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Mathematical Regression Models for Analyzing and Forecasting Diabetes prevalence in Oman

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Abstract

Diabetes mellitus has a significant impact on people's lives and drugs financial burden. On the other hand, diabetes also has substantial economic effects on countries and national health systems. Most countries spend between 5% and 20% of their total health expenditures on diabetes. This is due to the increased use of health services, lack of productivity, and the long-term demand for complications associated with diabetes, such as kidney failure, blindness, and heart problems. This is why diabetes poses a significant challenge to healthcare systems and hinders sustainable economic development. This work is concerned with proposing mathematical models characterized by accuracy and ease in predicting the number of diabetics type 2 in the Sultanate of Oman. By analyzing the proposed mathematical models of the current work (1, 2, and 3), it was found that the proposed mathematical model in Equation 6 can accurately predict the number of diabetics in Oman up to 2050. In order to test the model's accuracy and validity, we revised it with actual data. The results prove the accuracy of the proposed model in predicting future data of 99%. Lastly, several recommendations were recorded that could help to reduce the prevalence of diabetes type 2 in Oman.

Keywords: Chronic diseases; forecasting models; linear regression; soft computing; health-care.

1. Introduction

The most prevalent health problems, such as chronic diseases, especially cancer, diabetes, and cardiovascular diseases, are among the most significant challenges to modern societies regarding the high number of deaths and their economic cost (Yousif et al., 2021). Chronic illness means persistent or recurrent disease, usually affecting a person for three months or more and can be prevented and reduced risk by following medical advice (CDC, 2015). The term chronic diseases apply to conditions that can be treated but may take a long time. Patients with chronic diseases need intensive care in health care clinics to teach patients to practice rehabilitation methods. Patients with chronic diseases need to visit the doctor periodically for treatments and medical tests, which causes life-long discomfort. Therefore, health care homes offer different courses to reduce the effects of symptoms caused by chronic diseases, both healthily and psychologically (Alwan, 2014; Abusham & Zaabi, 2021).

Diabetes defines as a chronic disease that occurs when the body cannot use or produce enough insulin. It can be identified by testing the level of glucose in the blood. The World Health Organization (WHO) reports utilized data of 4.4 million adults in 200 countries in the world for survey age-adjusted diabetes prevalence. Adult population (20-79 years) in 2015 is 387 million, and it is expected to reach 635 million in 2040. The sum of patients with diabetes in 2015 is about 35.4 million. And it is expected to be increased to 72.1 million in 2040. The International Diabetes Federation (IDF) reports that diabetes will be the healthcare challenges in the 21st century as shown in Figure 1. The total losses gross domestic product (GDP) worldwide in the period 2011-2030 is 1.7 trillion US$. The highest rate was observed in high-income countries US$ 900 billion (WHO, 2016). An estimated average cost of USD1,622 to USD2,886 per person with diabetes need for treating and managing the disease in 2015 as shown in Figure 2.

Diabetes affects individuals, families, businesses, and society as a whole. Among the world’s 10 highest for the prevalence of diabetes, there are six Arabic countries named Egypt, United Arab Emirates (UAE), Bahrain, Kuwait, Oman and the Saudi Arabia. The annual mortality rate per 100,000 people from diabetes mellitus in Oman has increased by 21.3% since 1990, an average of 0.9% a year (IDF, 2019). The World Health Organization's current reports indicate that 60% of the number of deaths in the Arab Gulf countries results from chronic diseases, making it a large and growing problem and finding solutions quickly (IDF, 2020). Figure 3 displays the number of deaths due to non-communicable diseases in Gulf Cooperation Council in 2016. Figure 4 presents the comparison of prevalence of diabetes in Gulf Cooperation Council in 2015 and the predicted rate in 2040. The figure shows that Oman has the lowest prevalence rate of 9.9% and will be reached 17.2 % in 2040. While LAS has the highest prevalence rate of 17.6 % and will be reached 22.9 % in 2040 Statista, (2021).

