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RESEARCH

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Health disparities and inequalities in prevalence of diabetes in the Kingdom of Saudi Arabia

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Abstract

Background Over time, global health systems have witnessed significant improvements in the delivery and coverage of healthcare services. Nevertheless, the increasing prominence of non-communicable diseases remains a persistent challenge. Diabetes is one such non-communicable chronic disease that poses a threat with respect to both mortality and morbidity. This study investigated the socio-economic determinants and inequalities in the prevalence of diabetes in the Kingdom of Saudi Arabia according to data collected from the 2018 Saudi Family Health Survey conducted by the General Authority for Statistics.

Methods The analysis was limited to a sample of 11,528 respondents aged ≥ 18 years, selected across all 13 regions of Saudi Arabia, with complete responses for all variables of interest. Socio-economic determinants in diabetes prevalence were explored with univariate, bivariate, and multivariate logistic regression analyses. Furthermore, inequalities were visualised and quantitatively estimated according to construction of a concentration curve and calculation of the concentration index.

Results The prevalence of diabetes among the 11,528 respondents was 11.20%. Age, education, income, and residence area were significant determinants of diabetes prevalence, with a greater risk of diabetes found in older participants (odds ratio [OR]: 12.262, 95% confidence interval [CI]: 9.820–15.313, $p < 0.01$) compared to younger participants. Inequality analysis showed a negative education-based concentration index (–0.235, $p < 0.01$), indicating that diabetes prevalence is concentrated among people with relatively less formal education. For males, the income-based concentration index was significantly positive, whereas the education-based concentration index was significantly negative, indicating a greater concentration of diabetes among Saudi men with higher incomes and less education.

Conclusion These findings emphasize the need to prioritize policies and strategies for diabetes prevention and control with considerations of the socio-economic inequalities in prevalence. Key areas of focus should include improving education levels across all regions, raising awareness about diabetes and implementing nutritional interventions.

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Keywords Inequalities, Concentration curve, Concentration index, Diabetes, Diabetes prevalence, Saudi Arabia, Socio-economic status

Introduction

Global health systems have witnessed remarkable progress over the last several decades, resulting in significant improvements in the delivery and coverage of healthcare services. Despite these advancements, non-communicable diseases (NCDs) remain a persistent challenge and are posing an increasing threat to public health as they become dominant contributors to global morbidity and mortality [1]. In particular, diabetes has become an increasingly prominent NCD, with an estimated 5 million deaths in the 20–79 years age group worldwide attributed to diabetes in 2015 [2]. The global prevalence of diabetes is estimated to reach 578 million by 2030, and is estimated to surpass 700 million by 2045 [3]. Thus, the prevalence of diabetes, along with diabetes-related deaths and healthcare expenditure, continues to rise worldwide. Given these statistics, it is imperative for governments to prioritize the implementation of strategies aimed at addressing the global impact of diabetes.

Diabetes encompasses a collection of metabolic disorders characterized by high blood glucose levels [4]. Various factors, including physiological, genetic, and socio-economic aspects, influence the risk of developing this chronic condition [5]. Risk factors include the aging population and unhealthy habits, including poor diets [6, 7]. The combination of lifestyle changes and cultural shifts over time has resulted in a rise in physical inactivity and a high prevalence of obesity, further exacerbating the incidence of diabetes [8]. People with diabetes face higher morbidity and mortality risks compared to those of the general population, presenting social and financial challenges to healthcare systems worldwide.

As a chronic disease, individuals living with diabetes require lifelong medical follow-up and face a higher risk of complications and susceptibility to other health issues [9]. This places a significant burden on the healthcare system and leads to increased out-of-pocket healthcare expenses [10]. In 2015, the global health expenditure associated with diabetes reached approximately 673 billion US dollars, with projections estimating a burden of 802 billion US dollars by 2040 [2]. These costs primarily stem from treating diabetes-related complications, creating a burden on healthcare delivery, access, and coverage. This underscores the importance of addressing the far-reaching consequences of diabetes as a global concern.

Research on socio-economic inequalities in diabetes prevalence has yielded diverse findings. Richards et al. [11] identified an inverse correlation of diabetes prevalence with unemployment and alcohol consumption. In Denmark, Tapager et al. [12] revealed a consistent link between municipality socio-economic disadvantage and diabetes prevalence. Similarly, inequality in the prevalence of diabetes was identified in all regions of Bangladesh [13] and Iran [14]. In India, Maiti et al. [15] found a higher diabetes prevalence among individuals with lower education levels, lower socio-economic status, and those residing in rural areas. Other studies identified a family history of diabetes as a significant risk factor, including a study conducted by Moradpour et al. [8] in Iran. In South Africa, Sidahmed et al. [16] reported a higher diabetes prevalence among women compared to men, which was consistent with findings in Argentina reported by Rojas-Roque et al. [17]. However, Wang & Wild [18] reported a lower diabetes prevalence for women than men in Scotland.

