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Original Article

Socioeconomic Inequality in Chronic Complications of Type 2 Diabetes Mellitus in Iran: Concentration Index and Decomposition Approach

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ABSTRACT

Introduction: In Iran, evidence regarding the impact of socioeconomic status (SES) on the progression and complications of type 2 diabetes mellitus (T2DM) are sparse and needs growing body of research. Socioeconomic status is a complex construct and its impact on the health outcomes should be evaluated in an efficient and flexible way. The aim of this study is to investigate socioeconomic inequality in chronic complications among patients with T2DM using the concentration index and, also determine the contribution of various variables on inequality through the decomposition analysis.

Methods: This cross-sectional study included patients with T2DM who received care at the diabetes clinic in Hamadan from April to September 2023. Demographic information, household assets, and diabetes-related factors were obtained from medical records and face-to-face interviews. In this study, a healthy lifestyle was evaluated based on four characteristics of healthy behavior (smoking, dietary pattern, weight control, and physical activity) and the score obtained for each individual. The asset Index was considered as a measure of SES based on household assets and was created using principal component analysis. To examine the relationship between diabetes complications and independent variables, univariate logistic regression models were employed, and the concentration index (CI) was used to assess inequality. The decomposition approach was utilized to determine the contribution of each factor to the inequality.

Results: A total of 530 patients (60% females and 54.9% less than 60 years) were included. In the study population, 22.3%, 9.5%, and 4.7% had retinopathy, kidney failure, and diabetic foot ulcers, respectively. The CI for retinopathy, kidney failure, and foot ulcers were [(CI: -0.248, $p<0.001$), (CI: -0.085, $p<0.001$), (CI: -0.125, $p<0.001$), respectively]. Factors with the greatest contribution to socioeconomic inequality for retinopathy were economic status (57.25%), duration of T2DM (21.77%), and adherence to prescribed medication (10.89%), for kidney failure were economic status (38.83%), hypertension (24.71%), and education level (14.11%), and for foot ulcers were economic status (24%), duration of T2DM (24%), education level (20.80%), and HbA1c level (18.40%).

Conclusion: This study demonstrated that socioeconomic inequality in chronic complications of T2DM with greatest contribution for economic status. It is recommended that policymakers and health professionals consider the main causes of socioeconomic inequality in the chronic complications of T2DM when developing health strategies.

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Introduction

Type 2 diabetes mellitus (T2DM) is a leading clinical and public health challenge worldwide. The main reasons introduced for increasing rate of T2DM are population growth, increased life expectancy, aging, urbanization, unhealthy lifestyles.[1, 2] Although the burden of T2DM is rising globally, the highest burden is belonged to the low and lower-middle income countries.[1, 3] The International Diabetes Federation (IDF) predicts that the number of people with diabetes will increase from 537 million in 2021 to 783 million by 2045.[4] This increasing prevalence imposes significant economic costs on healthcare systems, communities, and patients.[4, 5] An estimated 193 million people worldwide are living with undiagnosed diabetes, which puts them at risk of developing numerous long-term complications associated with untreated chronic hyperglycemia.[6]

T2DM has linked to macro-vascular problems including peripheral artery disease, coronary heart disease, and stroke as well as micro-vascular problems like diabetic kidney disease, retinopathy, and peripheral neuropathy.[7] About 15% of T2DM patients suffer from foot complications, which is one of the main reasons for hospitalization and amputation.[8, 9] Another chronic complication is diabetic retinopathy, which is caused by chronic hyperglycemia and leads to retinal damage.[10] The previous studies showed that the overall prevalence of 17.6% for retinopathy in T2DM patients.11 Also, hyperglycemia is the main etiological factor in the development of diabetic kidney disease, which is one of the chronic complications of diabetes and the main cause of kidney failure.[12] The prevalence of 2.2% for diabetic nephropathy and 26.9% for microalbuminuria has been reported.[13]

Given the widespread occurrence of diabetes, its substantial economic costs, and the disproportionate burden it imposes on certain population groups, understanding the effects of socioeconomic status (SES) in the context of T2DM are priorities.[14] SES is combination of the social (e.g., education and occupation) and economic conditions (income or household assets) that impact on individual's health status. These non-medical factors are mostly responsible for health inequities.[15] Recent studies investigating the influence of SES on T2DM have predominantly concentrated on prevention and the risk of developing the disease. According the evidence, social determinants, including income, education, housing, and access to healthy food, play a significant role in the onset of T2DM.[16-18] However, evidence regarding the impact of SES on the progression and complications of T2DM are rare. Although the relationship between SES and the development and progression of T2DM has been elucidated through conventional statistical methods, there is advanced methods such as regression based methods to decompose socioeconomic inequality in efficient and flexible way. Through regression-based decomposition analysis approach, any health outcome (e.g. discrete, continuous, and binary) can be decomposed into explanatory variables regardless of type and scale. Then, robust and unbiased estimates can be yielded regarding the role of explanatory variables to socioeconomic inequality. Therefore, the decomposition approach has become an effective and appealing tool for studying inequalities, identifying the contribution of each factor in creating inequality and providing useful information about its sources. From

public health view, inequality decomposition analysiscan be utilized in policymaking and developing strategies to reduce the root causes of inequality, and it can assist in better disease management and the reduction of complications for patients. Therefore, this study aimed to quantify socioeconomic inequality in chronic complications among patients with T2DM and to decompose socioeconomic inequality to the main determinants.