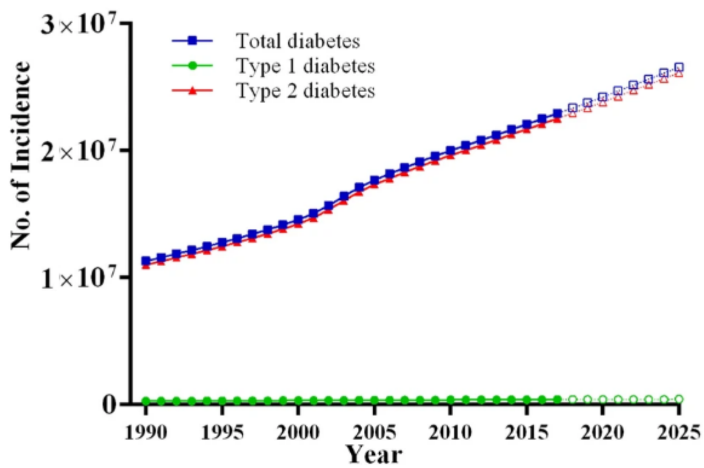


Figure 1. Global burden of diabetes mellitus from 1990 to 2025 (https://www.nature.com/articles/s41598-020-71908-9)

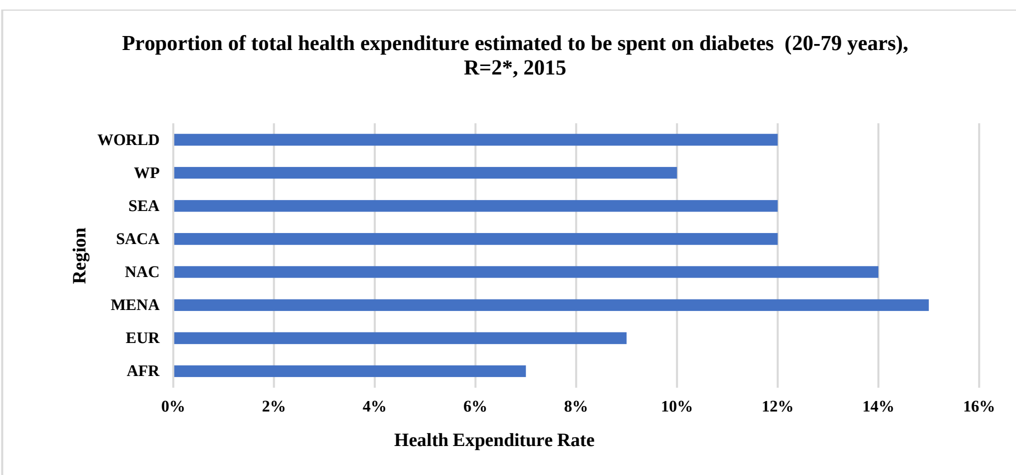


Figure 2. Proportion of total health expenditure estimated to be spent on diabetes (20-79 years), R=2*, 2015. Source IDF- atlas-2015. Africa (AFR), Europe (EUR), Middle East and North Africa (MENA), North America and Caribbean (NAC), South and Central America. (SACA), South-East Asia (SEA), and the Western Pacific (WP)

