Prevalence of Type 2 Diabetes Mellitus in the General Population of Saudi Arabia, 2000–2020: A Systematic Review and Meta-Analysis of Observational Studies

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Abstract

Background: The prevalence of type 2 diabetes mellitus (T2DM) has increased worldwide, including in Saudi Arabia.

Objective: To systematically review the available literature and assess the pooled prevalence of T2DM in Saudi Arabia between 2000 and 2020.

Methods: Observational studies that reported quantitative estimates of the prevalence of T2DM as their main outcome, included the general population of Saudi Arabia, and were published between 2000–2020 and in English were retrieved using three electronic databases (namely, CINAHL, Medline via PubMed, and Web of Science). Retrieved studies were screened, and relevant data were extracted. The Joanna Briggs Institute Critical Appraisal guideline was used to assess the methodological quality of included studies. A random-effects model was used to estimate the prevalence of T2DM.

Results: Twenty-three studies were included in the systematic review, of which 19 were included in the meta-analysis (total pooled population: 258,283). The overall pooled prevalence of T2DM in Saudi Arabia was 16.4% (95% CI: 11.6–17.5). However, there was heterogeneity in the results of the studies [$I^2 = 99.31\%$, $P < 0.0001$] and the summary values varied from 3.18% (95% CI: 1.46–5.95) to 94.34% (95% CI: 89.53–97.38). Although the prevalence of T2DM by age varied across studies, in most studies, it was higher among the older age groups. In addition, the prevalence of diabetes widely varied across the different geographical regions of Saudi Arabia.

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Conclusions: This is the first meta-analysis that determined the pooled prevalence of T2DM in Saudi Arabia, and it revealed a high prevalence over the past two decades. However, owing to data collection inconsistencies in the identified studies, neither the modifiable (such as obesity, educational status, emotional support, etc.) nor the non-modifiable (such as gender and age) risk factors of T2DM could be determined, thereby indicating the need for a nationally collective effort in determining these factors.

Keywords: Meta-analysis, prevalence, random-effects model, Saudi Arabia, systematic review, type 2 diabetes mellitus

INTRODUCTION

Diabetes mellitus (DM) is a major public health concern with increasing prevalence and long-term morbidity.[1] It is a debilitating and multifactorial disease that can be secondary to the existence of a genetic predisposition, is exacerbated by environmental factors, and can immensely the patients' quality of life.[2]

In 2019, the estimated prevalence of DM worldwide was 9.3% (463 million people), and this was expected to rise to 10.2% (578 million) by 2030 and to 10.9% (700 million) by 2045.[3] However, these estimates have already been revised: the International Diabetes Federation (IDF) estimated that in 2021, 10.5% (537 million) of all adults aged 20–79 worldwide had diabetes, and this would increase to 643 million adults by 2030, and 783 million adults by 2045. Consequently, whereas the global population is projected to expand by 20% in this period, the prevalence of DM is expected to increase by 46%.[4] Further, the estimated cost for diabetes care between 2011 and 2030 is projected to be approximately US$ 1.7 trillion, the burden of which is exacerbated by the fact that the majority of the increase in cases would occur in low-and middle-income countries.[2,4]

The Arab Gulf Cooperation Council (GCC), which includes Saudi Arabia, Kuwait, Bahrain, Oman, Qatar, and the United Arab Emirates, is one of the regions with the highest prevalence of DM.[5] Based on the IDF region-wise data, the prevalence of diabetes in Gulf countries among adults aged 20–79 years ranged from 8% to 22%. While the highest prevalence in GCC was in Kuwait (22%), the highest number of diabetes-related deaths were from Saudi Arabia.[6] The alarming increase in the number of patients with diabetes in Saudi Arabia has been attributed to the rapid epidemiological transition, urbanization, unhealthy diet, and reduced physical activity in the recent decades.[5] The increase in diabetes also places a considerable burden on the economy. In Saudi Arabia, the annual total direct expenditure of diabetes-related treatment in 2014 was estimated to be 17 billion Riyals, and the annual public medical healthcare expenditure on people with diabetes has been estimated to be tenfold that of those without diabetes.[7,8]

Several studies from Saudi Arabia have estimated the regional prevalence of DM; however, discrepancies between methods have even resulted in variation in the prevalence being reported from the same area. Therefore, the aim of this systematic review is to provide a pooled prevalence estimate for type 2 diabetes mellitus (T2DM) within the general population of Saudi Arabia, which can be useful for all the relevant stakeholders and policymakers.

