

Investigating Trend in Cardiovascular Disease Mortality and Its Association with Obesity in the Gulf Cooperative Council (GCC) Countries from 1990 to 2019

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Abstract

Background: Cardiovascular diseases (CVDs) are the leading cause of death globally. An estimated 17.9 million people died from CVDs in 2019, representing 32% of all global deaths. Of these deaths, 85% were due to heart attack and stroke. Over three quarters of CVD deaths take place in low- and middle-income countries. We have studied the pattern of mortality due to cardiovascular in the six countries of the Arabian Gulf and its association with obesity over the 29 years 1990 to 2019. **Methods:** We used the linear mixed effect models to investigate the pattern of CVD mortality over the year 1990 to 2019, together with the pattern of change in one of the most important risk factors that is obesity, and its association with CVD mortality over the same period. **Conclusions:** Although there were fluctuations in the pattern of mortality and the prevalence of obesity over the specified period, there has been a steady decline in the per-100,000 number of deaths and the prevalence of obesity. However, there was a strong association between the two variables. From the fitted models we estimated that a one percent increase in obesity is associated with an average increase in cardiovascular deaths of 2.7 deaths per 100,000.

Keywords

Cardiovascular Diseases, Risk Factors, Time Series Data, Generalized Linear Mixed Models, Predictive Analytics

1. Introduction

Cardiovascular diseases (CVDs) are a group of disorders of the heart and blood vessels [1]. These diseases include, among others:

- 1) Coronary heart disease—a disease of the blood vessels supplying the heart muscle;
- 2) Cerebrovascular disease—a disease of the blood vessels supplying the brain;
- 3) Peripheral arterial disease—a disease of blood vessels supplying the arms and legs;
- 4) Rheumatic heart disease—damage to the heart muscle and heart valves from rheumatic fever, caused by streptococcal bacteria;
- 5) Congenital heart disease—birth defects that affect the normal development and functioning of the heart caused by malformations of the heart structure from birth;
- 6) Deep vein thrombosis and pulmonary embolism—blood clots in the leg veins, which can dislodge and move to the heart and lungs.

Cardiovascular disease (CVD) is known as the leading cause of global death and one of the most serious health problems throughout the world. Commonly, CVD can refer to a class of diseases that involves the heart or blood vessels. CVD which has been recognized as the leading cause of morbidity and mortality is an important contributor to the cost of medical care [1]. In 2016, CVD was responsible for nearly one-third of all deaths across the globe [2]. Over the last decades, although the age-standardized mortality rates of CVD declined by 27.3%, the number of deaths increased by 42.4% from 1990 to 2015 [3]. On the other hand, CVD led to over 17 million deaths, 330 million years of life lost and 35.6 million years lived with disability in 2017 worldwide [4] [5]. Meanwhile, it was projected that CVD would be the cause of more than 23 million deaths in 2030 around the world [6]. Today, CVD is responsible for a remarkable reduction in quality of life and life expectancy and imposes huge costs on health systems in different countries. Accurate estimation of disease burden plays a key role in establishing convenient public health policies. To measure the burden of CVD, different outcome parameters can be used. There are some indices such as prevalence, incidence, mortality, and survival which can provide valuable information about the current situation and help the policy makers to organize the available resources. In general, the incidence and mortality rates of CVD vary from region to region because of several factors like lifestyle, dietary habits, appropriate health care accessibility, and so on. For example, people with a lower level of education in low-income and middle-income countries have a higher incidence of mortality from CVD [7].

The main goal of our study is to investigate the trend of age standardized mortality rate attributed to CVD (ASMR-CVD) over the period between 1990 and 2019 in the Arabian Gulf Countries. In addition to investigating the time trend we would like to establish the association between ASMR-CVD and country-level average obesity (AOB). This is achieved by constructing a linear mixed effects model which we then use to predict the ASMR-CVD in the year 2030.

