Explaining income-related inequalities in cardiovascular risk factors in Tunisian adults during the last decade: comparison of sensitivity analysis of logistic regression and Wagstaff decomposition analysis

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Abstract

Background: It is important to quantify inequality, explain the contribution of underlying social determinants and to provide evidence to guide health policy. The aim of the study is to explain the income-related inequalities in cardiovascular risk factors in the last decade among Tunisian adults aged between 35 and 70 years old.

Methods: We performed the analysis by applying two approaches and compared the results provided by the two methods. The methods were global sensitivity analysis (GSA) using logistic regression models and the Wagstaff decomposition analysis.

Results: Results provided by the two methods found a higher risk of cardiovascular diseases and diabetes in those with high socio-economic status in 2005. Similar results were observed in 2016. In 2016, the GSA showed that education level occupied the first place on the explanatory list of factors explaining 36.1% of the adult social inequality in high cardiovascular risk, followed by the area of residence (26.2%) and income (15.1%). Based on the Wagstaff decomposition analysis, the area of residence occupied the first place and explained 40.3% followed by income and education level explaining 19.2 and 14.0% respectively. Thus, both methods found similar factors explaining inequalities (income, educational level and regional conditions) but with different rankings of importance.

Conclusions: The present study showed substantial income-related inequalities in cardiovascular risk factors and diabetes in Tunisia and provided explanations for this. Results based on two different methods similarly showed that structural disparities on income, educational level and regional conditions should be addressed in order to reduce inequalities.

Keywords: Social inequalities, Global sensitivity analysis (GSA), Logistic regression, Wagstaff-type decomposition analysis, Diabetes, Cardiovascular risk factors, Tunisia
Key messages

- Our study explains the income-related inequalities in cardiovascular risk factors among Tunisian adults during the last decade.
- It compares two methods (sensitivity analysis of logistic regression model and Wagstaff decomposition analysis).
- Both methods pointed to find similar factors explaining inequalities (income, educational level and regional conditions (area and region)) but with different rankings of importance.

Introduction

Inequalities in health are considered unacceptable as Alma-Ata declared in 1978 by stating that “the existing gross inequality in the health status of the people particularly between developed and developing countries as well as within countries is politically, socially and economically unacceptable and is, therefore, of common concern to all countries” [1]. Accordingly, the World Health Organization (WHO) has issued a call to action to reduce health inequalities [2].

Several epidemiological studies have examined the income-related inequalities of noncommunicable diseases, in particular cardiovascular diseases (CVDs) and diabetes. Cardiovascular risk factors are well documented in Tunisia [3, 4]. However, such studies have been unable to address policy makers concerns on which interventions and preventive strategies will be most effective in reducing the observed inequalities and how to address the groups most in need of intervention [5, 6].

The major limitation of Tunisian and international research on income-related inequalities of cardiovascular diseases and diabetes is the dominant focus on the existence of inequalities without identifying their basis, which would allow greater understanding of the reasons for inequalities [7–10]. Some advanced statistical methods can help overcome many of these limitations playing a crucial role in helping to quantify inequality and explain the contribution of the underlying social determinants as well as to guide health policies and the development of strategies at different levels [11, 12].

In this context, this study aimed to quantify the income-related inequalities in five cardiovascular risk factors (diabetes, hypertension, obesity, hypercholesterolemia, smoking and high cardiovascular risk) in the last decade in Tunisia, and to determine the contribution of a broad range of social determinants of the inequalities. In order to identify the most explanatory social determinants, we used the two main approaches currently used to explain social inequalities, a global sensitivity analysis using logistic regression model and the Wagstaff-type decomposition analysis.

Methods

Study population

To study the evolution of income-related inequalities of cardiovascular risk factors in Tunisia during the last decade, we used two large national surveys: (i) the Epidemiological Transition and Health Impact in North Africa Survey in 2005 (TAHINA-2005) including 8007 individuals aged 35–70 years old (3417 men and 4590 women) and (ii) the Tunisian Health Examination Survey (THES-2016) in 2016 including 6007 individuals aged 35–70 years old (2859 men and 3148 women).

The two surveys used were representative of the underlying population and were based on the same sampling method. The definitions of cardiovascular risk were the same except for diabetes in 2016 where the Hemoglobin A1C was integrated as recommended by the American Diabetes Association.

Details of the study population were presented in the technical appendix.

Measurements

Socio-economic and demographic variables

The variables used as social determinants in our study included demographic and socio-economic factors that had plausible links with cardiovascular risk factors and diabetes [13, 14].