METHODS

This study followed the PRISMA items for systematic review and meta-analysis guidelines.[9]

Data source and search strategy

A systematic literature search was performed to identify studies that reported the prevalence of T2DM in Saudi Arabia. A rigorous literature search was conducted using the following three academic electronic databases: CINAHL, Medline (via PubMed), and Web of Science. In addition, the reference lists of eligible studies were screened to identify relevant studies.

Studies that described the prevalence in relevance to either former diagnosis of diabetes or diagnostic blood glucose-level test were included. The search in PubMed was carried out using the following terms: (Diabetes) OR (Hyperglycemia) AND (Prevalence) OR (Trend) OR (Incidence) OR (Epidemiology) AND (Saudi) OR (KSA); these terms was similarly adapted for the other two databases. The publication date (range: 2000–2020) and language (only English) filters were used during the searches. All searches were independently carried out by two reviewers.

All references retrieved in the searches were uploaded to RAYYAN software, which was used for first removing duplicates and then for screening the titles and abstracts.[10] Studies were included for a full-text review if they met the following criteria:

1. Were observational (i.e., cross-sectional or cohort design);
2. Reported quantitative estimates of the prevalence of T2DM as the main outcome; and
3. Included the general population in Saudi Arabia.

Studies were excluded if they:
1. Were systematic reviews, meta-analysis, and discussion articles;
2. Full-text was not published in English, or were unpublished articles, conference proceedings, or thesis; and
3. Estimated the prevalence of type 1 diabetes mellitus and gestational diabetes.

Then, both the reviewers independently evaluated the full text of the eligible articles, and any disagreements were settled through discussion.

Data extraction method and data items

Using a set of factors, data from qualifying research were extracted into a predetermined data extraction file. Both the reviewers compared and extracted the following data: author details, publication year, study period, design, setting and region of Saudi Arabia, sampling and the number of participants, age range, type of diabetes, and prevalence with outcomes of interest.

Study quality assessment

Each paper was assessed for study quality by two assessors, and discrepancies were resolved through discussion. The included studies were critically appraised for methodological quality using the Joanna Briggs Institute (JBI) Critical Appraisal guideline.[11] All papers were assessed based on data relevance and methodological strength, and only articles that satisfied at least four of the nine criteria were included in the final analysis.

Effect measure and evidence synthesis

The prevalence of T2DM was determined as a ratio by dividing the number of people diagnosed with the disease by the total number of people in the study population. The Comprehensive Meta-Analysis (CMA) software version 2.0 was used to conduct the meta-analysis. Using the stated crude estimates and population denominators, standard errors and 95% confidence intervals (CI) were calculated, presuming exact binominal distribution, as defined by Clopper and Pearson.[12,13] In a meta-analysis of prevalence, when the estimate for a study approached either toward 0% or 100%, the variance for that study shifts toward zero, and as a result, its weight is exaggerated in the analysis. Accordingly, we carried out the meta-analysis with prevalence estimates and transformed it by using the logit transformation method. Back transformation was used to simplify the interpretation of the final pooled prevalence and the 95% CI. The prediction interval was calculated based on logit transformation using the CMA software and Microsoft Excel spreadsheet.[12] The prediction interval for the random-effects distribution was computed to acquire an understanding of the potential range of T2DM. The heterogeneity and publication bias, of the included studies in the meta-analysis were explored in accordance with the recommendations by Higgins and Thompson.[14]

A random-effects meta-analysis was used on individual study estimates to obtain a crude summary estimate for prevalence, where this model was used depending on the degree of the clinical and methodological heterogeneity between studies. Higgin's I^2 and Cochran's Q-test were used to assess the heterogeneity.[15,16] I^2 measures the proportion of the total variability that is due to between-study heterogeneity. The higher the I^2 value, the greater the heterogeneity: I^2 0% indicates no observed heterogeneity, while >50% indicates high heterogeneity.[17,18] Tau-squared statistics were performed to predict the variance between effects on test accuracy seen in different studies.[19] P values < 0.05 were considered significant.