As the largest country in the Middle East (covering an area of ~2,150,000 km^2), the Kingdom of Saudi Arabia (KSA) faces particularly notable social and financial challenges linked to the rising prevalence of diabetes. The country primarily finances its healthcare system through revenue generated from oil production and exportation, with healthcare receiving a significant share of the national budget [19]. Despite the availability and provision of free healthcare services delivered in public facilities, healthcare costs are covered through private insurance and/or out-of-pocket expenditures for a majority of the workforce (~56%) [20, 21].

Given the high demand for the treatment and care of diabetes as a chronic disease, its prevalence further strains the already overburdened healthcare services in the KSA [22]. The rapid economic development occurring in the KSA in recent years has led to cultural shifts and lifestyle changes, including physical inactivity and the adoption of unhealthy habits [23]. Coupled with the rising trend in population aging resulting from improved health standards, the country has experienced a growing disease burden, especially NCDs such as diabetes. Therefore, research on diabetes holds significant implications for the welfare of individuals and the healthcare system in the KSA.

Despite the significant concern surrounding diabetes in the KSA, research tackling this topic remains scarce. Most studies in this field have primarily focused on the general prevalence of NCDs, with limited attention given to socio-economic inequalities specifically related to diabetes [24–26]. Al-Hanawi et al. [27] highlighted challenges in attempting to investigate socio-economic inequalities in diabetes prevalence in the KSA due to the lack of up-to-date data. They were compelled to utilize a dataset from 2013, which is significantly outdated considering the changes that have occurred over time.

The Saudi Family Health Survey (FHS) of 2018, conducted under the authority of the General Authority for Statistics (GaStat) [28], can help to fill this gap. Therefore, in this study, the FHS 2018 data were analysed to identify the socio-economic determinants and inequalities in the prevalence of diabetes in the KSA using univariate, bivariate, multivariate logistic regression, concentration curve, and concentration index techniques. Gaining a current and improved understanding of these socio-economic disparities can provide a vital resource for policymakers to guide the development of targeted diabetes education, prevention, and intervention strategies.

Materials and methods

Data

Data from the FHS were used in this study [28]. The FHS field survey is conducted on a three-year basis to collect population-level statistics in the KSA with respect to education and health, including geographical details, living situation, marriage and children, births and deaths, household income and expenditure, and health status (including the presence of chronic diseases and conditions such as diabetes, high blood pressure, and asthma, among others) [28]. The survey represents a collaboration between GaStat and the health sector (including the Ministry of Health and the Saudi Health Council) with additional participation from private and academic institutions. The sample was randomly selected among a representative population covering all administrative regions in the KSA with a total of 15,265 responses.

The questionnaire was designed by experts in the field of health statistics from GaStat with consideration of World Health Organization recommendations, standards, and definitions. The present analysis was based only on complete responses for the variables of concern, resulting in a total sample of 11,528 respondents.

Measurements

The FHS included a question about whether the respondent has received a diagnosis or/and informed with of various NCDs, including diabetes, high blood pressure, and asthma. The outcome variable (i.e., dependent variable) for this study was self-reported diabetes prevalence scored as a binary variable with a value of 1 if the respondent reported having diabetes and 0 otherwise.

The independent variables to assess the socio-economic determinants and inequalities in the prevalence of diabetes (dependent variable) included income and education level as socio-economic status indicators. Other demographic independent variables considered were age (<40 years=0 and ≥40 years=1), sex (1=male, 0=female), marital status (1=married, 0=unmarried, including never married, divorced, and widowed), education level (below primary school=reference, primary school, intermediate school, high school, and higher education), monthly income (in Saudi Riyal [SR]; 1 SR=USD 0.27: <3000=reference category, 3000 to <5000, 5000 to <7000, 7000 to <10,000, 10,000 to <15,000, 15,000 to <20,000, 20,000 to <30,000, and 30,000 or more), and region of residence among the thirteen administrative regions (Riyadh=reference, Mekkah, Madenah, Albaha, Aseer, Jazan, Najran, Aljouf, Tabouk, Haiel, Qaseem, Eastern Region, and Northern Borders). The decision to separate age groups according to a threshold of 40 years was based on the typical age of ≥40 as the onset of type 2 diabetes [29, 30].

Statistical analysis

The variations in socio-economic and demographic factors among respondents were evaluated with univariate analyses. Bivariate analysis was then used to compare the associated frequencies in different independent variables according to the dependent variable (diabetes presence/absence) using cross-tabulation with the Chi-square test. The independent associations of each socio-economic factor with the prevalence of diabetes were assessed by multivariate logistic regression models controlling for age, sex, marital status, and region of residence as covariates. Inequalities in the prevalence of diabetes according to socio-demographic factors were visualized using a concentration curve and quantified by calculation of the concentration index [31]. The influence of sex and regional inequalities on the prevalence of diabetes was further assessed, as these factors have previously been associated with health disparities [32–34].