2. Data Sources

In this study, the information from the Global Burden of Diseases (GBD) free online database on age-standardized CVD mortality and incidence rates per 100,000 persons were extracted from 1990 to 2019 for both genders. The national estimate of the disease burden for over 180 countries is managed by the IHME which provides the world's most important health measurements. To achieve the goals of our study, the age-standardized CVD incidence and mortality rates, and obesity data were extracted from the sources listed below:

<https://www.worldlifeexpectancy.com/cause-of-death/coronary-heart-disease/by-country/>

<https://data.worldobesity.org/tables/prevalence-of-adult-overweight-obesity-2/>

https://en.wikipedia.org/wiki/Obesity_in_the_Middle_East_and_North_Africa

3. Obesity as a Risk Factor for Age-Standardized CVD Mortality

The most important behavioral risk factors for heart disease and stroke are unhealthy diet, physical inactivity, tobacco use and harmful use of alcohol. The effects of behavioral risk factors may show up in individuals as raised blood pressure, raised blood glucose, raised blood lipids, and overweight and obesity. These “intermediate risk factors” can be measured in primary care facilities and indicate an increased risk of heart attack, stroke, heart failure, and other complications.

The most used method of measuring obesity is the Body Mass Index, or BMI, which divides a person's weight (in kilograms) by their height (in meters) squared. Medically speaking, BMI scores break down as follows [1]:

- BMI under 18.5 = underweight;
- BMI 18.5 to <25 = healthy;
- BMI 25 to <30 = overweight;
- BMI 30 to <35 = obese (class 1);
- BMI 35 to <40 = obese (class 2);
- BMI 40 or higher = obese (class 3 - morbid).

BMI is not a perfect measure. It can sometimes give a “false positive” score to athletic individuals whose high BMIs are due not to excess body fat, but to excess muscle. As a result of this inaccuracy, many medical experts are switching to the waist-to-height ratio, which compares the circumference of a person's waist to their height. If the waist is more than half the height, (or more than 6/10 the height for those over 50), that person is obese. The waist-to-height ratio is considered much more accurate than BMI but is also much newer. Over time, as it is adopted by more countries.

Obesity rates vary significantly by country because of different lifestyles and diets. There is no direct correlation between the obesity rate of a country and its economic status; however, wealthier countries tend to have more resources to implement programs, campaigns, and initiatives to raise awareness and educa-

tion people about what they are consuming.

Overweight and Obesity considered in this investigation include classes (2, 3, 4). Prevalence of overweight and obesity has been reported in many studies in the GCC countries (Saudi Arabia, Bahrain, Kuwait, Oman, Qatar and the UAE). Based on the available national representative studies, the prevalence of overweight in males and females in the GCC region ranged from 28.8% to 42.4% and from 27.3% to 32.7%, respectively, while the prevalence of obesity in males ranged from 10.5% to 39.2% and in females ranged from 18.2% to 53%. In general, the prevalence of overweight and obesity is remarkably high in the GCC states and Oman reported the lowest rates of obesity within the region. In **Table 1** we provide brief information for each of the Arabian Gulf States (AGS). In the first column we have the country name, followed by the population count, population density, the CVD mortality, and the last column is the population percentage of obese people.

Among many studies, the most relevant were carried out in Saudi Arabia [8] [9] between 1990-1993 to estimate obesity. The studies concluded that obesity and overweight are increasing in KSA with an overall obesity prevalence of 35.5%. A cross-sectional national epidemiological community survey was conducted involving 2013 Bahraini subjects aged 40 - 69 [10]. The age-standardized prevalence rate among native Bahraini men and women was high. Approximately 32% of women and 25% of men were obese ($BMI \geq 30.0 \text{ kg/m}^2$). The study concluded that the prevalence of obesity among the native middle-aged and elderly Bahraini population is high. We noted that the prevalence of obesity increased as the level of education increased, which reflects the perception of obesity being a sign of affluence among the Bahraini population. The study emphasized the necessity to develop an action plan for controlling obesity and its metabolic consequences among the populations of the Arabian Gulf. A cross-sectional study from the Kuwaiti [11] reported prevalence of overweight, obesity, and metabolic syndrome in the adult Kuwaiti population were 80.4%, 47.5%, and 36.2%, respectively. Overweight and obesity rates were higher in women 81.9% and 53% compared to men 78% and 39.2%, respectively. The study concluded that the prevalence of overweight, and obesity, is alarmingly high in Kuwait and recommended urgent intervention at the community level to control obesity at a lower level. Similarly, two studies from Oman [12] [13], based on probabilistic random of 1421 adults aged ≥ 20 years. The studies concluded that Omani subjects of Arab ethnicity were at high risk of CVD. However, the prevalence of obesity was lower than the levels reported by other countries within the Arabian Gulf region. A study from Qatar [14] whose main objective was to determine the prevalence of underweight, overweight, and obesity, as measured by the body-mass index, in a representative sample of adolescents aged 12 to 17 years from the population. The study concluded that adolescents living in the State of Qatar are at high risk for overweight and obesity and stressed the need to establish a national program for the prevention and treatment of obesity and related complications. In the UAE [15] data from the cross-sectional

