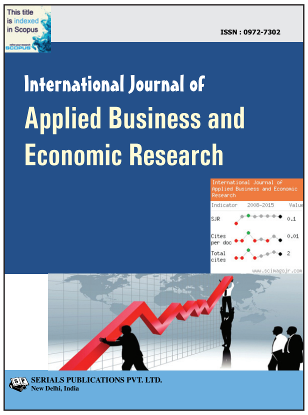

International Journal of Applied Business and Economic Research

ISSN : 0972-7302

available at http: www.serialsjournals.com

Volume 15 • Number 22 • 2017

Operations Research at the Service of Healthcare Decisions Case-Study from Iraq

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ABSTRACT

The mounting importance of operations research (O.R.) in the healthcare sector has become a landmark in decision-making strategy. O.R. can offer tools and methodologies can be used in analyzing the most difficult problems facing decision makers. One of the main areas that O.R. practice has outstanding contribution is in the field of healthcare decisions.

It is mandatory to implement procedures that optimize the usefulness of data collected even when the data is scanty and oblique. This research presents a case study of analyzing the relationship between the diabetic people with a genetic factor (family history) and the level of sugar in blood and urine. Modeling tools were applied to define the existing relationship. Data of more than 600 patients were collected from Baghdad – Iraq hospitals for the study and analyzed using the probability techniques and hypothesis testing instruments. The use of the statistical tools allowed us to identify a significant relationship between the family history and diabetes in our collected sample. A model was formulated to estimate the severity of risk being diabetes with regards to the Probability that an individual selected from the population has diabetes.

Keywords: Operation Research, healthcare, decision-making, diabetic, family history, modeling, statistical tools.

1. INTRODUCTION

No science has ever born on a specific day. Operations research is no exception. Its roots are as early 1885 when Frederick W. Taylor highlighted on the scientific analysis of production methods, that the real start took place. Taylor stressed the application of scientific study on the methods of production was the beginning point. Taylor led experiments in connection with a simple shovel. He aimed to find that weight load of material moved by shovel which would result in a maximum of material transferred with a minimum of effort.(Sharma S.C. 2006).

In 1917, A.K. Erlang, a Danish mathematician, issued his work on the problem of overcrowding of telephone traffic. This work was accepted later by the British Post Office as the basis for calculating circuit facilities (Saul I. Gass, Arjang A. Assad Feb. 2007). During the 1930s, H.C. Levinston applied scientific analysis to the problem of merchandising by studying the customers buying habits in response to advertising method with the relation to the environment of the sold item type. (Hira D.S., 2008).

During World War II, the military organization in England called on a team of scientists to study the strategic and tactical issues of air and land defence. Several of these problems have executive nature. The aim was to find out the most efficient military resources allocation method, and how to allocate the activities within each operation. (Ramamurthy P. Sept 2010)

Immediately after the world war, the success of military operations research teams attracted the attention of industrial managers who were seeking solutions to their problems.

Todays, most of the organizations around the world has specialists applying operations research, and the use of operations research in government sectors has spread out from military sector to a wide variety of departments at all levels. The growth of operations research has not limited to the U.S.A. and U.K.; it has reached many countries of the world. (P N Mishra & S Jaisankar 2007)

In Britan, the critical economic situation required a massive increase in the efficiency of production and formation of new markets. The case in U.S.A. was not the same as in Britan as most of the OR workers remained in army sector. In 1950, the OR Society of America (ORSA) was formed to increase the impact of OR.

Today, the influence of operation research can be felt in many areas which are exposed to the ever-increasing number of educational institutes offering this topic.

Operations research (OR) applies advanced statistical methods and mathematical modeling to solve an array of business and structural problems, as well as improve decision-making. (Ravi Ravindran A. 2008). When the firm settings grow more complex, businesses and government parties rely on analysis rather based mainly on management intuition. During and after World War II, operations research has helped many large institutions and government bodies in making better decisions, boost performance and reduce risk (Alireza Asadpoor 2013). Organizations usually collect significant amounts of data but may feel stunned by the size and limited time or proficiency to analyze these data, transforming them into useful information on which to base decisions (Meredith Zozus Jul 2017). To make the most of the organization's data, they may involve O.R. that uses mathematical and statistical techniques, such as linear programming (LP) and nonlinear programming, to support organizations decisions (Marlow W. H. 2013).