A concentration curve represents the relationship between the cumulative percentage of a health variable (y-axis) and the cumulative share of the population in a socio-economic status indicator (x-axis; ranked from the lowest to the highest) [35]. This enables a visual assessment of the degree of inequality in diabetes prevalence; for example, with respect to income and education level, a curve above (below) the line of equality (i.e. the 45-degree line) indicates that diabetes prevalence is concentrated among those with lower income/less education (higher income/higher education). Inequality is considered to be greater when the concentration curve lies further from the line of equality.

The concentration index was used to quantify the degree of inequality in the prevalence of diabetes according to a socio-economic characteristic, which is calculated as twice the area between the concentration curve and the line of equality [35]. The concentration index ranges from −1, indicating that the prevalence of diabetes is disproportionately concentrated among individuals with relatively low education or income, to +1, indicating that the prevalence of diabetes is disproportionately concentrated among individuals with relatively high education or income. This study used income and education as the measures of socio-economic status, which enabled ranking individuals from the poorest to the richest or the lowest to the highest education level, to estimate the concentration index.

Results

Univariate analysis

Table 1 summarizes the descriptive statistics of the dependent and independent variables. At the time of the survey, the prevalence of diabetes was approximately 11.20% ($n=1291$) for the total sample of 11,528 respondents with complete responses for the variables of interest. Less than half the sample was aged 40 years and above, 45% were female, and one-third were unmarried. Slightly less than 20% of the respondents had a below primary school education level and had completed higher education, respectively. The monthly income of approximately one-quarter of the respondents was less than 5000 SR, while only approximately 5% of the respondents indicating earning ≥ 30,000 SR monthly. Most of the survey respondents were from Mekkah and Riyadh regions.

Table 1 Summary statistics of the study population ($n=11,528$)

Variable	Respondents, *N*	%
Prevalence of diabetes	1291	11.20
Age (years)		
<40	6131	53.18
≥ 40	5397	46.82
Sex		
Female	5270	45.71
Male	6258	54.29
Marital status		
Unmarried	4133	35.85
Married	7395	64.15
Education level		
Below primary school	2227	19.32
Primary school	1246	10.81
Intermediate school	1893	16.42
Secondary school	3870	33.57
Higher education	2292	19.88
Monthly income (Saudi Riyal)		
<3000	1062	9.21
3000 to < 5000	1851	16.06
5000 to < 7000	1777	15.41
7000 to < 10,000	2220	19.26
10,000 to < 15,000	2174	18.86
15,000 to < 20,000	1118	9.70
20,000 to < 30,000	721	6.25
≥ 30,000	605	5.25
Region		
Riyadh	1652	14.33
Mekkah	2003	17.38
Madenah	834	7.23
Albaha	745	6.46
Aseer	582	5.05
Jazan	663	5.75
Najran	408	3.54
Aljouf	386	3.35
Tabuk	789	6.84
Haiel	745	6.46
Qassim	1261	10.94
Eastern Region	1049	9.10
Northern Border	411	3.57

Bivariate analysis

The associations of diabetes prevalence with the socio-economic characteristics based on the bivariate analysis are presented in Table 2. The prevalence of diabetes was significantly associated with age ($\chi^2=120.030$, $p<0.01$), in which diabetes was more frequently reported among those aged ≥ 40 years (21.88%) than those aged < 40 years (1.79%). There were significant associations of diabetes prevalence with marital status ($\chi^2=198.633$, $p<0.01$) and education level ($\chi^2=385.650$, $p<0.01$). Compared with that of respondents with higher education (7.64%) and secondary school education (6.25%), the diabetes prevalence was significantly higher (21.46%) among those with below primary school education. Moreover, diabetes was highly associated with income, with a greater prevalence among people reporting a monthly income of ≥30,000 SR (14.88%) than for those reporting a monthly income below 3000 SR (8.95%). Finally, there was a significant association between diabetes prevalence and region of residence ($\chi^2=75.260$, $p<0.01$), with a higher prevalence in Qassim (14.27%) and a lower prevalence in Northern Border (4.62%).

Income-related and education-related inequalities in diabetes prevalence

The income-based concentration curve among those reporting having diabetes almost completely overlapped with the line of equality; however, this curve was slightly below the equality line, suggesting that diabetes is somewhat concentrated among the rich (Fig. 1). By contrast, the education-based concentration curve was clearly above the line of equality, indicating a greater prevalence of diabetes among the less well-educated people in the KSA (Fig. 2). As the concentration curve for education was farther away from the line of equality, this analysis suggests that education level has a stronger impact on the inequal distribution of diabetes prevalence for the population of the KSA.