Materials and Methods

Study Design and Participants

This cross-sectional study was conducted on patients with T2DM during April to September 2023. Through a convenient sampling technique T2DM patients receiving routine check-ups at the diabetes clinic in Hamadan City, Iran were recruited. After obtaining informed consent and explaining the objectives of the study, patients who had been diagnosed with T2DM for at least a year and who were at least 20 years old were included in the study. The exclusion criteria included patients with gestational diabetes, mental disorders, dementia, and those who were using any medications known to significantly affect glucose metabolism, such as: corticosteroids, beta-blockers, diuretics and etc.

Study Population and Sample Size

The sample size was calculated based on the prevalence of outcomes (retinopathy, kidney failure, the presence of foot ulcers in the past year) in the study population in similar studies[19-21] with a 95% confidence level and a margin of error of 0.05. Considering the outcomes under study, the required minimum sample size was 384. According to the rule of thumb for the further analyses, a minimum of 5 subjects per each variable was added to the estimated sample size.

Data Collection and Variables

The researchers made checklists of the study were complete for each patient in face to face interview by trained interviewers. The checklists comprised several sections as follow;

a) Demographic: This section involved items regarding place of residence, age, gender, marital status, education level, occupation (In two categories, employed individuals and non-employed individuals (housewives, unemployed individuals, and retirees)), type of insurance and household assets.

b) SES: In this study, the asset index was used as a measure of economic status. The asset index reflects access to goods and services and[22] shows high validity compared to assessments based on personal income or individual expenditures.[23] The asset index using household assets such PlayStation/ Xbox console, side-by-side refrigerator, > 49-inch smart TV, washing machine, dishwasher, microwave, furniture, personal laptop (computer), and personal automobile (not for income). The variables of the asset index are based on studies conducted in Iran, and according to recommendations (23, 24). The household assets were included in the principal component analysis (PCA). The first component that explained highest variance was considered as a proxy of economic status. The score from first component was estimated and then divided

into quintiles from the poorest (Quintile 1) to the richest (Quintile 5).

c) Lifestyle status: The lifestyle factors including smoking, dietary pattern, physical activity and obesity as the main downstream mediating trait of lifestyle factors was measured.[25] The height and weight of individuals were measured using standard tools to estimate the Body Mass Index (BMI). BMI was calculated as weight in kilograms divided by the square of height in meters. The BMI index was classified into two categories: normal weight (BMI less than 25 kg/m²) and overweight and obesity (BMI greater than or equal to 25 kg/m²) (26). The individual's smoking status was considered as a categorical variable (current smoker: someone who has consumed 100 or more cigarettes in their lifetime and smokes daily or on some days, or someone who has smoked at least 100 cigarettes in their lifetime but does not smoke at the time of study; and non-smoker: someone who does not smoke or has consumed fewer than 100 cigarettes in their lifetime).[21] The physical activity variable was assessed based on the performance of walking or regular exercise with moderate or vigorous intensity for at least 30 minutes during a typical week. The nutrition questionnaire contains questions about the consumption of fruits and vegetables, dairy and dairy products, fast food/sodas, the type of oil used, and the use of salt shakers during meal consumption, which is based on guidelines related to non-communicable diseases.[27] The questionnaire, which included 6 questions with a score ranging from 0 to 2 for each question, had a total score of 12. A healthy diet was defined as the use of at least 4 and more than 6 components of a healthy diet (a score of 7-12). The lifestyle scores of the patients were classified into three categories: a score of 3-4 was considered "desirable lifestyle", a score of 2 was categorized as "moderate lifestyle," and a score of 0-1 was classified as "undesirable lifestyle."

d) Clinical and diabetic related factors: this section involved items regarding complications (such as retinopathy, kidney failure, foot ulcers or ulcers needing medical attention within the last year), medical history (HbA1c levels, number of HbA1c tests within the past year; less than 4 times, more than 4 times, unknown HbA1c), number of medical examinations (less than 4 examinations per year, greater than or equal to 4 examinations per year), type of treatment (tablet, insulin, both treatments), years since diabetes diagnosis (classified as less than or equal to 5 years, 6-9 years, greater than or equal to 10 years), and the presence of comorbidities (cardiovascular disease, hypertension, dyslipidemia) identified by a specialist physician.

The education variable is based on whether patients have ever been trained in diabetes management (Among them are the non-smoking and alcohol-free lifestyle, healthy dietary patterns, weight management, physical activity, and the importance of blood sugar control) at a medical clinic, diabetes clinic, or public health center .For the hemoglobin A1c (HbA1c), two categories were defined: unacceptable control (HbA1c > 7.5%) and acceptable control (HbA1c ≤ 7.5%) (28).

Statistical Analysis

Statistical analyses were conducted using

Stata version 17, with a significance level of less than 0.05 and a 95% confidence interval. To describe the studied variables, descriptive statistics were used, and to examine the existence of inequality, the concentration index was employed. Logistic regression was used to assess the relationships between the diabetic complications as outcome and independent variables. Initially, a univariate logistic regression was conducted between the outcome variables and the independent variables, and variables with a p-value of less than 0.10, in the presence of inequality in the intended outcome, were included in the decomposition approach.