Publication bias

The funnel plots and Egger's bias indicator test were used to detect publication bias. Funnel plots are scatter plots that indicate each study's influence concerning its sample size.[18] In the absence of skew or asymmetry, publication bias is ruled out. Egger's regression intercept is calculated when data from at least three trials are pooled.[19] In case of publishing bias, the results were adjusted using the Duval and Tweedie's trim and fill method.[19]

RESULTS

Search strategy and study selection

The searches resulted in the retrieval of 623 articles, of which 50 were duplicates. The remaining 573 articles were screened based on titles and abstracts, following which 544 records were excluded and the full text of 29 articles were assessed for eligibility. Six articles were excluded at this stage because either the prevalence of DM was not the main outcome (n = 3) or there was a significant risk for bias (n = 3), resulting in 23 studies being included in this systematic review [Figure 1].[20-43]

Study quality assessment

The quality of all the 23 articles were appraised based on the relevance of data and methodology,[21]

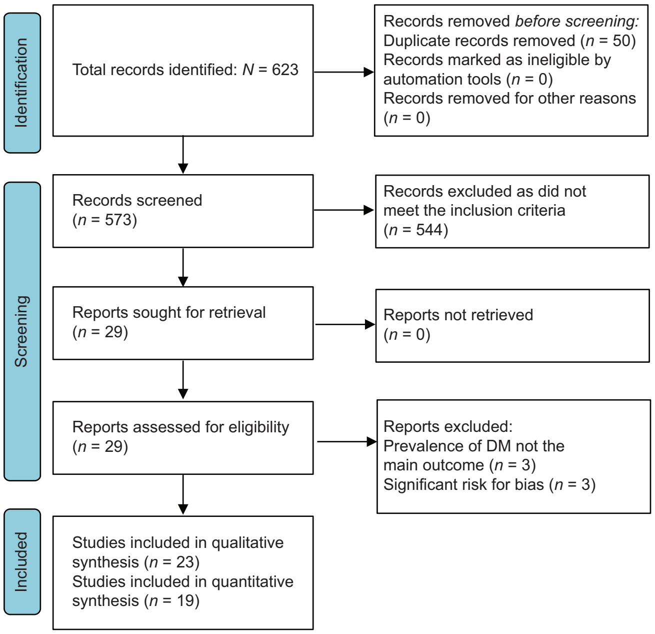

Figure 1: The PRISMA flowchart of study selection

which led to the exclusion of the four articles [Supplementary Table 1].[20-24] Finally, 19 articles had suitable quantitative designs for the prevalence research and were used to conduct the meta-analysis [Table 1].

Study characteristics

Of the 23 studies included in this systematic review, 18 were cross-sectional,[22-39] one was an estimation study that used the discrete state Markov model,[20] and the remaining four did not clearly state the study design.[40-43] The sample sizes of DM patients among the included studies ranged from 31 to 197,681. In terms of geographical representation of the sampled population, six studies were conducted nationwide;[20,27,28,31,41,43] four studies each in Riyadh[22,25,30,33] and Al-Kharj city;[24,35,39,42] two studies each in the Eastern Province,[29,40] Turaif,[36,37] and Tabuk;[34,38] and one study each in Taif,[26] Jeddah,[32] and Madinah.[23] The prevalence of T2DM varied across regions.

Moreover, of the 23 included studies, five studies used the random sampling technique.[24,27,31,38,43] four used the multi-stage stratified sampling,[32,35,39,41] two each used systematic random sampling[25,37] and convenience sampling,[28,40] and one each used a cluster sampling strategy[30] and a multi-phase screening plan.[26] The remaining eight studies did not specify the sampling procedure.[20-23,29,33,34,36,42]

In terms of study settings, five studies were carried out in tertiary hospitals,[24-26,29,42] four in primary healthcare centers,[28,30,33,43] four in households,[27,31,32,41] two each in university hospitals[29,39] and shopping malls,[29,34] one in both governmental and private institutes,[35] and one in Riyadh Social Welfare Home;[22] one study was conducted across >300 primary health care centers and government hospitals, private hospitals, dispensaries, and public venues;[40] one study was conducted in a public academic institute.[23] Four studies did not mention their settings.[20,36-38] In terms of the prevalence of diabetes, it widely varied across various geographical regions [Table 1].

Meta-analysis

Nineteen studies were included in the meta-analysis, with a total pooled population of 258,283. The overall prevalence of T2DM in Saudi Arabia was estimated to be 16.4% (95% CI: 11.6–17.5) [Figure 2] and the prediction interval was (95% CI) 7.03–27.3, which presented the confidence interval of estimated prevalence for possible population-based observational research to be conducted on diabetes in the future. The true prevalence size varied across studies. The mean prevalence probability was 0.116–0.175. The true effect size for any single study ranged 0.0703–0.273. The test for consistency across studies revealed substantial heterogeneity [$I^2 = 99.31\%$, $P < 0.0001$] [Table 2]. Moreover, the Q-statistic was used to test the null hypothesis (i.e., all articles in the analysis have the same effect size). All studies with similar effect sizes would have an expected Q value equal to the degrees of freedom (df) (the number of articles minus 1), where the Q-value was 7145.293, and the $P < 0.0001$ [Table 2]. The variance of true effect sizes (T^2, in log units) was 0.241. The standard deviation of the actual effects, which is represented by the letter "T = tau" (in log units), was 0.491.