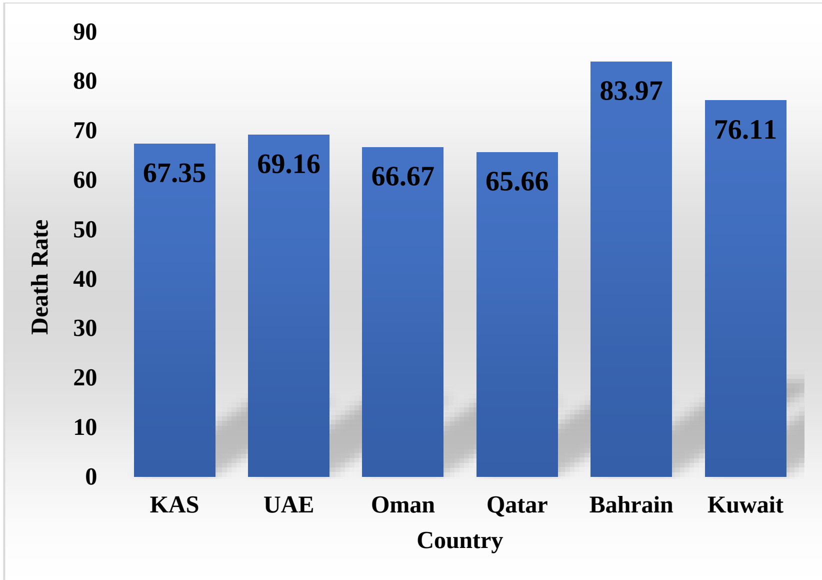
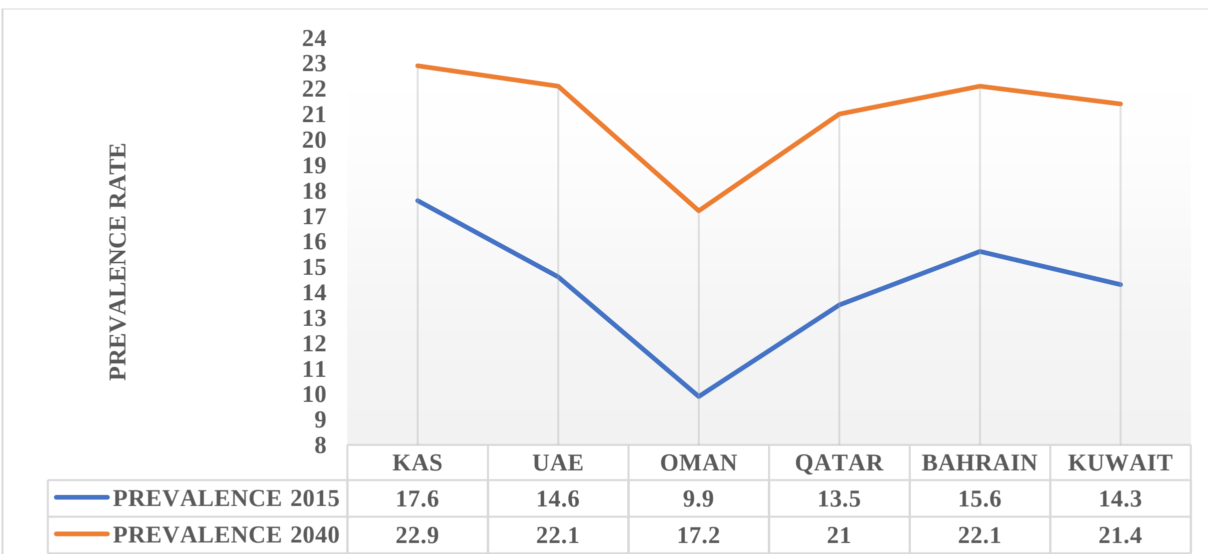


Figure 3. Death percentage causes. Non-communicable diseases in Gulf Cooperation Council in 2016, Source https://www.statista.com/statistics/1029705/gcc-share-of-total-deaths-due-to-ncds-country/



	KAS	UAE	OMAN	QATAR	BAHRAIN	KUWAIT
PREVALENCE 2015	17.6	14.6	9.9	13.5	15.6	14.3
PREVALENCE 2040	22.9	22.1	17.2	21	22.1	21.4

Figure 4. the comparison of prevalence of diabetes in Gulf Cooperation Council in 2015 and 2040 (Al-Lawati, 2014)

2. Diabetes Status in Oman

The number of People in Oman are about 4,992,364 in 2019. And the annual mortality rate is 2.44 per 1000 people from diabetes mellitus in Oman in 2018. According to IDF Diabetes Atlas 2019 (IDF, 2019), The number of adults in Oman aged 20 t0 79 is 291.800. The prevalence rate of diabetes in adults is 8%, with a low percentage of total health expenditure of 6.8%. Hence the undiagnosed and untreated case of diabetes can cause complications diseases comprising kidney, heart stroke, blindness, nerve damage and amputation that have a cumulative effect on a patient's health and finances. The total number of diabetes cases in 2020 is 149.195 (Male 80.490, Female 69.779). Figure 4 shows the annual mortality rate per 1000 people from diabetes mellitus in Oman in the period 2008-2018. Figure 4 illustrates that the rate of death related to diabetes is increased over time. Therefore, the government must to take series actions and do more research to specify the factors affecting the prevalence of diabetes.