Concentration Index and Concentration Curve

To demonstrate relative health inequality, the concentration Index (CI) was used. The CI is employed to quantify inequality in health-related variables based on the variable of living standards.[29] In this regard, the standard of living variable was based on the wealth index, which was created using PCA. The CI is derived from the concentration Curve (CC).[30] The CI is defined as twice the area between the CC and the 45-degree line (equality line).[31] The CI ranges between -1 and 1, with a value of 0 indicating that health indicators are equally distributed among the population. A positive CI indicates concentration of health indicators among the wealthier, while a negative CI indicates concentration among the poorer.[29]
The CI is calculated using the following Equation: $CI = \frac{2}{u} cov(h.r)$ (Equation 1)

In Equation [1], h represents the health variable, r represents the rank of an individual in terms of the SES index, and u represents the mean health status.[29]
Since all outcome variables in our study are binary, the corrected Erreygers concentration index was used to measure inequality.[32]

Decomposition of CI

In the decomposition method, CI can be decomposed into the determining factors that contribute to the inequality, and finally the contribution of the variables to the inequality can be obtained. This method is based on the linear regression model between the outcome variable h and determinants k (Xk)[30]:

$$h_i = \alpha + \sum_k B_k X_{ki} + \varepsilon_i \text{ (Equation 2)}$$

In Equation [3], i represents an individual or country, Bk represents the regression coefficient, and ε represents the error term.
The CI for h can be written as:

$$CI(h) = \sum_k \left(\frac{B_k \hat{X}_k}{u} \right) C_k + {GC_\varepsilon}/{u} \text{ (Equation 3)}$$

In Equation [4], u is the mean of h, $\widehat{X}_k$ is the mean of X_k, C_k is the CI for X_k, and GCε is the generalized concentration index for the error term (ε).[30]
For the Errygers corrected concentration index, a decomposition formula similar to the following is expressed[32]:

$$E(h) = 4\left[\sum_k \left(B_k \hat{X}_k \right) C_k + GC_\varepsilon \right] \text{ (Equation 4)}$$

In Equation [5], Bk represents the regression coefficient or marginal effect, $\widehat{X}_k$ is the mean of X_k, $C_k$is the CI for X_k, GCε is the generalized concentration index for the error term (ε) and The CI for the outcome variable

in the equation [4] and [5] are CI(h) and E(h), respectively.

Equation [5] is constructed from two components: the explained component and the unexplained component. The explained component consists of two parts: elasticity, which represents the effect of each determinant on the outcome variable, and the CI for the determinants, which shows how the distribution of each determinant affects health inequality within socioeconomic groups. The unexplained component is part of the inequality that cannot be explained by systematic changes in the determinants across socioeconomic groups.[29, 30]

Results

A total of 530 patients were included in the study. Most patients were female (60%), and less than 60 years (54.9%). The majority of patients were with education level of less equal than diploma (81%), married (82.1%), unemployed (73%), lived in urban areas (86.8%) and middle and less economic status (61.3%). About 22%, 6% and 7% of patients had retinopathy, kidney failure and foot ulcers, respectively. The distribution of demographic, SES and diabetic related parameters according to the three complications as well as resulting crude ORs are presented in the Table 1. Males, older ages, low education, single status, unemployment, insulin therapy, increase in diabetes duration, hypertension and CVD comorbidities, unfavorable lifestyle, HbA1c more than 7.5%, and poorer SES were significantly related with increased odds of diabetic complications and were included in the decomposition analysis.

As shown in the Figure 1, the rate of diabetes-related complications is more concentrated among patients with lower SES than those with higher SES because the CCs are lies above equality line. The overall CI of retinopathy, kidney failure and foot ulcers were -0.248, -0.085 and -0.125, respectively.

The results of decomposition analysis with providing elasticity,C_k (the CIs of the explanatory variables), absolute contributions and percentage contributions of explanatory variables of diabetes-related complications inequality are shown in the Table 2. As Table 2 and Figure 2 show the economic status had greatest contribution to socioeconomic inequality in the three studied diabetes-related complications (e.g., 57.25% for retinopathy, 38.83% for kidney failure and 24% for foot ulcers). Duration of T2DM (21.77%) and adherence to prescribed medication (10.89%) for retinopathy, hypertension (24.71%) and education level (14.11%) for kidney failure and duration of T2DM (24%) and education level (20.80%), and HbA1c level (18.40%) for foot ulcers were another determinants to socioeconomic inequality.

Discussion

In the current study, socioeconomic inequality in chronic complications of T2DM, retinopathy, kidney failure, and foot ulcers were investigated using CI and the contribution of each factor in inequality was determined using decomposition approach. This study is one of the few studies in Iran that determines the contribution of factors to the socioeconomic inequality in chronic complications of T2DM. The prevalence of retinopathy among participants was 22.3%, which was lower than studies conducted

Table 1. Sociodemographic Characteristics and Univariate Logistic Regression Model Analysis Results for Complications in Patients with T2DM