The results of analyses by time showed variable prevalence of T2DM among the Saudi population between 2000 and 2020. A recent study found extremely high prevalence of T2DM: 94.3%.[42] The weights of the studies reported from the random effect model ranged from 3.33% to 6.22%, as shown in Figure 2.

Publication bias and sensitivity analysis

Funnel plot

The funnel plot was used to assess publication bias [Figure 3]. A mild asymmetric funnel plot of all studies across the prevalence of T2DM among the Saudi population was shown in Figure 3. In this instance, the mild asymmetry of the funnel plot suggests the presence of some publishing bias. It is plausible that the mild asymmetry is related to the effects of small and large studies (such as a sampling error).

Egger's bias indicator test

The Egger's bias test was used to assess the funnel plot asymmetry. In this analysis, the intercept (B_0) was

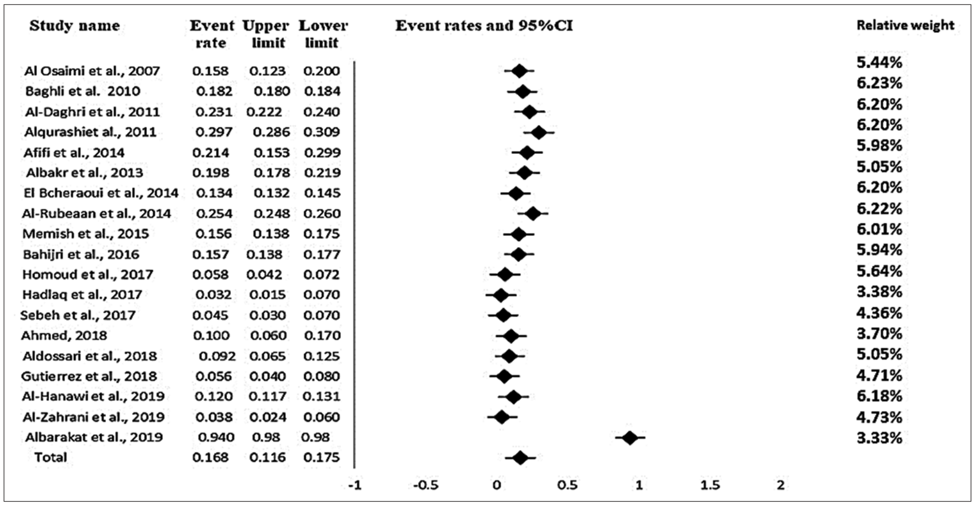

Figure 2: Forest Plot of the 19 studies showing the prevalence of T2DM among the Saudi population between 2000 and 2020. T2DM – Type 2 diabetes mellitus

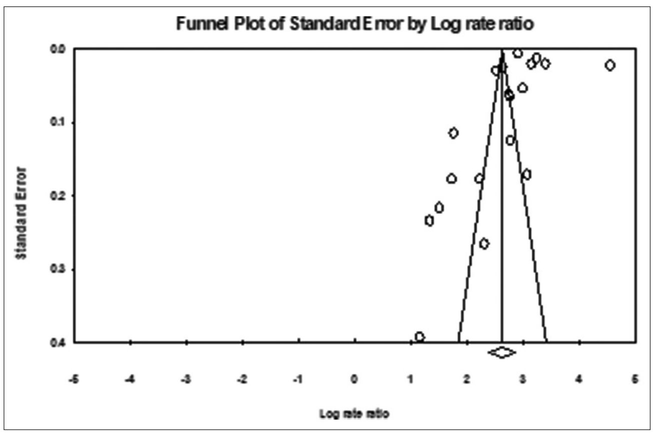

Figure 3: Funnel plot of standard error by log rate ratio associated with the prevalence of T2DM among the Saudi population. T2DM – Type 2 diabetes mellitus

determined to be 0.48, 95% CI (−11.63–12.58), with *t*-value = 0.084 and df = 17.00. However, this test showed nonsignificant publication bias, where the suggested 1-tailed *P* value was 0.47 and the 2-tailed *P* value was 0.93.