Table 1. Country Profile: Data for the year 2019.

Country	% GPD	Pop. Count	Pop. density	CVD mortality	% Obesity
Bahrain	4.01	1,711,057	2239	240.89	37.67
Kuwait	5.5	4,281,320	240	184.58	43.1
Oman	4.07	5,128,058	16	486.30	25.61
Qatar	2.91	2,889,284	248	337.30	35.66
KSA	5.69	34,905,942	16	332.09	37.01
UAE	4.28	9,910,892	118	325.877	30.08

Source: Worldometer.info/world-population/population-by-country.

UAE National Diabetes and Lifestyle Study (UAEDIAB), which surveyed adult expatriates living in the UAE for at least 4 years was used to estimate the prevalence of obesity in the country. In this sample, the prevalence of overweight and obesity, by BMI, were 43.0% and 32.3%, respectively. 52.4% and 56.5% of participants were at a substantially increased risk. Without comprehensive prevention and management, levels of disease will continue to increase. Increasing the risk of heart diseases

4. Data Analysis

The main interest of this paper is in modeling attenuation in CVD mortality over time and the association with obesity in the six Arabian Gulf countries. The model we use assumes a compound symmetry covariance structure that is a constant variance over time and equal positive correlation between any two successive observations from the same country. We start our modeling strategy by introducing a random slope and random intercept terms so that the proposed line mixed model is expressed as:

$$Y_{ij} = \beta_0 + b_{0i} + (\beta_1 + b_{1i})t_{ij} + e_{ij} \quad (1)$$

In Equation (1), Y_{ij} denotes the CVD mortality in the i^{th} country at the j^{th} time which we denote by t_{ij} . The random component e_{ij} is assumed to be normally distributed with mean zero and constant variance σ^2 , β_0, β_1 are respectively the fixed intercept and slope. Moreover, b_{0i} , is a random component of the intercept that has a normal distribution with zero mean and variance σ_0^2 , while b_{1i} is a random slope assumed to be normally distributed with mean zero and variance σ_1^2 . We complete the model specification by assuming that $\text{cov}(b_{0i}, b_{1i}) = \sigma_{01}$.

The proposed linear mixed model is quite flexible as it allows the introduction of “obesity” as a major risk factor in addition to other covariates and possible confounders. In our case the above model given in Equation (1) is thus written as:

$$Y_{ij} = \beta_0 + b_{0i} + (\beta_1 + b_{1i})t_{ij} + X_{ij} + e_{ij} \quad (2)$$

In Equation (2), X_{ij} denotes the population percentage of obese people in the i^{th} country at the j^{th} time.

The data analyses will be carried out using the package R (<https://cran.r-project.org/>).

5. Results

Figure 1 shows the scatter plot of CVD-mortality over the observation period. **Figure 2** shows the scatter plot of percentage of obesity in the population for the same observation period.