Variables	N(%)	Retinopathy (n=118)	Foot ulcers or other ulcers (n=39)	Kidney failure (n=31)
	Total(n=530)	Crude OR (95% CI)	Crude OR (95% CI)	Crude OR (95% CI)
Residence type				
Urban	460(86.79)	1.00	1.00	1.00
Rural	70(13.21)	1.48 (0.84, 2.60)	1.79 (0.79, 4.06)	2.02 (0.84 , 4.88)
Gender				
Woman	318(60.00)	1.00	1.00	1.00
Man	212(40.00)	1.36 (0.90, 2.05)	2.90 (1.47, 5.73)	3.39 (1.56 , 7.35)
Age group, years				
< 60	291(54.91)	1.00	1.00	1.00
≥ 60	239(45.09)	4.10 (2.62, 6.40)	2.96 (1.47, 5.98)	5.55 (2.24, 13.76)
Education Level				
Illiterate	127(23.96)	1.00	1.00	1.00
≤ Diploma	302(56.98)	0.25 (0.15, 0.39)	0.36 (0.18 , 0.71)	0.27 (0.12, 0.58)
> Diploma	101(19.06)	0.19 (0.09, 0.37)	0.11 (0.03 , 0.51)	0.13 (0.03, 0.58)
Marital status				
Married	436(82.26)	1.00	1.00	1.00
Not married	94(17.74)	1.71 (1.04, 2.80)	2.49 (1.23, 5.06)	2.32 (1.05, 5.10)
Occupation				
Unemployed	387(73.02)	1.00	1.00	1.00
Employed	143(26.98)	0.35 (0.20, 0.62)	0.47 (0.19, 1.15)	0.27 (0.08, 0.92)
Insurance				
Health insurance	64(12.08)	1.00	1.00	1.00
Social security	246(46.42)	0.49 (0.27, 0.89)	0.40 (0.17, 0.95)	0.36 (0.14, 0.92)
Medical service	75(14.15)	0.44 (0.20, 0.95)	0.25 (0.07 , 0.99)	0.09 (0.01, 0.78)
Armed force	56(10.57)	0.52 (0.23, 1.18)	0.47 (0.14, 1.62)	1.00 (0.33, 2.96)
Other[a]	89(16.79)	0.55 (0.2 , 1.13)	0.60 (0.22, 1.66)	0.24 (0.06, 0.95)
Supplementary insurance				
No	239(45.09)	1.00	1.00	1.00
Yes	291(54.91)	1.10 (0.73, 1.67)	1.20 (0.62 , 2.32)	1.15 (0.55, 2.39)
Family history				
No	144(27.17)	1.00	1.00	1.00
Yes	386(72.83)	1.34 (0.83, 2.16)	1.26 (0.58, 2.73)	1.29 (0.55, 3.08)
Type of medication				
Oral drug	361(68.11)	1.00	1.00	1.00
Insulin	25(4.27)	3.71 (1.59, 8.68)	12.35 (3.98 , 38.29)	9.63 (2.61, 35.52)
Oral drug and Insulin	144(27.17)	3.24 (2.08, 5.05)	7.82 (3.54 , 17.30)	8.15 (3.37, 19.76)
Duration of T2DM (years)				
≤ 5	183(34.53)	1.00	1.00	1.00
6-10	149(28.11)	3.62 (1.73, 7.55)	4.46 (0.91 , 21.81)	2.52 (0.62, 10.24)
> 10	198(37.36)	10.38 (5.30 , 20.34)	16.16 (3.80 , 67.68)	7.50 (2.21, 25.51)
Hypertension				
No	224(42.26)	1.00	1.00	1.00
Yes	306(57.74)	3.48 (2.10, 5.52)	4.32 (1.78 , 10.50)	11.43 (2.70 , 48.44)
Dyslipidemia				
No	79(14.91)	1.00	1.00	1.00
Yes	451(85.09)	1.92 (0.98, 3.77)	0.78 (0.33, 1.85)	2.65 (0.62, 11.32)
Cardiovascular disease (CVD)				
No	391(73.77)	1.00	1.00	1.00
Yes	139(26.23)	4.58 (2.96, 7.10)	5.23 (2.66, 10.31)	7.98 (3.57, 17.81)

Table 1. Continue

Variables	N(%) Total(n=530)	Retinopathy (n=118) Crude OR (95% CI)	Foot ulcers or other ulcers (n=39) Crude OR (95% CI)	Kidney failure (n=31) Crude OR (95% CI)
Training T2DM				
No	412(77.74)	1.00	1.00	1.00
Yes	118(22.26)	0.86 (0.52 , 1.43)	1.05 (0.48 , 2.28)	1.23 (0.54, 2.83)
Lifestyle				
Unfavorable lifestyle	125(23.59)	1.00	1.00	1.00
Intermediate lifestyle	233(43.96)	0.63 (0.39 , 1.02)	0.37 (0.17 , 0.81)	0.39 (0.16, 0.91)
Favorable lifestyle	172(32.45)	0.30 (0.17 , 0.54)	0.47 (0.21 , 1.04)	0.42 (0.17, 1.04)
Number of examinations(per year)				
< 4 times	412(77.74)	1.00	1.00	1.00
≥ 4 Times	118(22.26)	1.22 (0.75, 1.97)	1.88 (0.94 , 3.79)	2.06 (0.96 , 4.44)
Adherence to prescribed medication				
No	67(12.64)	1.00	1.00	1.00
Yes	463(87.36)	0.39 (0.23, 0.67)	0.38 (0.18 , 0.82)	0.39 (0.16, 0.90)
Number of HbA1c tests in the last year				
I don›t know	74(13.96)	1.02 (0.37, 2.70)	1.59 (0.32, 3.56)	1.80 (0.40, 8.82)
< 4 times	431(81.32)	0.53 (0.22, 1.27)	0.80 (0.18, 3.56)	0.53 (0.12, 2.42)
≥ 4 Times	25(4.72)	1.00	1.00	1.00
HbA1c, %				
≤ 7.5	240(45.28)	1.00	1.00	1.00
> 7.5	290(54.72)	2.23 (1.44, 3.46)	5.01 (2.06, 12.17)	3.00 (1.27, 7.10)
Received nutrition counseling(in last year)				
No	415(78.30)	1.00	1.00	1.00
Yes	115(21.70)	0.96 (0.58, 1.59)	0.51 (0.19 , 1.33)	0.86 (0.34, 2.15)
economic status				
Q1 (the poorest)	121(22.83)	1.00	1.00	1.00
Q2	93(17.55)	0.72 (0.41, 1.31)	0.37 (0.15, 0.90)	0.40 (0.14, 1.15)
Q3	111(20.94)	0.76 (0.44, 1.32)	0.21 (0.08, 0.58)	0.48 (0.19, 1.21)
Q4	99(18.68)	0.33 (0.17, 0.65)	0.14 (0.04 , 0.49)	0.22 (0.06, 0.79)
Q5 (the richest)	106(20.00)	0.05 (0.02 , 0.18)	0.09 (0.02 , 0.38)	0.07 (0.01, 0.52)