Demographic factors included four variables: (i) gender defined as male coded “1” and female coded “2”; (ii) age categorized into four groups: “1” 35–44, “2” 44–54, “3” 55–64 and “4” 65–70 years; (iii) geographic area (“1” Urban, “2” Rural) and (iv) region of residence categorized into 7 administrative regions of the country (“1” District of Tunis, “2” North-East, “3” North-West, “4” Central-East, “5” Central-West, “6” South-East and South-West).

Data on geographic area and region of residence was obtained from the sampling frame derived by the Tunisian National Institute of Statistics [15, 16]. Age and gender were self-reported by the survey participants.

Socio-economic factors included level of education, professional occupation and quintile of well-being. Data were self-reported by the survey participants.

(i) Education was classified according to the classification of National Tunisian Institute of Statistics into four categories [17]: level 0, Never educated “illiterate”; level 1, low level education “Primary” (6 years of schooling); level 2, intermediate-level education “Secondary” (7–13 years of schooling) and level 3, higher education “university and higher (> = 14 years of schooling).

(ii) The classification of the professional activity status is defined according to the structure of the International Standard Classification of Occupations.
and categorized into four groups: 1 higher level Senior level; 2 Intermediate level; 3 workers and 4 unemployed or retirees.

(iii) Quintile of income: income of household as categorized into quintiles with quintile 1 representing the lowest income and quintile 5 representing the highest.

Cardiovascular risk factors

**Hypertension** In both surveys (TAHINA-2005 and THES-2016), three blood pressure readings were measured separately; the mean systolic blood pressure (SBP) and diastolic blood pressure (DBP) of the three measures were considered. Based on WHO recommendations the following is considered hypertensive; any person with a SBP $\geq 140$ and / or DBP $\geq 90$ mmHg and / or who claims to be diagnosed for arterial hypertension and / or treated [19].

**Diabetes** For TAHINA Survey in 2005, diabetes prevalence was defined using the WHO criteria [20] as Fasting Plasma Glucose (FPG) $\geq 7$ mmol/L, confirmed medication usage from the medication inventory, self-reported use of antidiabetic medications within the past 2 weeks of the examination, or self-reported diabetes diagnosis.

For THES Survey in 2016, diabetes prevalence was defined according to the definition of the American Diabetes Association (ADA) as FPG $\geq 7$ mmol/L or postprandial glucose $\geq 11$ mmol/L, Hemoglobin A1C (HbA1C) $\geq 6.5\%$, self-reported diabetes diagnosis or confirmed medication usage from the medication inventory [21, 22].

**Hypercholesterolemia** In both surveys (TAHINA-2005 and THES-2016), the prevalence of hypercholesterolemia is defined by total serum cholesterol $\geq 6.2$ mmol /l or triglyceride $\geq 3$ mmol / or self-reported hypercholesterolemia diagnosis [23].

**Obesity** In both surveys (TAHINA-2005 and THES-2016), obesity is defined by Body Mass Index (BMI) $\geq 30$ Kg / m$^2$ [24].

**Smoking** In both surveys (TAHINA-2005 and THES-2016), the prevalence of smoking is defined by the daily consumption of tobacco at the time of the survey.

**High cardiovascular risk** In both surveys (TAHINA-2005 and THES-2016), high cardiovascular risk is defined by the cumulative number of risk factors $\geq 3$, out of the five mentioned above.

In the main manuscript, we only present results of the high cardiovascular risk. The analysis of other individual factors (Diabetes, Tobacco, obesity, hypertension and hypercholesterolemia) are presented in the technical appendix.

**Statistical analysis**

**Sensitivity analysis to select the most influencing risk factors**

The Global Sensitivity Analysis (GSA) was defined as how the uncertainty in the output of a model can be apportioned to the different sources of uncertainty in the model input. The method quantifies the contribution of uncertainty in different social determinants (inputs) to a specific output variable of interest (the disease) [25, 26].

The GSA in this study is generally based on the sensitivity index for measuring the importance of a given social determinant on the output variable designating the disease (sick, not sick, eg hypertension).

The sensitivity index of a determinant is defined by the fractional contribution to the variance of the output variable.

**GSA in a logistic regression model**

In this study, we are interested in the sensitivity analysis of the logistic regression model.

The theory of constructing a logistic regression model is detailed in the appendix [27, 28].