AL-LAWATI (AL-LAWATI et al., 2015) investigated the prevalence and incidence rate of type 2 diabetes mellitus in Oman over the past two decades. They conducted three regional surveys between 1991 and 2010 among Omani aged greater than 19 years. They implement the Linear regression method to discover trends and forecasts for diabetes in 2050. The results show that the prevalence rate of T2DM ranges between 10.4% and 21.1%, and it will increase in 2050 to reach 174%. Siba (Siba et al., 2006) conducted a cross-sectional interviewer-administered survey of 7179 people aged 20 years in Oman for blood and anthropomorphic tests. The result shows that many of the Omani population have diabetes, obesity, hypertension, and high cholesterol. The prevalence of diabetes in Muscat is 17.7% and 10.5% in rural areas. Al-Rashdi (Al-Rashdi & Al-Mawali, 2021) extracted 2000 diabetes patient records between 2000 and 2017. For the sake of investigating diabetic retinopathy (DR), Non-proliferatice diabetic retinopathy (NPDR), and Proliferative diabetic retinopathy (PDR). The study deployed a retrospective cross-sectional method to select only the proper 616 records of Omani patients, including both genders with different age groups. The results show 60% were females with DR, 62.3 % with NPDR, and 5% with PDR. Besides, there no significant relationship between acquiring DR and the gender of the patient. Awad (Awad et al., 2020) proposed an age-structured mathematical model to analyze and forecast type 2 diabetes mellitus risk factors and their cost in Oman between 1990 and 2050. The results show an increased prevalence rate from 15.2% in 2020 to 23.8% in 2050. Also, it showed a high health expenditure for Type 2 diabetes mellitus with 28.8% and the obesity cases with 71.4%.

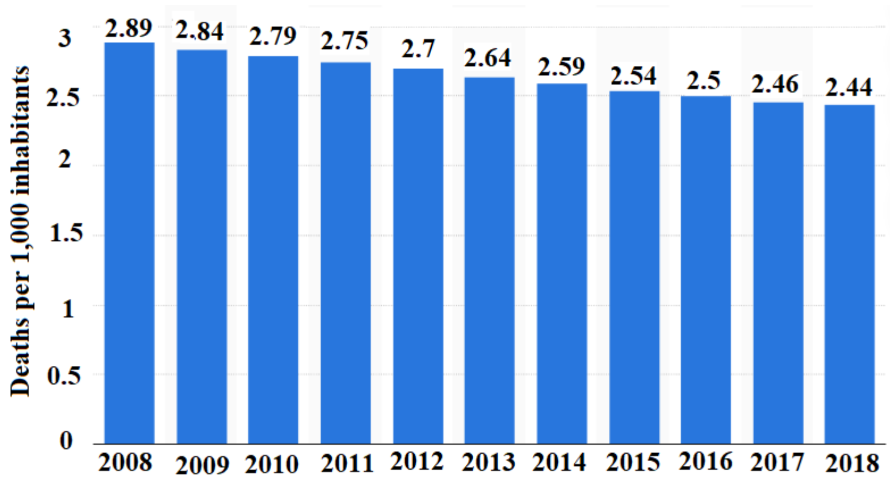


Figure 4. the annual mortality rate per 1000 people from diabetes mellitus in Oman2008-2018 (https://www.statista.com/statistics/580891/death-rate-in-oman/)

3. Forecasting Models Techniques

Regression methods focus on extrapolating data, which describes annual changes in data. However, predicting such differences in diabetes, for example, is necessary for the decision-maker and medical institutions to take the measures required to control the disease and its spread. Linear regression attempts to model the relationship between two variables by fitting a linear equation to the data under experiment (Hassan et al., 2009). The first variable is considered the primary variable (independent), while the other is regarded as the dependent variable. For example, we want to estimate the relationship of diabetes to overweight using a linear regression model.

The formula for a simple linear regression is:

$$Y = B_0 + B_1 x + e \quad (1)$$

where y is the predicted value of the dependent variable (Y) and (x) is the value of the independent variable. B_0 is the intercept, and B_1 is the regression coefficient. And e is the error (differences between the experimental and estimated data).

Two main factors are used to validate the predicated results including the coefficient of determine (R-squared) and Adjusted R-squared (Yousif, 2011). R-squared (R^2) is a statistical pattern representing how the predicted data fits the experimental data in a regression model, which is computed as in equation 2. The preferred regression model that gets a value of R^2 closer to 1 (Yousif, 2015).

$$R^2 = 1 - \frac{(\sum_i (y_i - f_i)^2}{(\sum_i (y_i - f\bar{y}_i)^2} \quad (2)$$

where yi is the actual output data, and fi is the expected (predicted) data, and ȳi is the arithmetic mean value of the real data targets.

Adjusted R-squared determines how many data sets befall within the regression line, which is computer as in equation 3.

$$R^2_{adj} = 1 - \left[\frac{(1-R^2)(n-1)}{n-k-1}\right] \quad (3)$$

where n is the number of data sets, and k is the number of independent variables in the regression model.

