higher as patients in Saudi Arabia are usually referred to hospitals when they need specialised level treatment.

Compared to the global prevalence of diabetic neuropathy (15%) and diabetic retinopathy (27%), this study showed a higher prevalence of these complications among people with T2DM [1,22,23]. Nevertheless, our results are comparable to the findings of previous studies in Saudi Arabia [4,5,9,24–26]. A slightly higher prevalence of retinopathy and diabetic foot in our study could be explained that the participants were asked directly about their history of retinopathy and lower extremities' ulcers and amputation. However, the previous studies from Saudi Arabia relied on documented

diagnosis in the patients' medical records. Information regarding retinopathy and diabetic foot in medical records may not be complete because the patients may have been followed up for retinopathy and diabetic foot at primary health care or other health care centres.

This study showed that 5.7% of the participants were smokers and 8.5% smoked in the past, while 14% were passive smokers. Moreover, current smoking was independently associated with 2.7-fold increase in the odds of both diabetic foot and neuropathy. Further, ex-smokers and passive smokers were at 2 and 1.9-fold increased odds of diabetic foot respectively. These findings are supported by the results of a previous systematic review [27]. The nicotine in tobacco has an adrenergic-vasoconstrictive effect on blood vessels [28]. This effect can lead to hypoxia, poor wound healing, ulcers, and gangrene among people with impaired vasodilatation activity such as people with diabetes [29].

Hypertension appeared as an independent predictor of CAD, stroke, renal impairment, and retinopathy in this study, while very poor glycaemic control (HbA1c ≥ 9%) increased the risk of neuropathy. Hypertension is more common among people with diabetes than the general population, and its association with diabetes macro- and microvascular complications is well-established [30]. For people with diabetes with poor glycaemic control (HbA1c ≥ 7%)

**Table 3**  
Adjusted association between each of the macrovascular complications and potential risk factors<sup>a</sup>.

| Variable  | CAD <sup>a</sup> |          |         | Diabetic foot <sup>**</sup> |          |         | Stroke <sup>***</sup> |           |         |
|---|------------------|----------|---------|-----------------------------|----------|---------|-----------------------|-----------|---------|
|   | OR               | 95% CI   | p-value | OR                          | 95% CI   | p-value | OR                    | 95% CI    | p-value |
| Age (ref: ≤60years)                                 |                  |          |         |                             |          |         |                       |           |         |
| 61–70 years   | 1.6              | 1.1, 2.5 | 0.030   |                             |          |         |                       |           |         |
| >70 years   | 1.9              | 1.1, 3.4 | 0.032   |                             |          |         |                       |           |         |
| Gender (ref: female)                                | 1.7              | 1.1, 2.5 | 0.018   |                             |          |         | 2.2                   | 1.1, 4.7  | 0.033   |
| Education level (ref: university/college)           |                  |          |         |                             |          |         |                       |           |         |
| Intermediate/secondary                              |                  |          |         |                             |          |         |                       |           |         |
| Illiterate/primary                                  |                  |          |         |                             |          |         | 2.6                   | 1.2, 5.8  | 0.017   |
| Income (ref: 9001 SAR and over)                     |                  |          |         |                             |          |         |                       |           |         |
| 6001–9000 SAR                                       |                  |          |         |                             |          |         |                       |           |         |
| 6000 SAR and less                                   |                  |          |         | 2.2                         | 1.4, 3.5 | 0.001   |                       |           |         |
| Region (Ref: Riyadh)                                |                  |          |         |                             |          |         |                       |           |         |
| Jeddah  | 0.6              | 0.3, 1.1 | 0.075   |                             |          |         |                       |           |         |
| Hofuf   | 2.2              | 1.3, 3.7 | 0.005   | 2.8                         | 1.7, 4.7 | <0.001  |                       |           |         |
| Smoking (ref: never)                                |                  |          |         |                             |          |         |                       |           |         |
| In the past (≥one year)                             |                  |          |         | 2.0                         | 1.0, 4.1 | 0.056   |                       |           |         |
| Currently smoking                                   |                  |          |         | 2.7                         | 1.2, 6.3 | 0.017   |                       |           |         |
| Passive smoking (ref: no)                           |                  |          |         | 1.9                         | 1.1, 3.2 | 0.021   |                       |           |         |
| Low level of Physical Activity (ref: ≥150 min/week) |                  |          |         | 1.7                         | 1.0, 2.8 | 0.045   |                       |           |         |
| Number of hours of sitting per day                  | 1.1              | 1.1, 1.2 | 0.005   |                             |          |         | 1.1                   | 1.0, 1.2  | 0.008   |
| BMI (ref: normal)                                   |                  |          |         |                             |          |         |                       |           |         |
| Pre-obesity   |                  |          |         |                             |          |         |                       |           |         |
| Obesity (class I – III)                             | 1.7              | 1.1, 2.6 | 0.021   |                             |          |         |                       |           |         |
| Duration of diabetes >10 years (ref: ≤10 years)     | 1.6              | 1.0, 2.6 | 0.039   |                             |          |         |                       |           |         |
| Treatment (ref: oral)                               |                  |          |         |                             |          |         |                       |           |         |
| Insulin   | 2.2              | 1.2, 3.9 | 0.008   | 2.5                         | 1.5, 4.3 | 0.001   |                       |           |         |
| Insulin + oral                                      | 1.9              | 1.2, 3.0 | 0.008   | 2.4                         | 1.4, 3.9 | 0.001   |                       |           |         |
| Hypertension (ref: no)                              | 3.4              | 1.9, 6.1 | <0.001  |                             |          |         | 4.9                   | 1.5, 16.0 | <0.001  |