Duval and Tweedie's trim and fill

Using these parameters, the method did not identify any missing study. The funnel plot for the trimmed and imputed study is shown in the Supplementary Figure 1. According to the random-effects model, the point estimate (95% CI) for the included studies was 13.78 (10.96–17.34). The trim and fill method was used to obtain an adjusted point estimate of 13.78 (10.95–17.34).

DISCUSSIONS

This meta-analysis found that the pooled prevalence of T2DM in Saudi Arabia was 16.4%, with indications that that the prevalence of T2DM in Saudi Arabia is increasing. These findings are in line with the previous estimations by IDF: Saudi Arabia was identified as one of the top ten countries with the highest prevalence of T2DM, and the prevalence of diabetes in the Middle East and North Africa region was estimated as 18.1%, the highest in the world.[4,44] The current findings will help health policy planners in anticipating the potential increase in the prevalence of T2DM in Saudi Arabia over the next decade.[30,34,35,37,38]

In terms of non-modifiable risk factors of DM such as gender, there have been contrasting findings from Saudi Arabia. While several studies reported that the prevalence of DM was higher among females,[24,40,42,43] others have found the prevalence to be higher among males.[20,27-32,35,41] The possible explanation for discrepancies in the findings is that women tend to seek healthcare more frequently than men, thereby increasing the likeliness of them being diagnosed. On the other hand, several risk factors have been correlated with the high prevalence of DM among Saudi males, including tobacco smoking,[45] obesity,[46] and vitamin D deficiency.[30] Furthermore, in the Arab society, men tend be under a higher level of chronic psychological stress than women, which, over time, has a role in inflammatory and metabolic stress, eventually leading to DM.[47] In contrast to the above studies, Mohamed *et al.*[38] revealed no significant gender-wise difference in the prevalence of DM among Saudi patients. These discrepancies highlight need for a country-wide study to determine the prevalence of DM among males and females in Saudi Arabia.

In terms of age as a risk factor, DM among the elderly is common worldwide. We found that while the prevalence of T2DM by age varied across studies, in most studies, the prevalence was higher among the older age groups than the

Table 1: Summary of the included studies

Number	Author (s) (date of publication)	Study period	Setting (s)	Study type	Sample size	Age
1	Karim *et al*., (2000)[24]	-	Al-Kharj Military Hospital	Retrospective cross-sectional study	3747 case notes (1683 males and 2064 females)	All ages
2	Al Osaimi *et al*., (2007)[25]	March-April 2002	East of Riyadh	Cross-sectional survey	380	Older than 18
3	Al-Baghli *et al*., (2010)[40]	August 2004-February 2005	Community screening campaign in Eastern province	-	197,681	Aged 30 years and above
4	Al-Quwaidhi *et al*., (2014)[21]	2005	Nationwide	Estimation study used discrete-state Markov model	-	Saudis aged ≥25
5	Al-Rubeaan *et al*., (2014)[27]	2007-2009	Nationwide	Cross-sectional study	18,034	Aged 30 and above
6	Alqurashi, *et al*. (2011)[28]	June 2009	Nationwide	Cross-sectional study	6024: 2279 (37.8%) males and 3744 (62.2%) females	Above 12
7	Memish *et al*., (2015)[43]	2009	Nationwide: one rural and two urban	Score	1485	≥20 years of age
8	Albakr *et al*., (2013)[29]	2010-2011	Dhahran Mall and King Fahad University Hospital, Al-Khobar City	Cross-sectional community-based survey	1552 subjects, 1206 Saudi's, 346 non-Saudi	15 years and above
9	Afifi, *et al*. (2014)[26]	2010-2011	The preventive medicine department at AFH, Taif city	Cross-section	117	40 years and above
10	Al-Daghri *et al*., (2011)[30]	2011	PHCC across Riyadh	Cross-sectional study	9149	Ages 7-80 years
11	Abou-Gamel *et al*., (2014)[23]	November 2011	The College of Science at Taibah University. 57.1% lived in urban regions	Cross-sectional study	99 subjects	Above 30 years old
12	Al-Orf (2012)[22]	2012	Riyadh nursing home	Cross-sectional study	31 elderly females	Ranged between 62 and 94 years
13	El Bcheraoui *et al*., (2014)[31]	April-June 2013	Nationwide: Participants invited to local health clinics	Cross-sectional study	10,735	Aged 15 years or older
14	Al-Hanawi, *et al*. (2019)[41]	2013	Nationalwide	-	8004	Between 18 and 80
15	Bahijri *et al*., (2016)[32]	2015	Jeddah	Cross-sectional study	1420 comprising both Saudi and non-Saudi families	Aged ≥18 years
16	Hadlaq *et al*., (2017)[33]	December 2015-January 2016	Riyadh	Cross-sectional study	283, 8.5% male (n=165) and 41.7% female (n=118)	The mean age was 36.6 years with SD of 13.5 years (18-65)
17	Gutierrez *et al*., (2018)[34]	October 2016	Tabuk region	Nonexperimental, cross-sectional design	432	≥18 years old; 89.4% were Saudi and 10.6% were non-Saudi
18	Aldossari *et al*., (2018)[35]	January-June 2016	Al-Kharj (different governmental and private institutes)	Population-based cross-sectional study	381 Saudi adult males	Aged 18 years of age or above
19	Alanazi *et al*., (2017)[36]	2016-2017	Turaif city, northern Saudi Arabia	Cross-sectional study	1287	1 year to >65 years
20	Alhazmi *et al*., (2017)[37]	May 2017	Turaif city, northern Saudi Arabia	Cross-sectional study	402	Aged between 6 and 63 years
21	Mohamed (2019)[38]	2019	Tabuk	Cross-sectional study	120 (60 males and 60 females)	Age >20
22	Albarakat & Guzu (2019)[42]	2019	Patients registered at home care center at family and community medicine department, Al-Kharj military industries corporation hospital	-	159	Older than 18 years
23	Al-Zahrani *et al*., (2019)[39]	2019	Alkharj public university, one governmental organization and one private institute	Exploratory cross-sectional survey	638 Saudi females	18 years of age and above