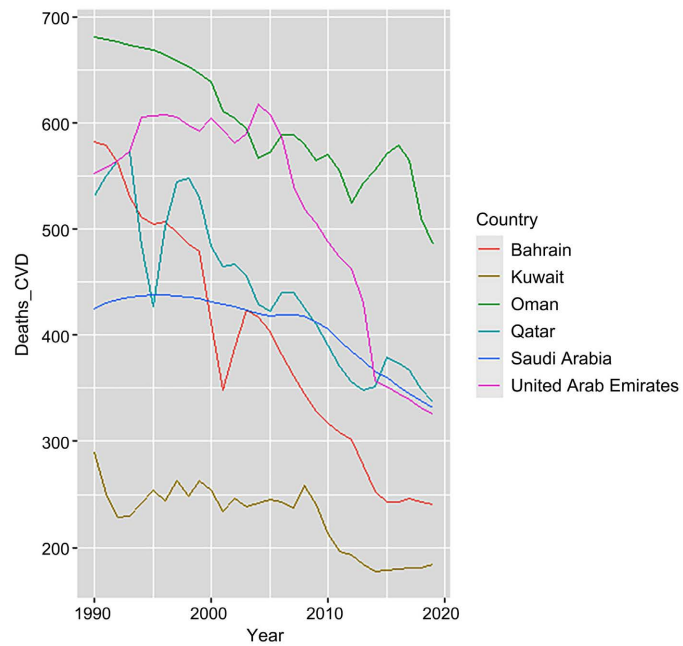


Figure 1. 30 years of CVD mortality in the six Arabian Gulf countries.

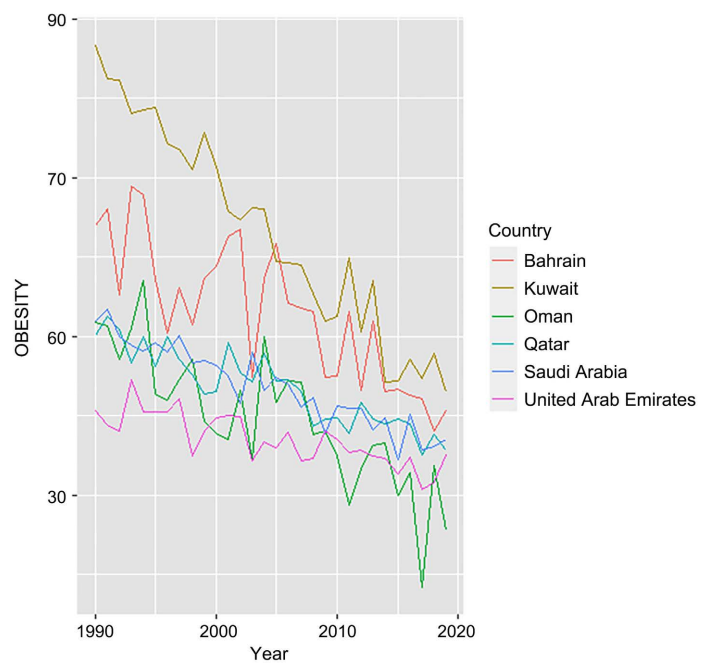


Figure 2. Percentage of obesity in the six Arabian Gulf countries.

There are common features between **Figure 1** and **Figure 2** the most notable is the steady decline of both CDV mortality and prevalence of obesity is over the observational period 1990 to 2019.

In **Table 2** we summarize the results of fitting the Linear Mixed Model (LMM) where obesity as a dependent variable. In **Table 3** we present the LMM results when CVD mortality is the dependent variable, with obesity being an added covariate. In both models we treated country as a categorical variable. We used “Bahrain” as the reference category in both models.

6. Model-Based Predictions of CVD Mortality in 2030

The prediction proceeded in two steps. In the first stage we predict the obesity level when year = 2030 based on the output in **Table 2**. In the second step we substitute the result obtained from step one together with year = 2030 and incorporate these values into the model using the output of **Table 3**. In **Table 4** we use the model-based predictions and compare them to the levels of obesity and CVD-mortality to calculate the rate of change as:

Change = (model-based predicted value – value in 2019)/value in 2019 × 100. Negative numbers means a drop in the predicted levels in the year 2030.

Table 2. The linear mixed effects model with Obesity being the dependent and year & country are fixed covariates.