Operations Research for Health Care (ORHC) is one of the critical topics in which emphasis on the involvement of operations research in health and healthcare activities. O.R. provides a broad range of methodologies that can help healthcare systems to improve their operations significantly (Margaret L. 2006).

There are at least three reasons why O.R. is related to health. (1) To improve program outcomes about medical care or prevention, (2) to assess the feasibility of new strategies or interventions in specific settings or populations, (3) and we have to promote policy change. (Priyan S. 2017)

Healthcare sector has become one of the largest industries in many countries with regards to the amount of revenue and size of employment. Healthcare may compromise hospitals, medical devices, clinical trials, outsourcing, telemedicine, medical tourism, health insurance and medical equipment. (Anne-Emanuelle Birn, Yogan Pillay, Timothy H. Holtz, 2017)

The development of operations research in the health services in the UK may be split into three periods. The first period has started from 1984 until approximately 1964. There were some studies of an O.R. nature many of which were supported by Nuffield Provincial Hospitals Trust (N.P.H.T), but there was no clear lead from the ministry of health. The next theme in O.R. was the work of Norman Bailey on Hospital Appointment Systems. Nuffield P.H.T had supported this work as part of studies of the design of hospitals (Nuffield Provincials Trusts. Jan. 1955). Also, published a series of papers in statistical journals (Bailey, N.T.J. 1952), (Bailey, N.T.J. 1955), as well as the operations, research Quarterly (Bailey, N.T.J. 1957) and Lancet(Bailey, N.T.J. & Welch 1952). Towards the end of 1950's in U.S.A. Charles Flagle established O.R. at John Hopkins Hospitals. He published some general papers on the use of O.R. in Hospitals (Flagle, C.D.1960, Flagle C.D.,1962). A very different stream of work was begun by Revans at Manchester on the relationship of communications, Moral and Efficiency in hospitals which were combined in his book (Revans, R.W. 1964)).

The second period of developing of O.R. in health service has started about 1964. This may well have been stimulated by the conference to discuss the O.R. which was sponsored by N.P.H.T and was reported in 1962(Nuffield Provincials Hospitals Trusts. Jan. 1962).On the whole, this period tackled tactical problems such as the work of Bailey on outpatients appointments, and work on the scheduling of inpatients. Other studies during this time have included the analysis of factors which affect patient stay by Aldred (Aldred, K. 1969) which could have fundamental implications for the allocation of resources in the health service. This period was concerned with making the most efficient use of existing resources such as the balance of the operating theatre timetable and staff tasks.

The third period started in 1970 when the DHSS in the UK established its own O.R. group headed by A.G. MacDonald. The primary focus of this period was on the location and size of new hospitals workforce levels and the creation of new resources for health service sector.

2. LITERATURE REVIEW

Diabetes mellitus (DM), commonly referred to as diabetes is a group of metabolic illness that either struck patients during the early years of growth (Juvenile diabetes) or later in life or is called as maturity-onset diabetes. It is considered as the body's incapability to effectively adjust the sugar stability which leads to severe problems such as hyperglycaemia, obesity, neuropathy, nephropathy, retinopathy, cardiopathy, osteoporosis and unconsciousness leading to death. Pancreatic damage subsequent will cause the dysfunction of and cells causes disordered glucose homeostasis. In diabetes, the regulation of glucose levels by insulin is defective, either due to inadequate insulin creation which is called as Insulin Dependent Diabetes Mellitus (IDDM) or due to insulin resistance that is termed as Non-Insulin Dependent Diabetes Mellitus (NIDDM). (Wikipedia)

Diabetes is becoming a significant public health problem that is approaching prevalent proportions universally. Worldwide, the level of this chronic diseases is increasing to a frightening degree. Nearly 18 million people die every year from cardiac disease, for which diabetes and hypertension are major influencing reasons. Currently, more than 1.7 billion adults worldwide are overweight, and 312 million of them are overweighted. Furthermore, at least 155 million children worldwide are obese. (Diabetes Atlas. 2006.)