Without health insurance and other types of insurance

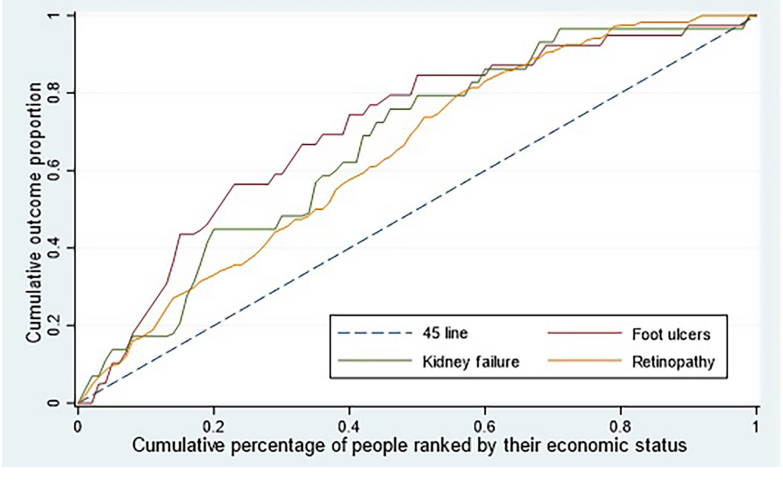

Figure 1. The Concentration Curve (CC (for Complications in Patients with T2DM

Table 2. Decomposition of Inequality for Complications in Patients with T2DM

variable	Retinopathy					Foot ulcers or other ulcers					Kidney failure				
	Elasticity		Contribution	%	Total	Elasticity		Contribution	%	Total	Elasticity		Contribution	%	Total
Gender															
Woman						Base					Base				
Man						0.151	0.078	0.012	-9.60	-9.60	0.106	0.078	0.008	-9.41	-9.41
Age, years															
< 60	Base					Base					Base				
≥ 60	0.171	-0.152	-0.026	10.48	10.48	-0.006	-0.152	0.001	-0.80	-0.80	0.016	-0.152	-0.002	2.35	2.35
Education Level															
Illiterate	Base					Base					Base				
≤ Diploma	-0.235	-0.009	0.002	-0.81		-0.049	-0.009	0.000	0		-0.092	-0.009	0.001	-1.18	
> Diploma	0.008	0.354	0.003	-1.21	-2.02	-0.074	0.354	-0.026	20.80	20.80	-0.038	0.354	-0.013	15.29	14.11
Marital status															
Married	Base					Base					Base				
Unmarried	-0.042	-0.144	0.006	-2.42	-2.42	0.035	-0.144	-0.005	4.00	4.00	0.013	-0.144	-0.002	2.35	2.35
Occupation															
Unemployed	Base					Base					Base				
Employed	-0.045	0.202	-0.009	3.63	3.63	-0.002	0.202	-0.000	0	0	-0.028	0.202	-0.006	7.06	7.06
Insurance															
Health insurance	Base					Base					Base				
Social security	-0.159	-0.011	0.002	-0.81		-0.038	-0.011	0.000	0		-0.046	-0.011	-0.000	0	
Medical service	-0.032	0.144	-0.005	2.02		-0.005	0.144	-0.001	0.80		-0.039	0.144	-0.006	7.06	
Armed force	-0.042	0.025	-0.001	0.40		-0.005	0.025	-0.000	0		0.010	0.025	0.000	0	
Other	-0.096	-0.104	0.010	-4.03	-2.42	-0.002	-0.104	0.000	0	0.80	-0.035	-0.104	0.004	-4.71	2.35

Table 2. Continue

variable	Retinopathy					Foot ulcers or other ulcers					Kidney failure				
	Elasticity		Contribution	%	Total	Elasticity		Contribution	%	Total	Elasticity		Contribution	%	Total
Type of medication															
Oral drug	Base					Base					Base				
Insulin	0.024	-0.041	-0.001	0.40		0.023	-0.041	-0.001	0.80		0.016	-0.041	-0.001	1.18	
Oral drug and Insulin	0.052	-0.132	-0.007	2.82	3.22	0.051	-0.132	-0.007	5.60	6.40	0.058	-0.132	-0.008	9.41	10.59
Duration of T2DM (years)															
≤ 5	Base					Base					Base				
6-10	0.126	-0.000	-0.000	0		0.072	-0.000	-0.000	0		0.004	-0.000	-0.000	0	
> 10	0.293	-0.184	-0.054	21.77	21.77	0.168	-0.184	-0.030	24.00	24.00	0.014	-0.184	-0.003	3.53	3.53
Hypertension															
No	Base					Base					Base				
Yes	0.087	-0.157	-0.014	5.65	5.65	0.036	-0.157	-0.006	4.80	4.80	0.133	-0.157	-0.021	24.71	24.71
Dyslipidemia															
No	Base														
Yes	-0.253	-0.096	0.024	-9.67	-9.67										
Cardiovascular Disease (CVD)															
No	Base					Base					Base				
Yes	0.090	-0.198	-0.018	7.26	7.26	0.028	-0.198	-0.005	4.00	4.00	0.022	-0.198	-0.004	4.71	4.71
Lifestyle															
Unfavourable lifestyle	Base					Base					Base				
Intermediate lifestyle	-0.098	-0.037	0.004	-1.61		-0.025	-0.037	0.001	-0.80		-0.020	-0.037	0.001	-1.18	