4. Results and Discussions

The experimental data that we used is presented in Figure 5. We notice a steady increase in the number of people with diabetes over the years. Then different linear and non-linear regression models were deployed for examine the expected number of diabetes prevalence in the next 30 years. This will help to accurately calculate the health expenses and the required equipment, medical personnel, including number of parents and nurses, and the volume of shipments of needed medicines.

The first model is implemented using a linear regression model, which is achieved a R-squared equal to (0.7934) and Adjusted R^2 equal to0.7851. This model is computed as in equation 4. X is the number of diabetes patient on yearly based.

Model-1 = -3686+1.86398*Year (4)

Figure 6 shows the regression of number of patients based on the model in equation 4. Through Figure 6, we notice that the predictive data line fits the actual data, which indicates that the used equation can accurately and efficiently simulate future data for predicting the number of diabetic patients.

The second model is deployed based on a polynomial regression model of third degree, which is obtained a R-squared equal to (0.7089). This model is computed as in equation 5. X is the number of diabetes patient on yearly based.

Model-2 = $0.0068x^3 - 0.1591x^2 + 1.5842x + 30$ (5)

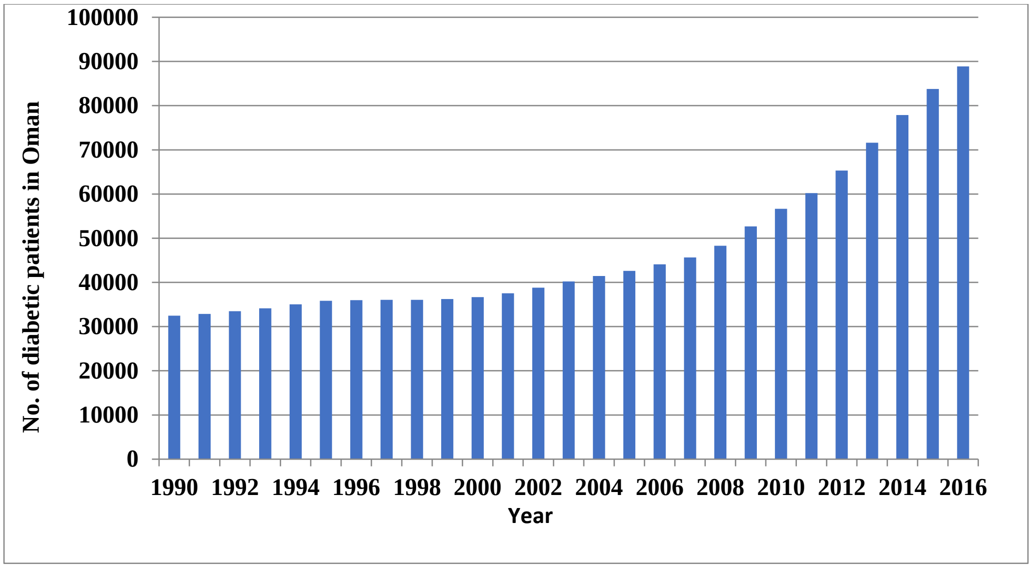


Figure 5. No. of patient with Diabetes in Oman 2000-2016 (MOH-Oman)

Figure 7 shows the regression of number of patients based on the model in equation 5. Through Figure 7, we notice that the predictive data line (blue color) fits the actual data with (red color), which indicates that the mathematical model based on equation 5. It can accurately and efficiently simulate future data for predicting the number of diabetic patients with 99% based on the value of R-squared of (0.9983).