<sup>a</sup> List of the variables adjusted for in the multivariable analysis for each of the complications is available in the appendix.

**Table 4**  
Adjusted association between each of the microvascular complications and potential risk factors<sup>a</sup>.

| Variable  | Neuropathy <sup>a</sup> |          |         | Renal impairment <sup>**</sup> |          |         | Retinopathy <sup>***</sup> |          |         |
|---|-------------------------|----------|---------|--------------------------------|----------|---------|----------------------------|----------|---------|
|   | OR                      | 95% CI   | p-value | OR                             | 95% CI   | p-value | OR                         | 95% CI   | p-value |
| Age (ref: ≤60years)                                 |                         |          |         |                                |          |         |                            |          |         |
| 61–70 years   |                         |          |         | 2.3                            | 1.3, 3.9 | 0.002   |                            |          |         |
| >70 years   |                         |          |         | 3.2                            | 1.6, 6.2 | 0.001   | 1.5                        | 1.0, 2.2 | 0.059   |
| Gender (ref: female)                                | 1.9                     | 1.2, 2.9 | 0.005   |                                |          |         |                            |          |         |
| Education level (ref: university/college)           |                         |          |         |                                |          |         |                            |          |         |
| Intermediate/secondary                              |                         |          |         |                                |          |         |                            |          |         |
| Illiterate/primary                                  |                         |          |         |                                |          |         | 1.3                        | 1.0, 1.7 | 0.052   |
| Income (ref: 9001 SAR and over)                     |                         |          |         |                                |          |         |                            |          |         |
| 6001–9000 SAR                                       |                         |          |         | 1.7                            | 1.0, 2.9 | 0.035   |                            |          |         |
| 6000 SAR and less                                   | 2.4                     | 1.7, 3.5 | <0.001  |                                |          |         |                            |          |         |
| Region (Ref: Riyadh)                                |                         |          |         |                                |          |         |                            |          |         |
| Jeddah  |                         |          |         |                                |          |         |                            |          |         |
| Hofuf   |                         |          |         | 2.4                            | 0.9, 6.2 | 0.079   |                            |          |         |
| Smoking (ref: never)                                |                         |          |         |                                |          |         |                            |          |         |
| In the past (≥one year)                             |                         |          |         |                                |          |         |                            |          |         |
| Currently smoking                                   | 2.7                     | 1.3, 5.5 | 0.005   |                                |          |         |                            |          |         |
| Low level of Physical Activity (ref: ≥150 min/week) | 1.4                     | 0.9, 2.2 | 0.087   |                                |          |         | 1.6                        | 1.2, 2.1 | 0.002   |
| Number of hours of sitting per day                  | 1.1                     | 1.0, 1.1 | <0.001  | 1.1                            | 1.0, 1.1 | 0.067   |                            |          |         |
| BMI (ref: normal)                                   |                         |          |         |                                |          |         |                            |          |         |
| Pre-obesity   |                         |          |         |                                |          |         |                            |          |         |
| Obesity (class I – III)                             | 1.5                     | 1.0, 2.2 | 0.044   |                                |          |         |                            |          |         |
| Duration of diabetes >10 years (ref: ≤10)           |                         |          |         |                                |          |         | 2.3                        | 1.7, 3.1 | <0.001  |
| Family history of diabetes (ref: no)                | 1.6                     | 1.1, 2.5 | 0.023   |                                |          |         | 1.5                        | 1.1, 2.0 | 0.010   |
| Treatment (ref: oral)                               |                         |          |         |                                |          |         |                            |          |         |
| Insulin   | 1.8                     | 1.1, 2.7 | 0.013   | 1.8                            | 1.0, 3.2 | 0.043   | 1.9                        | 1.3, 2.6 | <0.001  |
| Insulin + oral                                      | 2.1                     | 1.4, 3.2 | <0.001  |                                |          |         | 1.9                        | 1.4, 2.7 | <0.001  |
| HbA1c (ref: < 7.0%)                                 |                         |          |         |                                |          |         |                            |          |         |
| Poor control (7%–8.9%)                              |                         |          |         |                                |          |         |                            |          |         |
| Very poor control (≥9%)                             | 1.5                     | 1.0, 2.1 | 0.029   |                                |          |         |                            |          |         |
| HDL (ref: normal)                                   |                         |          |         | 1.9                            | 1.1, 3.1 | 0.018   |                            |          |         |
| Triglycerides (ref: normal)                         |                         |          |         | 1.8                            | 1.1, 3.0 | 0.026   |                            |          |         |
| Hypertension (ref: no)                              |                         |          |         | 2.2                            | 1.2, 4.3 | 0.017   | 1.4                        | 1.0, 1.8 | 0.033   |