Practically 80% of the total adult diabetics in the world are in developing countries with the highest rates are in the Eastern Mediterranean countries. The most frequently affected are in the middle, productive years of their lives, aged between 35 and 64. On the contrary, in developed countries, most people with diabetes are those who are above the age of retirement.

Estimation of an individual with Diabetes cause medical may cost two to five times higher than those without diabetes. According to the World Health Organization estimates, nearly 15% of health budgets per year are spent on diabetes-related illnesses. The direct healthcare costs of diabetes worldwide per year, for individuals in age groups between 20–79, are anticipated to be as much as 286 billion. (Tabish SA. 2007)

It is estimated that 366 million people have diabetes spread all over the world, with half of them unaware they have this disease. Six countries from the Middle East (Kuwait, Lebanon, Qatar, Saudi Arabia, Bahrain, and the United Arab Emirates) are among the ten countries with the highest prevalence of diabetes. Nearly 20.5 million people in the 20 Arab states have diabetes with another 13.7 million are in the prediabetes stage. In Arab countries almost (73.4%) of people with diabetes are at the age of under 60 years and therefore, they are in their most productive years. (International Diabetes Federation; 2011)

One of the previous studies related to diabetes mellitus was a survey undertaken to estimate the prevalence of D.M. in Iraq. The study managed to estimate blood-sugar sample of a village population 15+ years after glucose-loading. The study found that was 4.8% of the sample were suffering from diabetics symptoms. Most of diabetes in the study had symptoms referable to their diabetic state. (Fouad M. AL-Kasab, Ahmed M B ALKafaji, and Sami H Medbigh. 1979).

Mansour A, Wanoose HL, Hani I, Abed-Alzahrea A, & Wanoose HL. 2007, curred out a survey on 3176 in Iraq. They found that the percentage of the undiagnosed diabetes prevalence was %2.14. The rate of diabetes formed 5.29%. The overall prevalence of new and established diabetes was 7.43%. This study provided the first baseline data on diabetes mellitus in Basrah, Iraq. The prevalence has pointed out of the severity of diabetes in the Middle East. (Mansour A, Hani I, Abed-Alzahrea A, & Wanoose HL. 2007)

Abbas Ali Mansour 2017, conducted a research concluded that 90% of diabetic patients in Iraq were suffering from hypertension. Half of diabetic patients were achieving target blood pressure level.

Mansour AA,& Ajeel NA.2013 carried out a survey included 1079 patients, of whom 25% were smokers. The percentage of prevalence of symptomatic cardiovascular disease and hypertension was 16%, and 44.3% respectively. The study found that increased frequency of cardiovascular disease and its modifiable risk factors among adults with type 2 diabetes mellitus. This finding demanded urgent work to modify these risk factors in a population-based setting.

Mansour AA1, Al-Jazairi MI. 2007. Performed a study aimed to recognise cut-offs for BMI, and upper-body adiposity would be consistent with overweight and central adiposity. The findings showed that, in Iraqi adults, WHpR has a significant association with type 2 diabetes mellitus and WHtR for hypertension.

Mansour A, Al-Maliky AA, Kasem B, Jabar A, Mosbeh KA. December 2013, stressed that six countries of the top ten with the highest prevalence of diabetes mellitus in the world are in the area of Middle East.

The goal of this paper was to evaluate the prevalence rate of diabetes in Basrah, Southern Iraq. The study estimated the prevalence of diabetes in Basrah, Iraq is 20%, which it is significantly high. The epidemic of diabetes will result in draining on the financial resources of healthcare systems.

Bennet et. al., (May 2011) reveals a high prevalence of type two diabetics, independently of the country of origin (Iraq or Sweden), Diabetes was also found to affect 21.9% of Iraqis living in Sweden in 2010. That research's sample includes ages people between 45 to 65 years among 96 people with OGTT used as a tool for diagnosis.

A study by Ahmad Al-Windi et. al., March 2011, aimed to estimate the rate of prevalence and risk factors of self-reported diabetes mellitus, uncovered diabetes and pre-diabetes among a working sample. The research performed a survey by distributing 777 questionnaires on nine randomly selected areas in Sulaimani- north of Iraq. In conclusion, age and obesity were significantly and independently related to having undiagnosed diabetes and IFG.