The process of selecting the important covariates from the available set of covariates and constructing an appropriate logistic regression model involved three steps:

1. To identify the probability distribution $f(x_i)$ of each covariate in the model.
2. The logistic regression model, in terms of Logit (as in equation below) and the information about the covariates obtained in step one are used to create a Monte Carlo simulation to generate the sample that will be used in the decomposition and to estimate the unconditional variance of the response probability and the conditional variance for covariates.
3. The results from step two will be used in performing GSA in the binary logistic regression model and in the decomposition analysis, resulting in the estimate of $S_j$. In this step, we refer to the Sabol method [28] using R software.

**Wagstaff-type decomposition analysis**

The decomposition analysis quantifies the degree of income-related inequalities and explains the contribution of each factor to the observed inequality. The decomposition approach is the analysis of the contribution
that each of the inequalities in the social determinants has on the inequalities in the observed disease.

This analysis is based on the concentration curve (CC) and the concentration index (C) [29].

The analysis was done through the following steps:
1) Run a regression analysis;
2) Compute the elasticity (weighted coefficient);
3) Calculate the concentration indexes of the covariates;
4) Calculate the contributions.

Details of the method were presented in the technical appendix.

Results
Socioeconomic and demographic characteristics of the study populations
Table 1 shows the socioeconomic and demographic characteristics of the study populations.

In 2005, the mean age of the study population was $49.0 \pm 9.5$ years. Women accounted 50.4% of the study population and 68.0% lived in an urban area of residence. About one in four people were residing in the District of Tunis. 34.9% were illiterate, as well 43.2% were unemployed or retired. Additionally, 15.7% of the surveyed population lived at the lowest quintile in 2005.

In 2016, the mean age was $49.2 \pm 9.7$ years, and women accounted for 50.2% of the study population. The percentage of urban population was 67.6%. In addition, 23.2% of the study population were residents in the District of Tunis region and 19.3% reported having no education in 2016. In addition, 39.9% were unemployed or retired. The percentage of the surveyed population lived at the lowest quintile was 18.1%.

High cardiovascular risk in the last decade by social determinants
Evolution of high cardiovascular risk prevalence in the last decade by social determinants
Table 2 presented the high cardiovascular risk prevalence by social determinants in 2005 and 2016. In 2005, 12.4% [11.4–13.3] of the adults aged 35–70 years old had high cardiovascular risk (13.6% [12.0–15.0] among men and 11.2% [10.1–12.4] among women).

A greater prevalence of high cardiovascular risk was observed in those aged 55–64 years of age (19.1% [16.5–21.7]) compared to those aged between 35 and 44 years (7.4% [6.2–8.7]). High cardiovascular risk was twice as high in the urban area (14.8% [13.5–16.1]) compared to the rural area (7.3% [6.3–8.3]) and three times higher in the District of Tunis (19.2% [16.3–22.0]) than in the north-west (6.6% [5.2–8.1]). The High cardiovascular risk prevalence was more dominant among people with secondary education level (15.9% [13.3–18.4]) than other educational levels and among those intermediate occupation level (14.9% [10.4–19.4]). The highest prevalence was observed among people within the highest income quintile (16.2% [13.9–18.5]) compared to the lowest quintile (6.9% [5.4–8.3]).
In 2016, the high cardiovascular risk prevalence increased to reach 20.3% [19.1–21.6] among Tunisian adults aged between 35 and 70 years: 21.1% [19.2–22.9] among men and 19.6% [17.9–21.3] among women. This prevalence increased gradually with age in 2016 where it was 11.2% [9.4–13.0] in those aged 35–44 years reaching 31.9% [27.3–36.4] in those aged 65–70 years of age.

In 2016, the highest prevalence of high cardiovascular risk was observed in the urban area (22.8% [21.2–24.4]) and in the district of Tunis (22.4% [19.1–25.7]).

### Table 2: Evolution of the prevalence of high cardiovascular risk prevalence by social determinants between 2005 and 2016