Contd...

Table 1: Contd...

Number	Type of diabetes	Sampling technique	Method	Prevalence (%)		Overall prevalence (%)
				Female	Male	
1	Not mentioned	Medical records were selected randomly		5.32	2.55	4.08
2	Not mentioned	Systematic random sampling	FPG	24.2	11.3	15.8
3	Not mentioned	Convenience sampling (approached participants in their workplaces, major public places, malls and other venues)	CFBG FPG CCBG	18.6	15.9	18.2
4	T2DM	-	OGTT	2000 16.4 2008 24.7 2011 28.1 2022 47.7	17.7 26.7 29.8 41.3	17.2 25.9 29.2 44.1
5	T2DM	Random sampling	FPG	21.9	29.1	25.4
6	Did not differentiate between type 1 and type 2	Convenience sampling (patients were selected from those attending the department of primary care at King Fahad AFH)	Self-report	27.6	34.1	30
7	T2DM	Randomly chosen PHCCs	OGTT FPG	18.3	13.9	15.6
8	4.6 type 1 and 14.3% type 2	Not mentioned	Random capillary blood glucose	18.7	20.6	Self-reported diabetes 19.8, 17.6 Saudi, 27.5 non-Saudi Prevalence of high RBS was 21.5
9	Both	Multi-phase screening plan	RBS ≥200	-	-	21.4 (25/117) of recruits with RBS ≥200 mg, 68 (17/25) of them are known diabetics
10	T2DM	Randomly selected using a cluster sampling strategy	FPG	28.6	34.7	23.1
11	Not specific	Not mentioned	RBG	-	-	14.1
12	T2DM	Not mentioned	FBG	29	-	29
13	66.7% reported being diagnosed with T2DM and 19.9% did not know their type	Randomly selected from a national sampling frame	HbA1c	11.70	14.84	13.4
14	Not specific	Multi-stage stratified probability sample	Self-reported	10.7	13.9	12
15	T2DM	A 3-stage stratified cluster sampling technique	FBG, HbA1c	11.4	12.9	12.1
16	T2DM	Not mentioned	Fasting glucose test for 83 patients Random glucose test for 199 patients One refused	3.4	3.0	3.2
17	Not determined	The participants were voluntarily involved For a self-administered structured questionnaire	RBG	-	-	5.6
18	Not specific	Multi-stage sampling method	HbA1c	-	9.2	9.2
19	Not determined	Not mentioned	RBG	4.3	1.6	5.8
20	Not determined	Systematic random sampling technique	RBG	7.8	2.2	4.5
21	Not mentioned	Random sample	Fasting blood glucose	No significant differences between males and females Not mentioned	Not mentioned	10

Contd...