Table 2. Continue

variable	Retinopathy					Foot ulcers or other ulcers					Kidney failure				
	Elasticity		Contribution	%	Total	Elasticity		Contribution	%	Total	Elasticity		Contribution	%	Total
Favourable lifestyle	-0.137	0.218	-0.030	12.10	10.48	0.027	0.218	0.006	-4.80	-5.60	0.023	0.218	0.005	-5.88	-7.06
Number of examinations (per year)															
≥ 4 Times						Base					Base				
< 4 times						0.028	-0.014	-0.000	0	0	0.009	-0.014	-0.000	0	0
Adherence to prescribed medication															
No	Base					Base					Base				
Yes	-0.319	0.086	-0.027	10.89	10.89	0.099	0.086	0.008	-6.40	-6.40	0.008	0.086	0.001	-1.18	-1.18
HbA1c, %															
≤ 7.5	Base					Base					Base				
> 7.5	0.064	-0.178	-0.011	4.44	4.44	0.130	-0.178	-0.023	18.40	18.40	0.041	-0.178	-0.007	8.24	8.24
economic status															
Q1 (the poorest)	Base					Base					Base				
Q2	0.015	-0.258	-0.004	1.61		-0.012	-0.258	0.003	-2.40		-0.012	-0.258	0.003	-3.53	
Q3	0.020	0.014	0.000	0		-0.056	0.014	-0.001	0.80		-0.011	0.014	-0.000	0	
Q4	-0.031	0.309	-0.010	4.03		-0.051	0.309	-0.016	12.80		-0.021	0.309	-0.007	8.24	
Q5 (the richest)	-0.200	0.640	-0.128	51.61	57.25	-0.025	0.640	-0.016	12.80	24.00	-0.046	0.640	-0.029	34.12	38.83
Explained inequality			-0.294	118.54				-0.106	84.80				-0.086	101.18	
Residual			0.046	-18.54				-0.019	15.20				0.001	-1.18	
Total			-0.248	100				-0.125	100				-0.085	100	

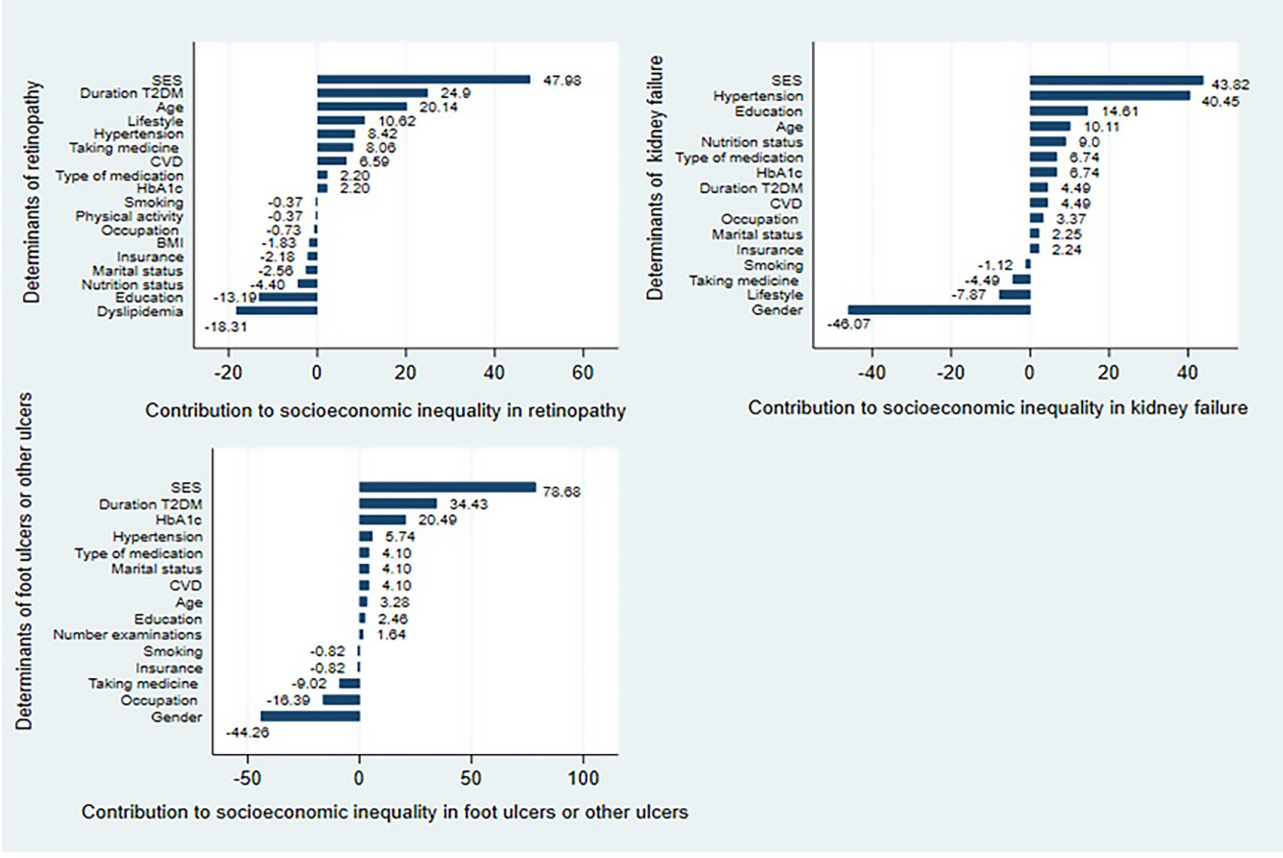

Figure 2. Contributions of determinants to Socioeconomic inequality in Complications among Patients with T2DM