Since the concentration curves in Figs. 1 and 2 cannot provide the magnitude of the inequality, we further used the Wagstaff concentration index to quantify and compare the degree of inequalities in diabetes prevalence

Table 2 Bivariate analysis of the association of diabetes prevalence with socio-economic characteristics

Variable	No Diabetes		With Diabetes		Chi-square
	N	%	*N*	%	
Age (years)					**120.030*** **
<40	6021	98.21	110	1.79	
≥40	4216	78.12	1181	21.88	
Sex					**0.215**
Female	4672	88.65	598	11.35	
Male	5565	88.93	693	11.07	
Marital status					**198.633*** **
Unmarried	3899	94.34	234	5.66	
Married	6338	85.71	1057	14.29	
Education level					**385.650*** **
Below primary school	1749	78.54	478	21.46	
Primary school	1054	84.59	192	15.41	
Intermediate school	1685	89.01	208	10.99	
Secondary school	3628	93.75	242	6.25	
Higher education	2121	92.54	171	7.46	
Monthly income (Saudi Riyal)					**20.704*** **
<3000	967	91.05	95	8.95	
3000 to <5000	1622	87.63	229	12.37	
5000 to <7000	1568	88.24	209	11.76	
7000 to <10,000	1967	88.60	253	11.40	
10,000 to <15,000	1940	89.24	234	10.76	
15,000 to <20,000	1009	90.25	109	9.75	
20,000 to <30,000	649	90.01	72	9.99	
≥30,000	515	85.12	90	14.88	
Region					**75.260*** **
Riyadh	1469	88.92	183	11.08	
Mekkah	1762	87.97	241	12.03	
Madenah	749	89.81	85	10.19	
Albaha	656	88.05	89	11.95	
Aseer	520	89.35	62	10.65	
Jazan	628	94.72	35	5.28	
Najran	379	92.89	29	7.11	
Aljouf	353	91.45	33	8.55	
Tabuk	682	86.44	107	13.56	
Haiel	657	88.19	88	11.81	
Qassim	1081	85.73	180	14.27	
Eastern Region	909	86.65	140	13.35	
Northern Border	392	95.38	19	4.62	

***$p<0.01$

according to income and education as the key socio-economic factors of interest (Table 3).

At the national level, the education-based concentration index was significantly ($P<0.01$) negative, confirming a concentration of diabetes among those with lower education levels, whereas the concentration of the income-based index was not significant at the national level. Both indices were statistically significant ($P<0.01$) in females and males; however, the direction of the effect differed according to sex. Both indices were significantly negative among females, indicating that diabetes prevalence is concentrated among women with a lower income level and lower education. By contrast, the male-specific income-based concentration index was significantly positive, whereas the male-specific education-based concentration index was significantly negative, indicating that the diabetes prevalence is concentrated among men in Saudi Arabia with less education but with higher income level.

All regions demonstrated significantly negative education-based concentration indices, indicating that the concentration of diabetes among less educated people is a consistent trend throughout the country. However, the income-based concentration indices varied according to region, ranging from insignificantly negative (i.e. in Albaha, Aljouf, Eastern Region, Haiel, Jazan, and Najran) to significantly positive (i.e. in Aseer and Northern Border). Although the income-based indices for Mekkah and Qassim were also positive, they were not statistically significant.

Regression analysis

Multivariate logistic regression analysis was further performed to assess the potential impacts of other variables on the observed associations between diabetes prevalence and socio-economic factors in the KSA (Table 4). Model 1 showed a higher likelihood of reporting diabetes among all higher-income categories compared with the lower-income category (below 3000 SR), with an odds ratio (OR) of 1.421 (95% confidence interval [CI]: 1.010–1.997, $p < 0.05$) for those reporting a monthly income of ≥30,000 SR. Model 2 showed that compared with people educated below the primary school level, those with higher education had a lower likelihood of having diabetes (OR: 0.568, 95% CI: 0.462–0.698, $p < 0.01$). The significance of the ORs for income and education categories was retained in Model 3. Therefore, the likelihood of diabetes increased with increasing income level and decreased with increasing education level.

However, model 3 further showed a nearly 12-fold increased likelihood of diabetes among people aged ≥40 years (OR: 12.262, 95% CI: 9.820–15.313, $p<0.01$). Moreover, regional differences in the likelihood of reporting diabetes were evident, in which residents of Jazan, Najran, and Northern Border were significantly less likely to report diabetes than residents of Riyadh.