| Study          | TAHNA-2005 |                     |                    | THES-2016 |                      |                    |
|----------------|------------|---------------------|--------------------|-----------|-----------------------|--------------------|
|                | N          | High cardiovascular risk prevalence % [CI 95] |                    | N         | High cardiovascular risk prevalence % [CI 95] |                    |
| Characteristics|            |                     |                    |           |                      |                    |
| Gender         |            |                     |                    |           |                      |                    |
| Male           | 3233       | 13.6 [12.0–15.0]    |                    | 2610      | 21.1 [19.2–22.9]      |                    |
| Female         | 4320       | 11.2 [10.1–12.4]    |                    | 2839      | 19.6 [17.9–21.3]      |                    |
| Age-Groups (years) |            |                     |                    |           |                      |                    |
| 35–44          | 2992       | 7.4 [6.2–8.7]       |                    | 1803      | 11.2 [9.4–13.0]       |                    |
| 45–54          | 2469       | 14.1 [12.3–15.9]    |                    | 1708      | 22.9 [20.6–25.3]      |                    |
| 55–64          | 1319       | 19.1 [16.5–21.7]    |                    | 1443      | 27.7 [25.0–30.3]      |                    |
| 65–70          | 773        | 17.7 [14.5–21.0]    |                    | 495       | 31.9 [27.3–36.4]      |                    |
| Area           |            |                     |                    |           |                      |                    |
| Urban          | 4372       | 14.8 [13.5–16.1]    |                    | 3606      | 22.8 [21.2–24.4]      |                    |
| Rural          | 3181       | 7.3 [6.3–8.3]       |                    | 1843      | 15.1 [13.3–17.0]      |                    |
| Region         |            |                     |                    |           |                      |                    |
| District of Tunis | 925       | 19.2 [16.3–22.0]    |                    | 685       | 22.4 [19.1–25.7]      |                    |
| North East     | 1024       | 9.5 [7.6–11.4]      |                    | 799       | 20.2 [17.3–23.0]      |                    |
| North West     | 1124       | 6.6 [5.2–8.1]       |                    | 886       | 19.0 [16.3–21.7]      |                    |
| Centre East    | 1099       | 15.1 [12.9–17.2]    |                    | 836       | 22.1 [19.6–25.3]      |                    |
| Centre West    | 1176       | 7.9 [6.3–9.4]       |                    | 763       | 16.2 [13.5–18.8]      |                    |
| South East     | 1070       | 8.8 [6.9–10.6]      |                    | 708       | 16.2 [13.4–19.0]      |                    |
| South West     | 1135       | 8.0 [6.4–9.6]       |                    | 772       | 20.3 [17.4–23.3]      |                    |
| Level of education |            |                     |                    |           |                      |                    |
| Illiterate     | 3258       | 10.7 [9.4–11.9]     |                    | 1240      | 22.9 [20.2–25.6]      |                    |
| Primary        | 2588       | 12.3 [10.7–13.9]    |                    | 2117      | 21.1 [19.1–23.1]      |                    |
| Secondary      | 1233       | 15.9 [13.3–18.4]    |                    | 1472      | 19.6 [17.3–22.0]      |                    |
| University     | 474        | 11.7 [8.3–15.1]     |                    | 620       | 15.6 [12.1–19.0]      |                    |
| Occupation     |            |                     |                    |           |                      |                    |
| Unemployed/retired | 3844      | 11.5 [10.2–12.8]    |                    | 2461      | 22.6 [20.7–24.5]      |                    |
| Employee/worker| 2370       | 12.2 [10.6–13.9]    |                    | 2187      | 18.9 [17.0–20.8]      |                    |
| Intermediate   | 359        | 14.9 [10.4–19.4]    |                    | 317       | 18.9 [13.7–24.1]      |                    |
| Upper          | 980        | 14.2 [11.5–16.9]    |                    | 484       | 18.6 [14.4–22.8]      |                    |
| Quintile income|            |                     |                    |           |                      |                    |
| 1st quintile   | 1510       | 6.9 [5.4–8.3]       |                    | 1089      | 18.2 [15.6–20.8]      |                    |
| 2nd quintile   | 1510       | 9.0 [7.2–10.7]      |                    | 1090      | 18.7 [16.0–21.4]      |                    |
| 3rd quintile   | 1511       | 12.2 [10.2–14.3]    |                    | 1090      | 21.9 [19.1–24.7]      |                    |
| 4th quintile   | 1511       | 14.9 [12.6–17.1]    |                    | 1090      | 22.5 [19.6–25.4]      |                    |
| 5th quintile   | 1511       | 16.2 [13.9–18.5]    |                    | 1090      | 19.8 [17.0–22.6]      |                    |
| Total          | 7553       | 12.4 [11.4–13.3]    |                    | 5449      | 20.3 [19.1–21.6]      |                    |

CI 95% 95% Confidence Interval
p: p value at 5% significance level
Additionally, the prevalence of high cardiovascular risk was particularly high among illiterate participants (22.9% [20.2–25.6]), the unemployed and retired (22.6% [20.7–24.5]) and within the fourth income quintile (22.5% [19.6–25.4]) (Table 2).