in Japan (23.2%), Sri Lanka (26.1%), and Germany (25.8%), and higher than studies conducted in West Africa (17.9%).[33-36] The prevalence of renal insufficiency in the studied individuals was 5.9%, which is lower than the studies conducted in Japan (8.9%) and China (10.7%).[6, 33] The prevalence of foot ulcers and other wounds, with the majority being foot ulcers, among the participants was 7.4%, which is higher than the studies conducted in Saudi Arabia (3.3%), Sri Lanka (2.6%), and Pakistan (7%).[34, 37, 38] Based on the results of simple regression, variables such as being age 60 years or older, being single, type of treatment, cardiovascular disease, high blood pressure, longer duration of illness, and poor blood sugar control were found to be associated with an increased likelihood of complications in patients with T2DM. Additionally, an inverse relationship was observed between the highest economic status, individual education level, adherence to prescribed medication, and the presence of complications. In the conducted studies, factors such as low socioeconomic status,[33, 39] increasing age,[19] being single,[40] insulin use,[41] cardiovascular diseases,[42] high blood pressure,[43] poor blood sugar control,[44] duration of diabetes,[34] low education,[19, 45] and non-adherence to treatment[46] were associated with an increased risk of complications, confirming our findings. The results of studies on the relationship between gender and complications are inconsistent.[47, 48] In our study, male gender was associated with a higher

likelihood of developing kidney failure and foot ulcers or non-healing wounds, but was not related to retinopathy. The effects of diabetes on rural populations are more pronounced than on urban populations;[49] however, in our study, the residential area was not associated with the related complications, which may be due to the small sample size of the rural population.

We found that T2DM patients with low SES suffer more disease complications than patients with high SES. In our study the main contributors to socioeconomic inequality for retinopathy were economic status, duration of diabetes, adherence to prescribed medication, patients age, and unhealthy lifestyle. For kidney failure, economic status, hypertension, education level, and type of treatment were the significant contributors and for foot ulcers, economic status, duration of diabetes, education level and HbA1c level played major roles.

Consistent with our findings, results of the conducted study in Canada showed that patients with a lower income exhibited a higher prevalence of visual impairment in comparison to those with a higher income level.[50] In another study in China, the highest prevalence of retinopathy and neuropathy was in patients with the lowest household income.[51] Similarly, Kim et al. found that males with lower SES have a higher risk of developing diabetic retinopathy.[52] Sortsø et al. in their study showed that diabetes has higher influence on patients of lower SES and these patients engage more severe complications and die earlier.[53] Our findings confirm the studies that show the existence of inequality in disease complications of T2DM.[51, 53-55] The presence of a higher concentration of diabetes complications among diabetes patients with lower SES is a well-established and expected outcome. It is widely acknowledged that income plays a pivotal role in influencing health outcomes.[56] Evidence shows that individuals with the highest income levels are approximately two and a half times more likely to report good health compared to those with the lowest income.[57] After identifying the existence of inequality, it is crucial to determine the extent of the role of both modifiable and unmodifiable factors in the observed inequality using a decomposition approach.

Decomposing inequalities are important tool in influence on policy in inequality studies. The decomposing analysis provides important information about the sources of the observed disparities. In the decomposition approach, the first effective factor of inequality in retinopathy, kidney failure, and foot ulcers was economic status, which had the largest contribution among the studied variables. Individuals with higher economic status can pay more for medical services, prevention and various goods that lead to improved health care.[58] Therefore, improving the economic status and financial ability of people with low SES and financial aid in the form of paying the costs of disease treatment and preventing complications may reduce inequality.

The next influencing factor with a equal share with economic economic status in the inequality for foot ulcers, and the second important factor in the inequality for retinopathy, was the duration of diabetes. The effect of this factor on inequality can be attributed to the progressive nature of chronic diseases like diabetes, which tend to worsen over time and give rise to additional complications and functional limitations.[59] Consequently, individuals affected by these chronic diseases may face

reduced participation in labor markets and economic activities. To address this inequality, it is imperative for policy makers, employers, and business owners to provide support, while healthcare providers should prioritize the needs of patients with longer durations of disease. These efforts can contribute to mitigating inequality.[59]

Hypertension emerged as the second most contributor factor to inequality in the case of kidney failure. Individual with T2DM who also have hypertension tend to be more prevalent in socioeconomic groups with lower SES. A study conducted in Japan examining the relationship between hypertension and diabetes mellitus revealed that the presence of either of these two diseases increases the risk of developing the other by 1.5 to 2 times. Furthermore, the coexistence of these two diseases further amplifies the risk of complications.[43] Socioeconomic inequality have a significant impact on the prevalence and management of hypertension.[15] Expanding supplemental insurance coverage,[15] and enhancing access to healthcare services for treatment and disease control can potentially mitigate the inequality associated with hypertension.