Discussion

By employing a range of statistical techniques, including univariate, bivariate, multivariate logistic regression, and concentration curves and indices, based on self-weighted data from the 2018 FHS, this study highlights the socio-economic disparities in the prevalence of diabetes in

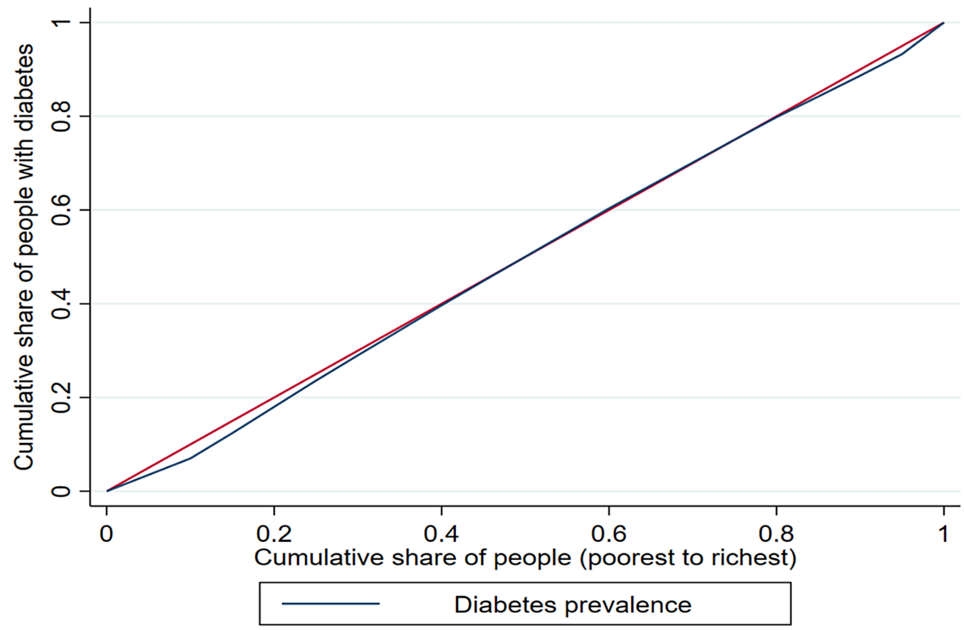

Fig. 1 Income-based concentration curve for diabetes prevalence

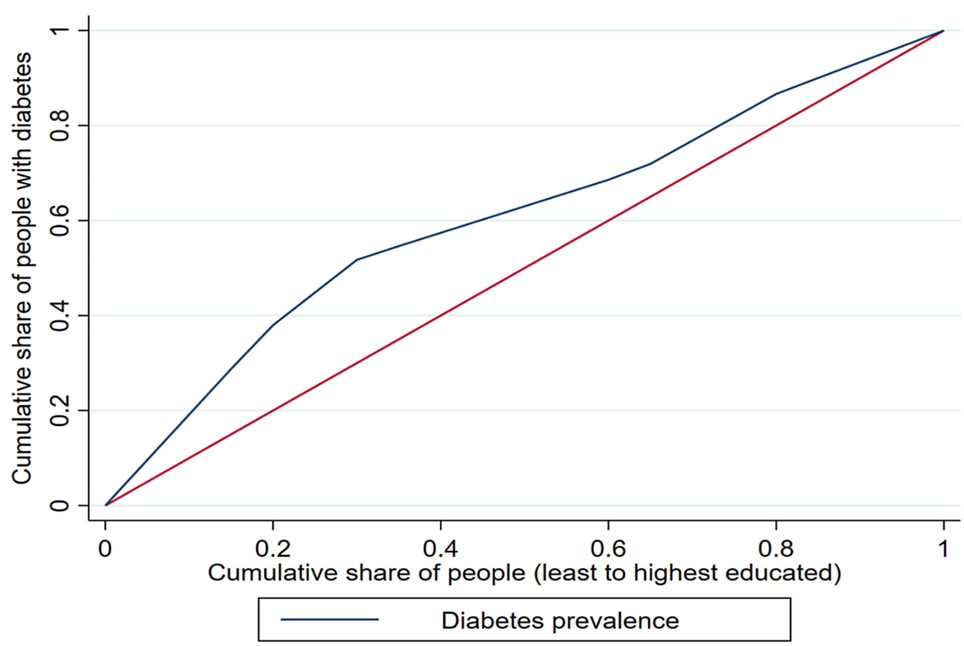

Fig. 2 Education-based concentration curve for diabetes prevalence

the KSA. These findings thus offer crucial targets for the development of effective diabetes education, prevention, and intervention programs. Given that disparities in the prevalence of diabetes were linked to various factors, including sex, education, income, and region of residence, the government must prioritize strategies that address these associated socio-economic factors to reduce the prevalence of diabetes and improve its treatment and management.