**Global sensitivity analysis in a logistic regression model method of high cardiovascular risk**

The global sensitivity analysis in a logistic regression model, reflecting the ranking of variables ordered by the level of importance and contribution of each in explaining the total variance of the high cardiovascular risk prevalence, showed that the most influential factors were the geographical area, the region of residence and the income contributing 30.7, 21.4 and 20.1% respectively in 2005.

In 2016, the education level occupied the first place (36.1%), followed by the area (26.2%) and the income (15.1%). The occupation level represented 11.7% of the total variance (Table 3).

**Wagstaff-type decomposition analysis of high cardiovascular risk prevalence**

**Income-related inequality in high cardiovascular risk prevalence** The concentration curves of income-related inequalities of high cardiovascular risk prevalence in 2005 and 2016 are presented in Fig. 5. The concentration curve lies under the diagonal line of equity, with the overall concentration index is estimated at 0.116 (95% CI: 0.092 to 0.140) in 2005 and 0.085 (95% CI 0.048 to 0.122) in 2016. High cardiovascular risk was mainly concentrated among those with the highest income in both observation periods (Fig. 1).

**Decomposition analysis of high cardiovascular risk**

The Wagstaff decomposition analysis of high cardiovascular risk found that, in 2005, regional conditions had a principal role in explaining the income-related inequalities in high cardiovascular risk: The geographical area was in first place (34.6%) followed by the region (21.8%). The education level and occupation were ranked next explaining 13.8 and 13.2% respectively. Then, income explained 10.8%. Lastly, age and gender contributed 4.8 and 1.0% to the observed inequalities respectively.

In 2016, the geographical area still occupied the first place and explained 40.3% of the adult social inequality in high cardiovascular risk followed by the income, education level and occupation with contributions of 19.2, 14.0 and 13.6% respectively. The age and the region represented 6.3 and 4.6% of the observed inequalities respectively. Gender only explained 2.1%.

Based on the positive concentration indices in 2005 and 2016, men, people aged 45 to 54 years, residents in urban areas, residents in the North-East and Central-East, those with secondary education, middle managers and those belonging to the highest income quintiles were mainly concentrated in the richer population. These groups contributed to the inequalities in the prevalence of high cardiovascular risk.

Furthermore, the social determinants included in the model accounted for 53 and 51% of the estimated inequality of high cardiovascular risk in Tunisia respectively in 2005 and 2016, based on the residual, reflecting the unexplained part of the inequality in terms of prevalence of high cardiovascular risk (Table 4).

**Discussion**

The study revealed a high evolution of cardiovascular risk factors among Tunisian adults during the last decade with substantial pro-rich income-related inequalities. Similar upward trends have been previously been shown [30, 31] particularly in low and middle-income countries [32, 33].

We have used the two most common methods to measure and explain health inequalities, the global sensitivity analysis of logistic regression model and the Wagstaff-type decomposition analysis using the cardiovascular risk factors in the last decade as outcomes in Tunisia. To the best of our knowledge, this is the first study comparing these two methods mathematically and epidemiologically in Tunisia and the Maghreb region.

This study highlights that the results provided by the GSA and Wagstaff decomposition analysis methods show that higher risk for cardiovascular diseases is concentrated among those with higher socio-economic status in 2005. Similar results were observed in 2016. Moreover, both methods show similar factors explain the inequalities (income, educational level and regional conditions (area and region)) but with different rankings of importance.

### Table 3 Sensitivity indices and social determinants ranking of high cardiovascular risk

| Social determinants | 2005 | 2016 |
|---------------------|------|------|
|                     | $S_i$ | $S_i$ (%) | Rank | $S_i$ | $S_i$ (%) | Rank |
| Gender              | 0.009 | 0.9 | 7 | 0.006 | 0.4 | 7 |
| Age                 | 0.117 | 11.1 | 5 | 0.031 | 2.3 | 6 |
| Area                | 0.323 | 30.7 | 1 | 0.35 | 26.2 | 2 |
| Region              | 0.225 | 21.4 | 2 | 0.109 | 8.1 | 5 |
| Education level     | 0.045 | 4.3 | 6 | 0.483 | 36.1 | 1 |
| Occupation          | 0.122 | 11.6 | 4 | 0.157 | 11.7 | 4 |
| Household income    | 0.212 | 20.1 | 3 | 0.202 | 15.1 | 3 |
| Total               | 1.053 | 100.0 | | 1.338 | 100.0 | |

$S_i$: Sensitivity indice
An interesting result from this analysis is that those with high socio-economic status have a higher risk for cardiovascular diseases and diabetes than those from lower socio-economic groups in both 2005 and 2016, except for hypertension. Hypertension was the most prevalent disease in the lowest socio-economic groups in 2016 and the use of tobacco in 2016, was most common in those with income in the mid-range. The findings of the present study are generally in line with another Tunisian study which showed that those with high living standards had a three times higher risk of developing a cardiovascular event in 10 years than those with low living standards [34].