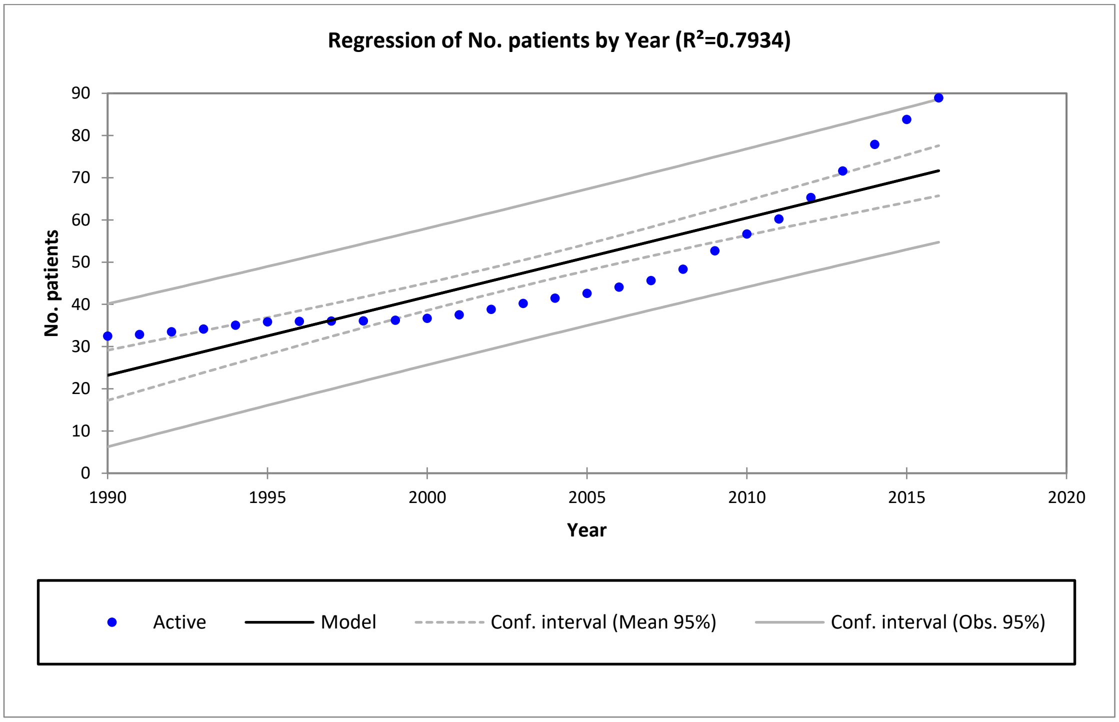


Figure 6. the forecasting number of patients based on the model in equation 4.

The third model is deployed based on non-linear polynomial regression model, which is obtained a R-squared equal to (0.9778). This model is computed as in equation 6. X is the number of diabetes patient on yearly based.

Model-3 = 514940-515.99368*Year+0.12927*Year^2 (6)

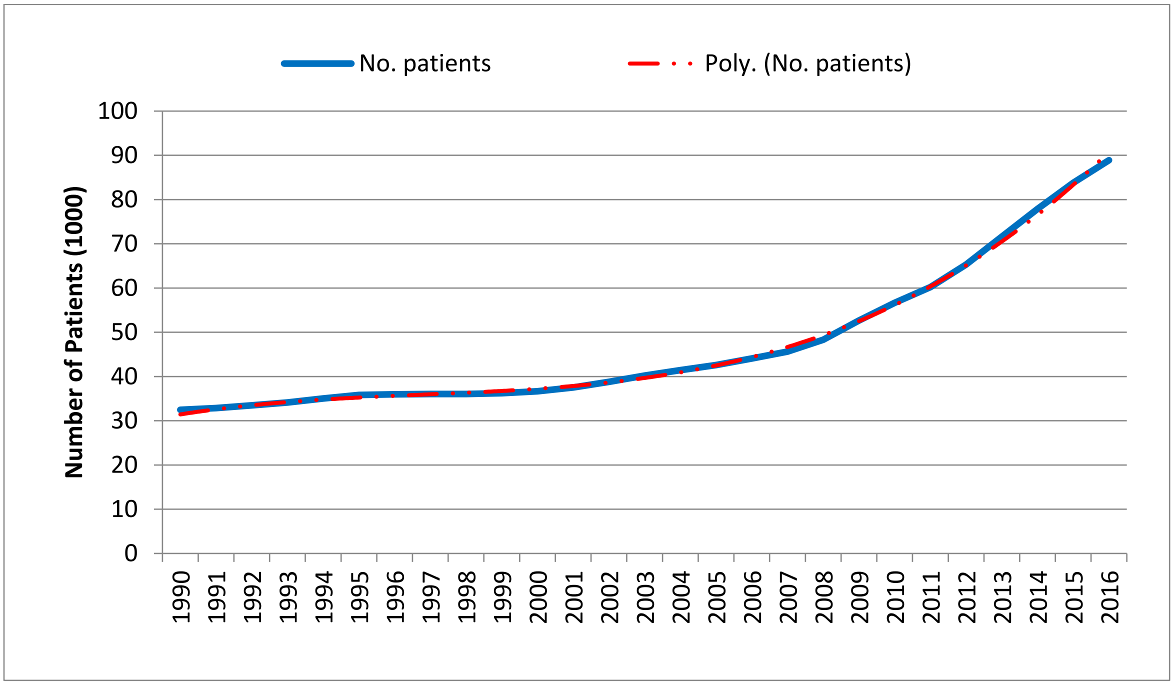


Figure 7. the forecasting number of patients based on the model in equation 5.