The bivariate analysis revealed a significant association between the prevalence of diabetes and age ($\chi^2 = 120.030$, $p < 0.01$), in which diabetes was more concentrated among individuals aged 40 years and above (21.88%) compared to those aged below 40 years (1.79%). Similarly, there was an approximately 12-times higher likelihood of reporting diabetes among individuals aged 40 years and above (OR: 12.262, 95% CI: 9.820–15.313, $p < 0.01$) compared to younger individuals below 40 years. Numerous studies support this finding, demonstrating that the

Table 3 Inequality indices for diabetes prevalence according to variations in income and education in the Kingdom of Saudi Arabia

	Income		Education	
	Index estimate	95% CI	Index estimate	95% CI
National level	0.003	(−0.030 to 0.036)	−0.235***	(−0.267 to −0.203)
Sex				
Female	−0.104***	(−0.153 to −0.056)	−0.396***	(−0.443 to −0.349)
Male	0.094***	(0.049 to 0.139)	−0.091***	(−0.135 to −0.047)
Region				
Riyadh	−0.075*	(−0.162 to 0.013)	−0.178***	(−0.264 to −0.093)
Mekkah	0.035	(−0.042 to 0.111)	−0.145***	(−0.220 to −0.070)
Madenah	−0.164**	(−0.291 to −0.037)	−0.490***	(−0.612 to −0.368)
Albaha	−0.037	(−0.162 to 0.088)	−0.256***	(−0.379 to −0.133)
Aseer	0.130*	(−0.020 to 0.280)	−0.159**	(−0.308 to −0.012)
Jazan	−0.123	(−0.317 to 0.071)	−0.180*	(−0.370 to 0.010)
Najran	−0.171	(−0.386 to 0.045)	−0.427***	(−0.634 to −0.220)
Aljouf	−0.023	(−0.225 to 0.178)	−0.094	(−0.293 to 0.105)
Tabuk	−0.053	(−0.169 to 0.062)	−0.358***	(−0.470 to −0.246)
Haiel	−0.010	(−0.137 to 0.117)	−0.375***	(−0.497 to −0.253)
Qassim	0.059	(−0.031 to 0.149)	−0.166***	(−0.253 to −0.078)
Eastern Region	−0.055	(−0.156 to 0.047)	−0.311***	(−0.407 to −0.214)
Northern Border	0.266**	(0.007 to 0.526)	−0.323**	(−0.579 to −0.068)

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

prevalence of diabetes varies across different age groups, with the older population facing a higher risk compared to younger individuals [36, 37]. This is not surprising considering that the natural aging process leads to reduced physical activity, a weakened immune system, and various healthcare access challenges, all of which contribute to an increased disease burden among the older population [38, 39].

The results also indicate a greater prevalence of diabetes among individuals with lower levels of education. In particular, an education level below primary school was significantly associated with a higher prevalence of diabetes (21.46%) compared to that of higher education levels, including a university degree or above (7.64%). The multivariate analysis confirmed that a lower education level was an independent predictor of reporting having diabetes. This result is in line with findings in several other countries and regions, including Ghana [37], Europe [40], France [41], and others [8, 42]. People with lower education levels may face greater exposure to risk factors and thus have higher susceptibility to developing diabetes compared to those with more favourable living conditions [43].

Education plays a crucial role in creating awareness and enabling individuals to translate information into practical behaviours that help mitigate the risks of chronic diseases [44]. Conversely, individuals with lower levels of education may be more prone to engaging in risky behaviours due to a lack of awareness [45, 46]. Indeed, there is evidence that people with lower education levels are less likely to participate in diabetes training programs [47, 48]. These educational disparities ultimately contribute to differential risks of diabetes prevalence and treatment. Moreover, individuals with lower educational attainment often face limited access to healthcare services and lack health insurance coverage [49, 50]. These results highlight that government-led diabetes intervention policies should explicitly target and address these disparities related to education.

This study demonstrates a concentration of diabetes prevalence among individuals reporting a monthly income of ≥30,000 SR (14.88%) compared to those with a monthly income below 3000 SR (8.95%). The likelihood of reporting diabetes was higher among all higher-income categories compared to the lower-income category (<3000 SR monthly). These findings suggest a concentration of diabetes prevalence among the rich, as evidenced by the concentration curve falling below the line of equality. Some studies have presented a contrasting relationship between income and diabetes prevalence, whereas others align with the present findings [5, 12]. For instance, Richards et al. [11] discovered that a 1% increase in per-capita income corresponds to a 0.92% increase in diabetes prevalence. Mutyambizi et al. [51] revealed a significant concentration of self-reported diabetes and total diabetes (including both diagnosed and undiagnosed cases) among individuals with higher wealth in South Africa. Su et al. [45] identified a significant correlation between income and diabetes prevalence in China. These positive associations between income and diabetes prevalence could be explained by the escalation of adverse health behaviours such as physical inactivity, smoking, and alcohol consumption with rising income levels [52]. Moreover, considering the International Diabetes Federation's estimate of approximately 40% undiagnosed diabetes cases in Saudi Arabia, the elevated prevalence among affluent individuals identified in this study may stem from the higher diagnosis and detection rates for diabetes among the wealthy due to