Parameter	Value	Std. Error	p-value
(Intercept)	942.5555	68.46458	0.0000
Year	-0.4477	0.03415	0.0000
Kuwait	-1.4760	1.02404	0.1516
Oman	-6.3810	1.02404	0.0000
Qatar	-4.7507	1.02404	0.0000
Saudi Arabia	-2.2527	1.02404	0.0294
UAE	-7.7697	1.02404	0.0000

Table 3. The linear mixed effects model with CVD-Deaths being the dependent and year, country, and country level obesity are fixed covariates.

Parameter	Value	SE	p-value
(Intercept)	11836.108	1021.07	0.0000
Year	-5.772	0.4968	0.0000
OBESITY	2.749	0.7833	0.0006
Kuwait	-159.292	10.6133	0.0000
Oman	228.471	11.6742	0.0000
Qatar	66.430	11.1871	0.0000
KSA	22.898	10.6967	0.0340
UAE	148.061	12.1796	0.0000

Table 4. Model-based predictions of obesity rate and age standardized CVD mortality per 100,000. The bracketed number is the predicted rate of change in the predictions relative to 2019.

Country name	Predicted obesity in 2030	Predicted CVD deaths in 2030
Bahrain	33.72 (−10%)	211.64 (−12%)
Kuwait	32.25 (−25%)	207.60 (−12%)
Oman	27.34 (−7%)	194.11 (−60%)
Qatar	28.97 (−19%)	198.59 (−41%)
KSA	31.47 (−15%)	205.46 (−38%)
UAE	25.95 (−14%)	190.28 (−40%)

The predictions in **Table 4** may be used by public health officials for disease management and cost allocations in order to establish policies to control future CVD mortality in each of the six countries.

7. Discussion

As far as we know, no similar studies focusing on predicting CVD mortality in the Arabian Gulf region have been published. The main focus of our research is to build a fixed effects model to analyze the association between obesity and CVD mortality in the Arabian Gulf countries between 1990 and 2019. The major strength of our study is that it is based on all available data sources that could be accessed for the six countries of the Arabian that are geographically and culturally homogeneous. Another major strength is the availability of data sources that can be accessed by other researchers to validate our results [16].

Our study revealed that between 1990 and 2019, age standardized CVD is strongly associated with obesity or high BMI. However, other meta-analyses studies examining BMI change showed that increases in BMI demonstrated lower mortality risks compared with decreases in BMI. The apparent contradiction is that, unlike the present study, estimates included in the meta-analyses were not standardized for age. Overweight BMI classification or a higher BMI value may be protective for all-cause mortality, relative to normal BMI, in older adults. These findings demonstrate the potential need for age-specific BMI cut-points in older adults and further studies [16].

8. Study Limitations

Our study is not without limitations. First our study is ecological, that is the demonstrated association is reported at the country level, not at the individual subject level. To avoid committing what is known as the “ecological fallacy” no attempt is made to extend the results from the country level to an individual subject. Another limitation is that the study focused on one risk factor namely, obesity, and did not include other potential covariates such as age, or other comorbid conditions such as diabetes, or elevated blood pressure levels and their joint effect on CVD mortality. Such data were not available in a longitudinal

structure like the data we have analyzed in this study.

9. Conclusion

Based on the findings regarding mortality trends, it is apparent that nearly all countries have experienced a significant declining trend from 1990 to 2019 with an annual reduction in CVD mortality of 33.8 per 100,000 individuals. However, a study in Central Asia (which includes low- and middle-income countries) indicates that the trend of CVD mortality has increased during the past two decades. The authors concluded that this increment might be the result of insufficient preventive care, lack of awareness about the disease signs and symptoms, decreased physical activity, raised blood pressure, and underutilization of health care services [16]. Overall, advances in treatment, improving the level of care, and controlling the risk factors of death in CVD patients (such as smoking, hypertension, and overweight) are the most important reasons for the reduction in the mortality rate of this disease. The prevalence of high BMI (overweight and obesity), and CVD mortality decreased dramatically by 2019 compared to 1990 in the Arabian Gulf states. The predictive model showed that a one percent increase in the prevalence of obesity is associated with an average increase of 2.7 in CVD mortality per 100,000.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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