Table 1: Contd...

Number	Type of diabetes	Sampling technique	Method	Prevalence (%)		Overall prevalence (%)
				Female	Male	
22	94.3% of participants had T2DM, whereas 3.8% had type 1	Not mentioned Patients registered at home care center at family and community medicine department	HbA1c	-	-	94.3 T2DM
23	Not mentioned	Multi-stage cluster Sampling	HbA1c	3.8	-	3.8

AFH: Armed force hospital, SD: Standard deviation, T2DM: Type 2 diabetes mellitus, PHCCs: Primary health care centers, FPG: Fasting plasma glucose test, CFBG: Capillary fasting blood glucose, CCBG: Casual capillary blood glucose, OGTT: Oral glucose tolerance test, RBS: Random blood sugar, RBG: Random blood glucose, HbA1C: Hemoglobin A1C

younger age groups.[29,31,32,35,36,39,42] In terms of proportion, in those aged ≥50 years, Albakr *et al*., Bahijri *et al*., and Albarakat and Guzu found that more than half of the people in this age group had DM, while another 10–15% had pre-diabetes.[29,32,42] One of the included studies found that the prevalence of DM was similar in the rural and urban areas.[43] However, the findings of this study cannot be generalized to Saudi Arabia, and thus there is need for additional studies to determine if region-wise factors contribute to DM in Saudi Arabia.

Comorbidities are common in patients with diabetes. A study from Al Kharj found that in addition to diabetes, 20.8% of the patients had ≥3 comorbidities and 74.2% had 1–2 comorbidities.[42] However, due to the lack of available comorbidity rates among T2DM patients in many of the included studies, subgroup analysis related to comorbidity rates was not possible. Therefore, additional research is needed to determine the comorbidity rates associated with T2DM in Saudi Arabia.

Obesity is a commonly known predictor of DM, regardless of the presence or absence of other factors.[35] In a country-wide study from Palau, both overall and central obesity were found to be significant predictors of prediabetes and/or diabetes; in fact, in obese individuals, diabetes occurred at a younger age than non-obese individuals.[48] In this meta-analysis, Alqurashi *et al*., in their logistic regression findings, showed that BMI >25 was significantly associated with diabetes,[28] a finding that was in accordance with those of several other included studies.[23,29,30,32,35,39]

Educational status is another factor that has been reported as a predictor of DM. Unsurprisingly, several studies included in this meta-analysis have found the prevalence of DM to be higher among socioeconomically disadvantaged groups with lower education levels and higher unemployment.[31,35,39,41,43] These finding are coherent with the findings of studies conducted in other countries.[49-51] Between these two variables, a recent study found that in Saudi Arabia, education inequality was higher than income inequality among patients with DM compared with those without DM. This study also found that rate of DM decreased with an increase in education level.[41]

In this meta-analysis, Al-Hanawi *et al*., Al-Zahrani *et al*., El Bcheraoui *et al*., and Aldossari *et al*.,[31,35,39,41] found that married individuals are more likely to develop DM than divorced, widowed, or single individuals. This may be explained by the fact that those married are likely to

Table 2: The heterogeneity, publication bias and hypothesis testing of the included studies in the meta-analysis

Variable	Publication bias									
	Heterogeneity				Random			Hypothesis test		
					Prevalence	95% CI		Random		
	Q	*P*	df (Q)	I^2		Lower limit	Higher limit	*Z*	*P*	Number of studies
T2DM	2136.257	<0.0001	18	99.31	0.164	0.116	0.175	−19.442	<0.0001	19

T2DM: Type 2 diabetes mellitus, CI: Confidence interval

have greater responsibilities in their personal life and, as a result, are less physically active and more prone to obesity and an increased likelihood of developing DM. Among Greeks, married status has been found to be associated with obesity,[52] whereas among Americans,[53] marital status has been found to be associated with higher physical activity levels compared with those who are single, and among Malaysians,[54] physical activity did not differ according to marital statuses. These findings indicate that cultural factors may be associated with obesity, physical activity, and consequently, T2DM, and thus there is need for further studies from Saudi Arabia regarding this factor.