<sup>a</sup> List of the variables adjusted for in the multivariable analysis for each of the complications is available in the appendix.

and high blood pressure the risk of macro- and micro-vascular complications was found to increase independently and additively [31]. About three-quarters (75.9%) of our participant's had poor control of their blood glucose level and more than one third (35.6%) had high blood pressure. Thus, to reduce the risk of macro- and micro-vascular complications for people with diabetes, an intensive treatment plan is required for both hyperglycaemia and hypertension [31].

Our results showed that with every one hour of sitting per day there was a 10% increase in the risk of CAD, stroke, and neuropathy, while less than 150 min of physical activity per week increase the risk of diabetic foot by 70% and retinopathy by 60%. A Danish study showed that people who sit for 10 h or longer per day and are physically inactive during leisure time were at 80% increased risk of myocardial infarction [13]. About 29.4% of our participants were sitting for six to nine hours per day, while 17.3% spent 10 h or more sitting daily. Moreover, more than two-thirds (70.1%) of the participants were not achieving the recommended physical activity target of 150 min per week [32]. Hence, an awareness program about the role of physical activity for prevention of complications is an urgent need in Saudi Arabia.

Diabetes Mellitus is a progressive disease. With longer duration of the disease the function of the pancreas further deteriorates and the risk of complications increases, especially when there is long standing hyperglycaemia. This study showed that a duration of diabetes of more than 10 years was independent predictor of CAD and renal impairment. Similar findings were reported in a previous study from Saudi Arabia [2]. The progression of the disease is also the probable explanation for the association between using insulin and macro- and micro-vascular complications.

This study supports the well-established association between diabetes complications and advanced age as well as male gender among people with diabetes [2,11,12,33]. We have also found that family history of diabetes increase the risk of both neuropathy and retinopathy. Similar findings in regards to retinopathy was reported in a study from Greece [34]. The latter study, however, have found that people with positive family history of diabetes had earlier onset of diabetes [34]. Our data also shows that participants with family history of diabetes had earlier onset of the disease ( $42.7 \pm 11.5$  years) compared to those without family history ( $46.8 \pm 12.4$  years) ( $p$ -value  $< 0.001$ ). Early onset of diabetes is known to increase the risk of complications [35]. Other than the earlier onset, genetic and epigenetic have also been suggested to contribute in the association between diabetic retinopathy and family history of diabetes [36].