Figure 8 shows the regression of number of patients based on the model in equation 6. Through Figure 8, we notice that the predictive data line (blue color) fits the actual data with (red color), based on the mathematical model in equation 6. It accurately and efficiently simulates future data for predicting the number of diabetic patients with 97% based on the value of R-squared of (0.9778).

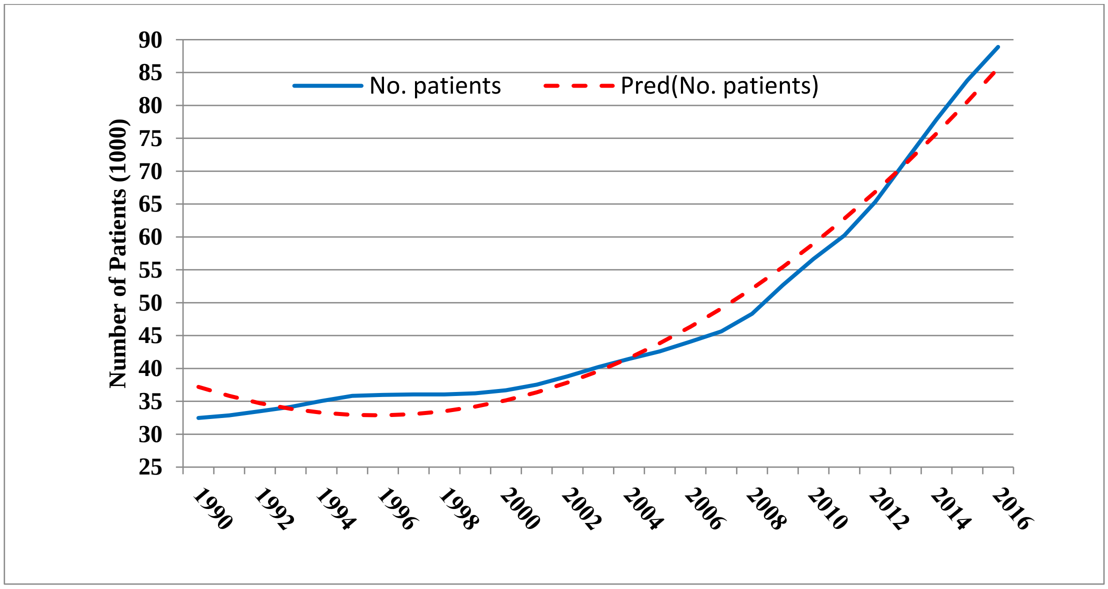


Figure 8. the forecasting number of patients based on the model in equation 6.

By analyzing the mathematical models, a mathematical model could predict the number of diabetics in Oman up to 2050. For the sake of testing the accuracy and validity of the model, we cross-checked it with actual data. Results proved the accuracy of the proposed model in predicting future data by 99%, as shown in Figure 9.