Some of the other risk factors of DM reported in the included studies were an increase in exposure to stress (which were indicators for elevating the prevalence of DM), family history, and the metabolic syndrome with its alarming manifestations among Saudi adults.[23,29-31,35,37]

Limitations and future directions

This meta-analysis has a few limitations that should be considered while interpreting its results. First, only studies that examined the prevalence of diabetes as the main outcome were included. Second, this review was limited to T2DM, and does not include the prevalence of T1DM and gestational diabetes; however, heterogeneous methods were used to measure glucose status and some of the included studies did not distinguish between T1DM and T2DM. Finally, we were unable to do any subgroup analysis of the prevalence for males/females and other associated factors of T2DM, as most of the included studies did not document gender or associated risk factor prevalence, thereby making it difficult to generate pooled gender or associated risk factor-specific prevalence figures for the region.

CONCLUSIONS

This systematic review found the pooled prevalence of T2DM in Saudi Arabia between 2000 to 2020 was 16.4%. The increasing trend in the prevalence of T2DM in Saudi Arabia indicates the need for urgent remedial actions by policymakers. This review also highlights the current deficiencies in the literature of T2DM from Saudi Arabia, and thus provides directions for future studies.

Peer review

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Conflicts of interest

There are no conflicts of interest.

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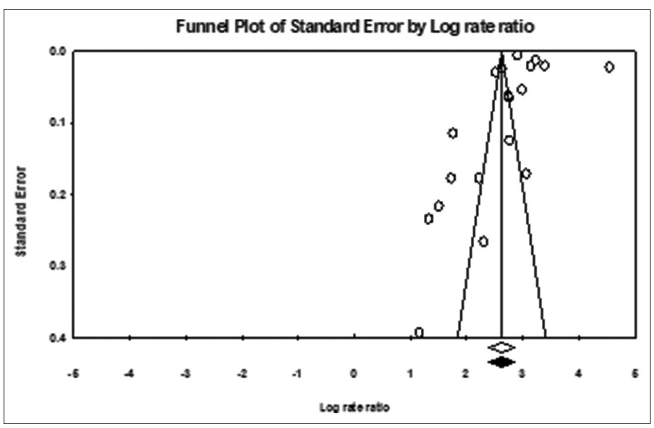
Supplementary Table 1: JBI critical appraisal checklist applied for included articles reporting prevalence data

Author Name/Year	Was the sample frame appropriate to address the target population?	Were the participants appropriately recruited?	Was the sample size adequate?	Were the study subjects and setting described in detail?	Was data analysis conducted with sufficient coverage of the identified sample?	Were valid methods used for the identification of the condition?	Was the condition measured in a standard, reliable way for all participants?	Was there appropriate statistical analysis?	Was the response rate adequate, and if not, was the low response rate managed appropriately?
Abou-Gamel *et al*. (2014)	F	F	F	UC	T	T	UC	UC	UC
Al-Orf (2012)	F	UC	F	UC	T	T	F	T	UC
Karim *et al*., (2000)	T	F	T	F	F	UC	UC	UC	UC
Al-Baghli *et al*. (2010)	T	T	T	T	T	T	T	T	T
Al-Daghri *et al*. (2011)	T	T	T	T	T	T	T	T	T
Al-Rubeaan *et al*. (2015)	T	T	T	T	T	T	T	T	T
Al-Qurashi *et al*. (2011)	T	F	T	T	T	UC	T	T	T
Al-Hanawi (2019)	T	T	T	T	T	F	UC	T	T
Al-Quwaidhi (2014)	*NA	*NA	*NA	T	UC	T	T	T	UC
Al-Zahrani *et al*. (2019)	T	T	T	T	UC	T	T	T	T
Alanazi *et al*. (2017)	T	UC	T	T	T	T	T	T	T
Aldossari *et al*.(2018)	T	T	T	T	T	T	T	T	T
Bahijri (2016)	T	T	T	T	UC	T	UC	T	T
Al Osaimi (2007)	T	T	UC	T	UC	T	T	T	T
Hadlaq (2017)	UC	UC	UC	T	T	T	T	T	T
El Bcheraoui (2013)	T	T	T	T	UC	F	T	T	T
A. Mohamed (2019)	T	T	T	T	UC	T	UC	T	T
Memish (2015)	T	T	UC	F	UC	T	T	T	T
Gutierre (2018)	T	F	T	F	T	T	T	T	T
Afifi (2015)	T	F	F	T	T	T	UC	T	T
Albakr1 (2011)	F	F	F	T	F	T	T	T	T
Alhazmi (2017)	T	T	T	T	T	T	T	T	T
Albarakat (2019)	T	UC	T	T	T	T	T	T	T

*NA, Not applicable; T, Yes; F, No; UC, Unclear.



Supplementary Figure 1: Funnel plot for the trimmed and imputed study