Obesity was an independent risk factors for CAD and neuropathy among people with T2DM in Saudi Arabia. Obesity is well-known risk factor for diabetes as well as for CAD [33,37], and it substantially increases the risk of CAD among people with diabetes especially if it is accompanied by other metabolic syndrome components including hypertension and dyslipidaemia [37]. Given that 62.6% of our study participants were obese and 27.2% were overweight, a program to reduce weight for people with T2DM is likely to be highly beneficial in reducing their risk of macro- and micro-vascular complications.

Our results are in the keeping with previous reports that showed a strong association of macro- and micro-vascular complications with low level of education as well as low income [38,39]. Higher level of education reduces the risk of cardiovascular disease indirectly by encouraging healthier lifestyle behaviours and positive attitude toward health and disease prevention [40,41], while high income increases the likelihood of adherence to healthy diet, physical activity, treatment regimen and access to health care [38]. The socioeconomic status of our participants varied between regions. A larger proportions of participants from Hofuf region had

lower level of education and lower household income. This may explain why people from Hofuf had higher prevalence of obesity, smoking, and longer time sitting as well as increased risk of CAD, diabetic foot, and renal impairment. People with low socioeconomic status should be considered as a high risk group and should be provided with more health education and referred to appropriate social support services available in Saudi Arabia to improve their economic status.

In contrast to previous studies [42,43], total cholesterol and LDL did not appear to have an association with macro- or micro-vascular complications in our study, while high triglycerides and low HDL were associated with renal impairment. Compared to participants without complications, a larger proportion of those with complications were having normal total cholesterol and LDL. This is probably because the management for this group of people was intensified to reduce their risk of progression or acquiring further complications. In order to prevent diabetes complications, however, lipid profile as well as hypertension and blood glucose should be controlled adequately before complications manifest [31].

This study has strengths and limitations. The relatively large sample size from three different regions gives strength to this study. The use of pretested electronic questionnaire that was validated to reduce data errors and the exploration of wide variety of potential risk factors also add strength to this study. The cross-sectional study design, however, lack temporality, and we can only infer association rather than causation. In addition, for participants who did not have ophthalmology examination report in their medical file we have relied on self-reporting of retina problem to assess the prevalence of retinopathy which may reduce objectivity. Nonetheless, this study clearly revealed the burden of diabetes macro- and micro-vascular complications among people with T2DM in Saudi Arabia and their associated risk factors. Given the high prevalence of diabetes in Saudi Arabia and that people with diabetes in the country are at high risk of developing complications, future researchers should establish risk prediction tools for diabetes complications. Such essential tools will help clinicians to validate their clinical risk assessment as well as to raise the awareness of people with diabetes about their risk, which will motivate them to adhere to the management plan and lifestyle modifications.

## 5. Conclusion

Macro- and micro-vascular diabetes complications of coronary artery disease, diabetic foot, stroke, neuropathy, renal impairment, and retinopathy are common among people with T2DM in Saudi Arabia. These complications can be prevented or their progression can be delayed by prioritizing the following lifestyle modification factors in the management plan: increasing physical activity, decreasing sitting time, smoking cessation, maintaining healthy body mass index, and adequate control of hypertension, blood glucose and lipids. The findings of this study will be useful for developing individualise complication prevention strategies based on the risk factors present on the patient. Future research should aim for developing risk prediction tools to predict diabetes complication, which will be useful in validating clinical assessment of these complication as well as raising prevention awareness among the patients.

## Declaration of interest

None.

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## Conflicts of interest

All authors declare that they have no competing interests.

## Author contributions

All authors were involved in the conception and design of the study. MJA, AJA, SMA, GMA, WAA and NAB contributed to the acquisition of data. MJA, BB, DJM, and HAA contributed to data analysis and interpretation of results. MJA and BB drafted the manuscript. All authors critically reviewed the manuscript and approved the final version.

## Availability of data and material

The datasets generated during and analysed during the current study are available from the corresponding author on reasonable request.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.dsx.2018.11.007>.

## Appendix

Operational definition.