Result are also consistent with the descriptive study conducted in 2011 in Morocco that showed that cardiovascular risk increased proportionally with household income [35].

In contrast to our results, other studies from low and middle-income countries have shown that cardiovascular risk factors are often higher in groups with low socio-economic status than in those with high socioeconomic status [36–38]. These studies have suggested that observed social gradient depends on the economic and social context of the country.

It is known that income-related inequalities in cardiovascular risk factors and diabetes exist in all countries and are considered unacceptable [39–44]. The challenge facing policymakers is, to ensure that strategies for reducing inequalities must be targeted and justified by rigorous research.

A study in Swedish middle-aged women and men showed that the magnitude of income-related inequalities in CVRFs and their determinants differed between the risk factors and gender. Income was the dominant factor for BMI, abdominal obesity, triglycerides, glucose regulation and LDL-cholesterol, explaining between 30 and 49% of the inequality, whereas education was more important for HDL-cholesterol and total-cholesterol (explaining 24.3 and 41.0% respectively), and occupation was more important for blood pressure (explaining 47.3%) [45].

We found similar results in our study. Income was the major factor for obesity, hypertension hypercholesterolemia and diabetes in Tunisia in 2016, and education was more important for tobacco use.

A key priority message of this study is that the income-related inequalities of cardiovascular risk factors and diabetes are explained by regional disparities, education level and income.

Thus, in Tunisia, promoting equity through universal coverage and improving access to quality care, are two fundamental elements to help remedy the situation and interventions should specially be targeted to high risk groups [46]. It is also important to improve the governance of the system and to make the multisectoral approach a reality for a more effective response to major health problems, such as cardiovascular disease and diabetes.

In term of methodology, several studies in the field have used a simple logistic regression for the study of association between the outcome and determinants Where the results are interpreted in terms of odds ratio (OR) [9, 10, 47].

To overcome the limitations of the single logistic regression some studies develop a global sensitivity analysis to assess the relative importance of input
Table 4: Decomposition of the concentration index of high cardiovascular risk prevalence among Tunisian adults in 2005 and 2016