Table 4 Association between diabetes prevalence and socio-economic factors

Variables	Model 1		Model 2		Model 3	
	OR	95% CI	OR	95% CI	OR	95% CI
Age (years)						
<40	Reference		Reference		Reference	
≥ 40	14.966***	(12.109–18.498)	12.164***	(9.758–15.163)	12.262***	(9.820–15.313)
Sex						
Female	Reference		Reference		Reference	
Male	1.014	(0.891–1.155)	1.059	(0.927–1.209)	1.081	(0.945–1.237)
Marital status						
Married	Reference		Reference		Reference	
Unmarried	0.983	(0.825–1.171)	0.881	(0.739–1.051)	0.913	(0.764–1.092)
Education level						
Below primary school			Reference		Reference	
Primary school			0.809**	(0.664–0.985)	0.799**	(0.655–0.974)
Intermediate school			0.860	(0.708–1.045)	0.847*	(0.695–1.032)
Secondary school			0.594***	(0.493–0.716)	0.578***	(0.476–0.701)
Higher education			0.568***	(0.462–0.698)	0.551***	(0.442–0.686)
Monthly income (Saudi Riyal)						
<3000	Reference				Reference	
3000 to < 5000	1.497***	(1.145–1.958)			1.523***	(1.163–1.993)
5000 to < 7000	1.403**	(1.068–1.842)			1.458***	(1.109–1.917)
7000 to < 10,000	1.423***	(1.092–1.854)			1.596***	(1.221–2.086)
10,000 to < 15,000	1.297*	(0.991–1.696)			1.513***	(1.151–1.989)
15,000 to < 20,000	1.005	(0.737–1.370)			1.258	(0.913–1.732)
20,000 to < 30,000	1.135	(0.805–1.600)			1.421*	(0.998–2.023)
≥ 30,000	1.421**	(1.010–1.997)			1.768***	(1.248–2.506)
Region						
Riyadh	Reference		Reference		Reference	
Mekkah	1.030	(0.827–1.283)	1.035	(0.832–1.286)	1.027	(0.823–1.281)
Madenah	0.846	(0.633–1.133)	0.801	(0.600–1.067)	0.832	(0.621–1.114)
Albaha	0.845	(0.635–1.123)	0.807	(0.607–1.074)	0.785*	(0.589–1.046)
Aseer	0.995	(0.719–1.378)	0.955	(0.690–1.322)	0.921	(0.664–1.278)
Jazan	0.527***	(0.357–0.778)	0.531***	(0.360–0.784)	0.538***	(0.364–0.795)
Najran	0.601**	(0.392–0.917)	0.569***	(0.371–0.871)	0.564***	(0.368–0.865)
Aljouf	0.816	(0.539–1.236)	0.791	(0.523–1.195)	0.781	(0.515–1.186)
Tabuk	1.091	(0.830–1.435)	1.016	(0.772–1.338)	1.001	(0.747–1.302)
Haiel	1.120	(0.837–1.498)	1.137	(0.851–1.519)	1.079	(0.805–1.445)
Qassim	1.127	(0.888–1.431)	1.153	(0.912–1.457)	1.112	(0.875–1.414)
Eastern Region	1.001	(0.780–1.282)	1.004	(0.783–1.289)	0.988	(0.769–1.270)
Northern border	0.541**	(0.325–0.901)	0.495***	(0.297–0.825)	0.479***	(0.286–0.801)
Constant	0.015***	(0.010–0.021)	0.030***	(0.022–0.041)	0.211***	(0.014–0.030)
Observations	11,528		11,528		11,528	
Pseudo R-squared	0.1692		0.1724		0.1747	
Chi-square	1367.75***		1393.94***		1412.03***	

Note 95% confidence intervals are in parentheses; Abbreviation: OR, odds ratio; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

their superior access to healthcare [3]. Conducting additional research specifically targeting undiagnosed diabetes could provide a clearer understanding of the actual prevalence of the disease in the KSA.

The income-based and education-based concentration indices were statistically significant at the 1% level for both sexes, although with different patterns and directions. Both indices were significantly negative for females, suggesting that the prevalence of diabetes is concentrated among women with lower income levels and less levels of education. Studies have consistently shown that women tend to have a higher risk of diabetes compared to men in similar settings [53, 54]. This can largely be attributed to biological factors such as insulin resistance and abdominal adiposity, which are more prevalent among females and increase their susceptibility to diabetes [37]. Additionally, women exhibit higher rates of physical inactivity and are more prone to obesity, further exacerbating their susceptibility to diabetes [54]. These factors are particularly amplified among women with lower levels of education and income, as they may face even more unfavourable conditions that put them at a greater risk of developing diabetes.