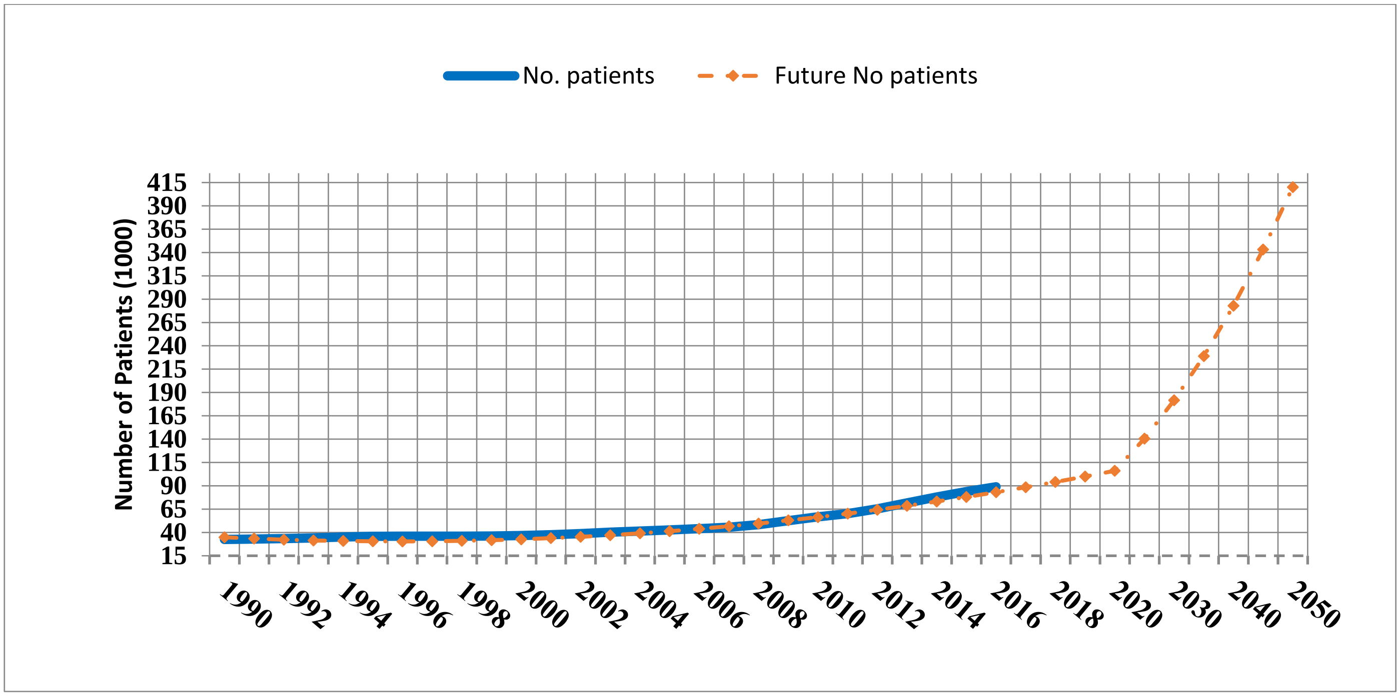


Figure 9. the proposed mathematical model predicates the number of diabetics in Oman up to 2050

5. Conclusion & recommendations

Diabetes has a significant impact on people's lives and the financial burden of medication. On the other hand, diabetes has substantial economic effects on countries and national health systems. Most countries spend between 5% and 20% of their total health expenditures on diabetes. In addition to the significant physical burden that diabetes places on individuals and their families due to the cost of insulin and other essential drugs, diabetes also has substantial economic impacts on countries and national health systems. This is due to the increased use of health services, lack of productivity, and the long-term demand for complications associated with diabetes, such as kidney failure, blindness, and heart problems. This is why diabetes poses a significant challenge to healthcare systems and hinders sustainable economic development.

This work is concerned with proposing mathematical models characterized by accuracy and ease in predicting the number of diabetics in the Sultanate of Oman.

Review and analysis of previous research and studies showed that there is a forced increase in the number of diabetic patients due to several reasons, including the following:

- Lack of health awareness of the disease and its risks, as most patients do not see a doctor until after infection or symptoms appear.
- Lack of interest in performing exercise and walking for specific periods during the week.
- Lack of interest in knowing or following up the sick family history and taking the necessary precautions.
- Lack of attention to the quality of healthy foods suitable for the body.
- Exercising harmful activities to the body, such as smoking, is a catalyst for increasing diabetes.

By analyzing the mathematical models of the current work (1, 2, and 3), the proposed mathematical model in Equation 6 can predict the number of diabetics in Oman up to 2050. In order to test the model's accuracy and validity, we revised it with actual data. The results prove the accuracy of the proposed model in predicting future data of 99%.

Among the recommendations for current work:

a) The results of the current work show that there is an urgent need for more community education to diagnose and manage all types of diabetes efficiently. The social robot could be used in educating the diabetes patients (Yousif, 2021).

b) Interest in knowing and following up the family's history accurately and continuously. Early diagnosis of type 2 diabetes can prevent or delay the long-term health complications of affected people.

c) Encouraging lifestyle changes that slow the rise of type 2 diabetes, for example, exercise regularly. This reduces the risk of obesity, which contributes to increasing the number of type 2 diabetes.

d) Promoting the necessary behavioral change to prevent disease through awareness of the dangers of smoking is a catalyst in increasing diabetes.

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