|                  | 2005 Coef | 2005 Elast | 2005 CI | 2005 Cont to C | 2005 % cont | 2005 % Adj | 2016 Coef | 2016 Elast | 2016 CI | 2016 Cont to C | 2016 % cont | 2016 % Adj |
|------------------|-----------|------------|--------|----------------|-------------|------------|-----------|------------|--------|----------------|-------------|------------|
| Gender           |           |            |        |                |             |            |           |            |        |                |             |            |
| Male             | 0.004     | 0.015      | 0.129  | 0.002          | 1.7         | 1.0        | 0.021     | 0.048      | 0.070  | 0.003          | 3.9         | 2.1        |
| Female (Ref)     |           |            |        |                |             |            |           |            |        |                |             |            |
| Age              |           |            |        |                |             |            |           |            |        |                |             |            |
| 35–44 years (Ref)| 0.0       |            |        |                |             |            |           |            |        |                |             |            |
| 45–54 years      | 0.071     | 0.221      | 0.043  | 0.010          | 8.2         | 4.8        | 0.133     | 0.203      | 0.050  | 0.010          | 12.0        | 6.3        |
| 55–64 years      | 0.150     | 0.249      | 0.032  | 0.008          | −6.9        | 0.0        | 0.184     | 0.238      | −0.081 | −0.019         | −22.7       | 0.0        |
| 65–70 years      | 0.162     | 0.158      | 0.157  | 0.025          | −21.3       | 0.0        | 0.238     | 0.106      | −0.179 | −0.019         | −22.2       | 0.0        |
| Area             |           |            |        |                |             |            |           |            |        |                |             |            |
| Rural (Ref)      | 0.0       |            |        |                |             |            |           |            |        |                |             |            |
| Urbain           | 0.032     | 0.174      | 0.398  | 0.069          | 59.5        | 34.6       | −0.079    | −0.131     | −0.497 | 0.065          | 76.4        | 40.3       |
| Region           |           |            |        |                |             |            |           |            |        |                |             |            |
| District of Tunis (Ref) | 0.0       |            |        |                |             |            |           |            |        |                |             |            |
| North_east       | −0.049    | −0.063     | 0.014  | −0.001         | −0.7        | 0.0        | 0.006     | 0.004      | 0.043  | 0.000          | 0.2         | 0.1        |
| North_west       | −0.060    | −0.085     | −0.232 | 0.020          | 17.0        | 9.9        | 0.003     | 0.002      | −0.275 | −0.001         | −0.7        | 0.0        |
| Central_east     | −0.016    | −0.022     | 0.244  | −0.005         | −4.6        | 0.0        | 0.022     | 0.016      | 0.252  | 0.004          | 4.8         | 2.5        |
| Central_west     | −0.046    | −0.068     | −0.262 | 0.018          | 15.2        | 8.9        | −0.013    | −0.009     | −0.265 | 0.002          | 2.7         | 1.4        |
| South_east       | −0.052    | −0.071     | 0.035  | −0.002         | −2.1        | 0.0        | −0.053    | −0.034     | −0.024 | 0.001          | 0.9         | 0.5        |
| South_west       | −0.054    | −0.078     | −0.078 | 0.006          | 5.2         | 3.0        | −0.001    | −0.001     | 0.060  | 0.000          | 0.0         | 0.0        |
| Education Level  |           |            |        |                |             |            |           |            |        |                |             |            |
| Illiterate       | 0.015     | 0.060      | −0.412 | −0.025         | −21.3       | 0.0        | 0.082     | 0.091      | −0.059 | −0.047         | −54.6       | 0.0        |
| Primary          | 0.038     | 0.125      | −0.008 | −0.001         | −0.9        | 0.0        | 0.071     | 0.134      | −0.220 | −0.029         | −34.4       | 0.0        |
| Secondary        | 0.042     | 0.066      | 0.421  | 0.028          | 23.7        | 13.8       | 0.052     | 0.068      | 0.334  | 0.023          | 26.6        | 14.0       |
| University (ref) | 0.0       |            |        |                |             |            |           |            |        |                |             |            |
| Occupation       |           |            |        |                |             |            |           |            |        |                |             |            |
| Unemployed       | −0.022    | −0.106     | −0.216 | 0.023          | 19.7        | 11.5       | −0.021    | −0.045     | −0.202 | 0.009          | 10.7        | 5.7        |
| Workers          | −0.028    | −0.084     | −0.041 | 0.003          | 3.0         | 1.7        | −0.039    | −0.077     | −0.167 | 0.013          | 15.0        | 7.9        |
| Medium           | −0.014    | −0.006     | 0.683  | −0.004         | −3.7        | 0.0        | −0.016    | −0.005     | 0.506  | −0.002         | −2.7        | 0.0        |
| High (Ref)       | 0.0       |            |        |                |             |            |           |            |        |                |             |            |
| Household income |           |            |        |                |             |            |           |            |        |                |             |            |
| Lowest quintile  | −0.035    | −0.068     | −0.993 | −0.067         | −57.7       | 0.0        | −0.022    | −0.022     | −0.099 | 0.022          | 25.4        | 13.4       |
| 2                | −0.021    | −0.041     | −0.507 | 0.021          | 17.8        | 10.3       | 0.004     | 0.004      | −0.498 | −0.002         | −2.1        | 0.0        |
| 3                | −0.006    | −0.011     | 0.001  | 0.000          | 0.0         | 0.0        | 0.024     | 0.023      | 0.005  | 0.000          | 0.1         | 0.1        |
| 4                | 0.001     | 0.002      | 0.498  | 0.001          | 0.7         | 0.4        | 0.019     | 0.019      | 0.498  | 0.009          | 10.9        | 5.7        |
| Highest quintile | 0.000     |            |        |                |             |            |           |            |        |                |             |            |
| C (conindu)      | 0.116     |            |        |                |             |            |           |            |        |                |             |            |
| Residual         | 0.055     |            |        |                |             |            |           |            |        |                |             |            |

*Coeff coefficient, Elast elasticity, C concentration index, Cont. to C contribution to concentration index, % percentage contribution, Adj % Adjusted percentage

parameters in the system model and the relative importance of variables allowing analysis of the robustness of the logistic model [28, 48].