Although the education-based concentration index was also significantly negative for males, indicating that the prevalence of diabetes is concentrated among men with lower levels of education in the KSA, they exhibited a significantly positive income-based concentration index, indicating that the prevalence of diabetes is concentrated among men with higher income levels. Men generally exhibit a lower prevalence of diabetes compared to women [55]. However, among men with low levels of education, the prevalence of diabetes tends to be high due to limited awareness of the disease, resulting in increased exposure to its risks [42]. Moreover, as men are often the primary source of the family income and maintain control over wealth in the KSA, they may be more likely to adopt unhealthy habits such as smoking and unhealthy diets, further increasing their risk of diabetes [52]. Given these gender inequalities in diabetes prevalence and risk factors, it is essential to implement targeted and gender-sensitive measures for prevention and education. Gender-specific interventions are necessary as policies addressing diabetes in women may not be applicable to men, given their distinct needs.

The education-based concentration indices were significantly negative across all regions in the KSA, indicating that the prevalence of diabetes is concentrated among individuals with lower levels of education throughout the country. However, there were also regional variations in the likelihood of reporting diabetes, with higher prevalence in Qassim, Tabuk, Mekkah, and Riyadh compared to the Northern Border, Jazan, and Najran. This regional disparity is further supported by the income-based concentration indices, which were positive for certain regions (Aseer and Northern Border) but negative for others (Riyadh and Madenah). Therefore, the observed regional differences in diabetes prevalence are likely influenced by associated disparities in income levels, leading to the adoption of different lifestyles and varying degrees of diabetes risk exposure. Furthermore, variations in healthcare access across regions, with some regions experiencing regional deprivation while others having better access, likely contribute to these disparities [56]. Similar regional variations in diabetes prevalence have been reported in the related literature for various countries, including Pakistan [53], Bangladesh [13], Iran [14] and China [5]. Therefore, diabetes prevention and intervention programs should consider location-specific effects when designing policies to address the prevalence of diabetes.

This study is subject to certain limitations that should be considered when interpreting the results. The conclusions and discussions should be contextualized, considering that health inequalities have various structural determinants, including commercial and environmental factors, that can impact prevalence but were not implicitly examined in this analysis. Furthermore, the use of self-reported data is subject to biases, including differences in access to healthcare and diabetes awareness, which can influence the accuracy of reported diabetes cases. It would be beneficial to include a more objective and standardized measure of diabetes that considers both diagnosed and undiagnosed cases. Additionally, the focus of the study was limited to socio-economic determinants and inequalities in the prevalence of diabetes; thus, further research could explore socio-economic inequalities in other dimensions such as race or ethnicity and citizenship status. Another limitation is that the study primarily focused on diabetes as a whole without distinguishing between different types, such as type 2 diabetes and other variations. Future research could delve into inequality determinants when differentiating between various types of diabetes. Nonetheless, the study offers valuable insights that can inform the implementation of strategies to address inequalities in diabetes prevalence.

Conclusions

This study provides new insight into the socio-economic determinants and inequalities related to diabetes prevalence in Saudi Arabia. Data from the 2018 FHS were analysed using various techniques such as univariate, bivariate, multivariate logistic regression, concentration curves, and concentration indices. The results align closely with existing literature on the topic, reinforcing current understanding in the field. The prevalence of diabetes demonstrates variations according to gender and region of residence. The older generation tends to experience a higher prevalence of diabetes compared to the younger generation. The concentration indices based on income and education reveal that high diabetes prevalence is associated with lower levels of education but higher levels of income. These findings emphasize the need to prioritize policies and strategies for diabetes prevention and control that address socio-economic inequalities in diabetes prevalence. Key areas of focus should include improving education levels across all regions, raising awareness about diabetes including through the use of social media, implementing nutritional interventions, and reducing income disparities. Moreover, deliberate efforts should be made to modify risk factors such as obesity and physical inactivity. Public policies need to incorporate strategies that promote healthy habits and lifestyles, ultimately leading to a reduction in diabetes prevalence, complications, and the burden on the health-care system.

Author contributions
Conceptualization, M.K.A.; data curation, M.K.A.; formal analysis, M.K.A.; investigation, M.K.A.; methodology, M.K.A.; project administration, M.K.A.; software, M.K.A.; writing funding acquisition, M.K.A.;—original draft preparation, M.K.A.; writing—review and editing, M.K.A. The author have read and agreed to the published version of the manuscript.

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Data availability
The datasets generated and/or analysed during the current study are not publicly available due to privacy, confidentiality, and other restrictions. Access to data can be gained through the General Authority for Statistics in Saudi Arabia via https://www.stats.gov.sa/en.

Declarations

Ethics approval and consent to participate
The secondary data used in this study were based on the survey conducted, commissioned, funded, and managed in 2018 by GaStat that was responsible for all ethical procedures. All participants provided informed consent and all procedures complied with institutional and/or national research committee ethical standards and with the 1964 Helsinki Declaration and subsequent amendments or equivalent ethical standards. The dataset was de-identified prior to analysis by GaStat to allow for secondary data use. GaStat granted permission to use the data and thus no further clearance was necessary as this was performed at the data collection phase.

Consent for publication
Not applicable.

Competing interests
The author declares no competing interests.

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