- CAD was defined as documented diagnosis of CAD, taking medication for CAD, or underwent a procedure for CAD. Stroke was defined as documented diagnosis of irreversible cerebrovascular accident.
- Diabetic foot was defined as a history of lower extremity ulcers or amputations. Retinopathy was defined as documented diagnosis of retinopathy, or the participant had been told by an ophthalmologist that he or she had retinopathy.
- Diabetes peripheral neuropathy was defined as a score of seven or more using the Michigan Neuropathy Screening Instrument [19].
- Renal impairment was defined as estimated glomerular filtration rate  $\leq 60$  ml/min/1.73 m<sup>2</sup> which was calculated from serum creatinine using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation [44,45].
- Using the Global Physical Activity Questionnaire (GPAQ) [17], the total number of minutes of physical activity per week was categorised into  $\geq 150$  min and  $<150$  min [46].
- Using the Morisky Medication Adherence questionnaire [18] medication adherence was categorised into good adherence (a score of 0), moderate adherence (a score of 1–2) and poor adherence (a score of 3–4).

- Based on HbA1c level, glycaemic control was categorised into good control (HbA1c  $< 7.0\%$ ), poor control (HbA1c  $7.0\%$ – $8.9\%$ ), and very poor control (HbA1c  $\geq 9.0\%$ ).
- Body mass index (BMI) was categorised according to the current World Health Organization guidelines into normal ( $<25.0$  kg/m<sup>2</sup>), pre-obesity ( $25.0$ – $29.9$  kg/m<sup>2</sup>), and obesity (class I, II and III  $\geq 30.0$  kg/m<sup>2</sup>).
- High waist-hip ratio was defined as a ratio  $>0.96$  for men and  $>0.98$  for women [47].
- Hypertension was defined as either a documented diagnosis of hypertension, taking antihypertension medications, or three previous high blood pressure measures (systolic  $\geq 140$  mmHg or diastolic  $\geq 90$  mmHg) [46].
- High cholesterol was defined as cholesterol  $>4.0$  mmol/L, high LDL was defined as LDL  $>2.0$  mmol/L, and high triglycerides was defined as triglycerides  $>2.0$  mmol/L, while low HDL was defined as HDL  $<1.0$  mmol/L [48].

Variables adjusted for in the multivariable logistic analysis.

- The risk of Coronary artery disease as adjusted for age, gender, level of education, region, active smoking, physical activity, number of hours of sitting per day, duration of diabetes, modality of treatment, BMI, hypertension, cholesterol, LDL, HDL, triglycerides (area under the receiver operating characteristic curve: 75.7%, Hosmer-Lemeshow goodness-of-fit test p-value: 0.302).
- The risk of diabetic foot was adjusted for age, gender, income, region, active smoking, passive smoking, physical activity, number of hours of sitting per day, duration of diabetes, modality of treatment, adherence to medications, and HDL (area under the receiver operating characteristic curve: 71.7%, Hosmer-Lemeshow goodness-of-fit test p-value: 0.433).
- The risk of stroke was adjusted for age, gender, level of education, physical activity, number of hours of sitting per day, duration of diabetes, hypertension, cholesterol, LDL (area under the receiver operating characteristic curve: 68.8% and the Hosmer-Lemeshow goodness-of-fit test p-value: 0.413).
- The risk of neuropathy was adjusted for age, gender, level of education, location of residence, income, region, active smoking, passive smoking, physical activity, number of hours of sitting per day, duration of diabetes, family history of diabetes, modality of treatment, hypertension, BMI, HbA1c, and triglycerides (area under the receiver operating characteristic curve: 72.8%, Hosmer-Lemeshow goodness-of-fit test p-value: 0.338).
- The risk of renal impairment was adjusted for age, gender, level of education, income, region, physical activity, number of hours of sitting per day, duration of diabetes, modality of treatment, adherence to medication, hypertension, waist-hip ratio, cholesterol, LDL, HDL, and triglycerides (area under the receiver operating characteristic curve: 73.6%, Hosmer-Lemeshow goodness-of-fit test p-value: 0.638).
- The risk of retinopathy was adjusted for age, gender, level of education, income, physical activity, number of hours of sitting per day, duration of diabetes, family history of diabetes, modality of treatment, hypertension, and HbA1c (area under the receiver operating characteristic curve: 70.5%, Hosmer-Lemeshow goodness-of-fit test p-value: 0.667).

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