Unfortunately, this approach also has some limitations as it based on the sampling of the distribution function and is not intended to identify the cause of the input variability. It only indicates the type and extent of impact on the model output. Therefore, it cannot be used to determine the source(s) of variance.

Other advanced and recent methods have also been developed to study income-related inequalities such as Wagstaf’s decomposition analysis [29]. This approach
should help to overcome the limitations of the previous approach. This method demonstrates that the health concentration index can be decomposed into the contributions of individual factors to income-related health inequality, in which each contribution is the product of the sensitivity of health with respect to that factor (the elasticity) and the degree of income-related inequality in that factor (the respective concentration index).

These two methods differ on the mathematical and statistical level; however, they can be complementary in application to public health and help address the expectations of decision-makers.

The GSA and the decomposition gave similar results, however, the decomposition requires much more information to be performed and is mathematically a more complex method.

Therefore, in settings where: a) information is not routinely collected or data do not match the standard requirements to run a decomposition or b) the statistical skills are not in place, then a GSA could be carried out similar results are shown.

Conclusions

Our study revealed considerable inequalities in cardiovascular risk factors and diabetes in Tunisia in 2005 and 2016, before and after the revolution. The results suggest that most of this inequality can be attributed to socioeconomic factors, regional conditions (region and area of residence) and demographics.

The results, therefore, suggest that income and educational level inequalities as well as regional conditions (area and region) represent the main factors responsible for the income-related inequalities in cardiovascular risk factors and diabetes in Tunisia during the last decade.

The results to explain the income-related inequalities of cardiovascular disease and diabetes in Tunisia over time are consistent across the two methods used, the global sensitivity analysis of logistic regression and the decomposition of the concentration index. The findings contribute to gaps in the literature concerning the analysis of social determinants in mathematical and epidemiological terms.

This study argues that, although, the two methods used are mathematically different in nature, their results are complementary and can provide valuable explanations to the observed social inequities of cardiovascular risk factors and diabetes.

Thus, these findings suggest that addressing the root cause of inequality is essential for promoting cardiovascular risk factors and diabetes equity in Tunisia.

The information provided by the analysis might be helpful to identify potential targets for health interventions in order to reduce these income-related inequalities in Tunisia and the methods can be applied to other health problems and populations.

Abbreviations

ADA: American Diabetes Association; BMI: Body Mass Index; C: Concentration Index; CC: Concentration Curve; CVDs: Cardiovascular Diseases; DBP: Diastolic Blood Pressure; FPG: Fasting Plasma Glucose; GSA: Global Sensitivity Analysis; HbA1C: Hemoglobin A1C; OR: Odds Ratio; SBP: Systolic Blood Pressure; s: Sensitivity index; TAHINA-2005: Epidemiological Transition and Health Impact in North Africa Survey-2005; THES-2016: Tunisian Health Examination Survey-2016; WHO: World Health Organization

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Authors’ contributions

OS, MOF, SC, DM and HBR conceived the idea of the study. OS and NZ analysed the data with support from PM. OS, NZ, DM and MOF wrote the first draft of the paper and OS, HBR, MOF, SC, KB and PM finalized the manuscript. All authors contributed to the analysis, intellectual content, critical revisions to the drafts of the paper and approved the final version.

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Availability of data and materials

For TAHINA-2005 survey, the datasets used and analyzed during the current study are available from the corresponding author on reasonable request. For THES-2016 survey, The Tunisian Ministry of Health/National Institute of Health and World Health Organization will publish the datasets online.

Ethics approval and consent to participate

The main ethical considerations applicable to all forms of medical research stemming from the declaration of Helsinki of the World Medical Association have been respected for both surveys (TAHINA-2005 and THES-2016). For THES-2016 survey, the protocol of the study was approved by the Tunisian Ministry of Health and the World Health Organization. The protocol was also approved by the Tunisian National Council of Statistics (Visa n° 09–2015 of 10 November 2015) and by the National Body for the Protection of Personal Data (Authorization to process health data N° 185-01 / 16 from 06 May 2016).

For TAHINA-2005 survey, the protocol of the study was approved by Tunisian Ministry High Education and Research, Ministry of Health and the Tunisian National Council of Statistics. For both surveys, at the beginning of the study, each randomly selected participant was appropriately informed about the objectives, methods, funding, institutional affiliation, expected benefits and data collection modalities. Before the inclusion of each participant, verbal consent was obtained from him or his parents.

Consent for publication

For both surveys used in this study, before the inclusion of each participant, verbal consent was obtained for participation and publication.

Competing interests

The authors have declare that they have no competing interests.

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