Education was the second and third most important factor in creating inequality for foot ulcers and kidney failure, respectively. Our findings indicate a positive CI for higher education, suggesting that individuals with T2DM who possess higher education tend to be concentrated in higher economic status groups. Moreover, our research reveals that having education acts as a protective factor against disease complications. In the population under study, the illiteracy rate was approximately 24%, with a higher prevalence among females compared to males. Consequently, it is imperative to implement and expand home-based literacy programs specifically designed for illiterate individuals, placing particular emphasis on empowering females. Furthermore, promoting literacy among patients can serve as a vital strategy in mitigating educational disparities and reducing associated inequalities.[60]

HbA1c level emerges as the third factor contributing to inequality in foot ulcers. In the studied individuals with foot ulcers, 85% had poor control and 56% were in the lowest economic quintile. The negative CI between poor blood sugar control and economic status, indicating that individuals with T2DM who belong to low economic groups tend to have weaker blood glucose control. Consequently, these patients are more likely to experience complications associated with chronic diseases.[54] Providing a level of health care focusing on high-risk patients may reduce the inequality associated with HbA1c level.

Adherence to prescribed medication by patients is the third influencing factor in the inequality associated with retinopathy. In a study conducted in Cameroon, patients attributed their lack of adherence to treatment to various factors such as the disappearance of symptoms, financial issues, and forgetfulness.[61] Additionally, issues like the high cost of medications and limited access to insulin make it more challenging for patients with T2DM to achieve treatment goals.[62] Therefore, it is essential to consider both individual and social factors to promote and improve behaviors, including adherence to treatment.[63]

Age was identified as the fourth factor contributing to inequality in retinopathy. The negative CI for age indicates that older individuals with T2DM tend to be more

concentrated in socioeconomic groups with lower economic status. Older age is directly associated with lower income levels and educational attainment.[64] Additionally, in older diabetic patients, a higher prevalence of various complications is observed.[65] Considering the aging populations and the increase in the number of elderly people,[66] age inequality is indeed an important issue that needs to be addressed in social welfare programs. Providing special attention and more financial support for the aging population can help reduce disparities and improve their quality of life.[60]

Healthy lifestyle choice was identified as the fourth most important factor in creating inequality, with a contribution equal to that of age for retinopathy. A strong association between SES and lifestyle behaviors exists among individuals with diabetes.[67] Educating and promoting healthy lifestyles, improving access to healthy food and sports places can reduce inequality associated to healthy lifestyle.[68]

Study strengths and limitations

The present study possesses several notable strengths. Firstly, it was the first investigation in Iran to explore inequalities in chronic diabetes complications through the utilization of the CI. By employing a decomposition approach, the study effectively sheds light on the specific contributions of each factor to the observed inequalities. These insights offer a comprehensive understanding of the underlying dynamics that drive disparities in chronic diabetes complications, thereby significantly advancing the existing knowledge in this field. Second, in this study, all three indicators of socioeconomic status (economic status, level of education, and occupational status) were examined. Thirdly, the complications and comorbidities were assessed and confirmed by specialist physicians, ensuring accuracy in the diagnosis. Finally, the study utilizes HbA1c levels as a reliable measure of glycemic control. By relying on this established marker of blood glucose control, the study provides a robust and standardized assessment of the participants' glycemic status. These strengths enhance the credibility and significance of the study's findings, contributing to the advancement of knowledge in the field of chronic diabetes complications and their socioeconomic determinants.

The study does indeed have certain limitations that should be acknowledged. Firstly, the cross-sectional design of the study poses challenges in establishing causal relationships. Secondly, the small sample size represents another limitation of the study. A larger sample size would enhance the statistical power and generalizability of the findings. Thirdly, in this study, due to cultural and religious reasons, the participants avoided answering the question about alcohol consumption. As a result, the role of alcohol consumption in relation to chronic diabetes complications was not investigated in this particular study. Finally, it should be noted that some of the variables included in the decomposition analysis, such as HbA1c, may act as a mediating variable mediating variable in the SES- diabetes complication association. Then, there is a need to decompose the total effect of SES on diabetes complications into direct and indirect effects through HbA1c. Under such circumstances, the contribution of mediating variables like HbA1c in socioeconomic inequality related to diabetes complications should be interpreted with caution.

Conclusion

Individuals with lower SES bear a greater burden of complications associated with T2DM. In the case of retinopathy, economic status, duration of T2DM, adherence to prescribed medication, age, and the absence of a healthy lifestyle emerged as significant factors driving disparities. For kidney failure, economic status, hypertension, education level, and type of treatment were found to be important contributors. Similarly, in the context of foot ulcers, economic status, duration of T2DM, education level and HbA1c level played a significant role in inequality. To address inequalities, it is essential to implement targeted interventions aimed at improving the SES of patients. These actions include providing financial assistance to individuals with low economic status to cover treatment costs and reduce financial barriers, addressing the needs of the elderly population through social welfare programs and government financial support for this group, and supporting companies and business owners in assisting patients with T2DM, especially those who have been living with this condition for a longer period. Furthermore, promoting education among diabetes patients and teaching them how to adopt a healthy lifestyle is also of great importance for reducing inequalities.

Ethical Considerations

Participation in this study was voluntary. Verbal and written consent was obtained from all participants before completing the questionnaire. This study was approved by the research committee of the Hamadan University of medical sciences, Hamadan, Iran (IR.UMSHA.REC.1401.879).

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Competing interests

The authors declare that there is no conflict of interest.

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