3. IRAQ DIABETES CASE STUDY

Iraq is considered as one of the countries with the frightening proportion of debates. The prevalence of diabetes in Iraq increased from 5% in 1978 to 19.7% in 2012. (Abbas Ali Mansour. March 2015). In December 2011, the International Diabetes Federation (IDF) reported that Iraq is ranked as having a medium level of prevalence rate (9.3%) of diabetes in the Middle East based on surveys from 2006-2007(Boutayeb A. et. al., 2012). Data on diabetes in Iraq are scanty and anecdotal. (Abbas Ali Mansour. March 2015)

The gravity of the diabetes disease in Iraq has led the researcher to study this case. A survey is carried out in Bagdad the capital of Iraq included more than 600 diabetic patients from some hospitals located in Baghdad area. These patients were nearly evenly distributed between males and females. Questions relating to social, physical and medical aspects of the patients were asked and recorded. In particular, these also included the past family history. The present paper explores the genetic influences (family History) that operate on diabetic patients. Observations on the patients include sugar levels in the urine and blood. The standard classification of 0, 1, 2, 3 and 4 levels for urine is followed. Since the patients are known people with diabetes confirmed by sugar level in blood, 0 level in urine may mean that the disease has not yet manifested itself in urine. The measuring tools that used in the literature are the Michigan Neuropathy Screening Instrument questionnaire (MNSIq) and Physical Assessment (MNSI –2010). Levels 1 to 4 in this study denotes to Symptom assessment (score) for fasting and Non-fasting blood glucose test as follows: (How Blood Sugar Affects Your Body, published by WebMD.)

Fasting blood glucose values:

0. Disease has not yet manifested itself in urine
1. Low – less than 70mg/dL
2. Normal - between 70 to 99mg/dL
3. Pre-diabetic – between 100 – 125mg/dL
4. Diabetic – greater than 126mg/dL

Non-fasting blood glucose values:

0. Disease has not yet manifested itself in urine
1. Low – less than 70mg/dL
2. Normal - between 70 to 139mg/dL
3. Pre-diabetic – between 140 – 199mg/dL
4. Diabetic – greater than 200mg/dL

The standard diagnosis of diabetes is made when at least two separate blood tests show that the blood sugar is elevated.

4. THE SIGNIFICANCE OF THE GENETIC FACTOR ON THE SUGAR LEVEL IN URINE

Genetic influences are transmitted from generation to generation. In this study, we have tried to cover the first generation influences only. Thus, the patients whose father or mother (or both) were known people with diabetes are called patients with family history and are denoted by $W._{His.}$. The other group thus formed is $W.O_{.His}$ relating to patients without family history.

To test if the family history has a relationship with gender differences in diabetic symptoms, two sets of calculations were performed for each of the male and female patients. These are presented transparently in Table 1.

Table 1
Represents the number of Diabetes of Sugar in Urine

Sex		*Levels of Sugar in Urine*					*Total numbers of patients*
		0	*1*	*2*	*3*	*4*	
Male	$W._{His.}$	18	13	38	57	9	135
	$W.O._{His.}$	152	22	4	2	1	181
Female	$W._{His.}$	25	13	47	57	13	155
	$W.O._{His.}$	111	23	2	2	0	138
Total							609

The pattern looks the same for both sexes so that no sex differences are suspected. We have not formally tested this, but the data is evidence enough.

Chi-square χ^2 test for testing the hypothesis (below) of no genetic influences (no family history) against the hypothesis of genetic influence is 190.3 (with three degrees of freedom) for males and 162.3 (with four degrees of freedom) for females.

H_0: Assumes that there is no association between the Male diabetic patients with family history and those without history

H_1: Assumes that there is an association between the Male diabetic patients with family history and those without history.

Similarly, for Female Patients Hypothesis:

H_0: Assumes that there is no association between the Female diabetic patients with family history and those without history

H_1: Assumes that there is an association between the Female diabetic patients with family history and those without history.

The conclusion of these hypothesis testing shows a highly significant influence of family history on the sugar level in urine. A substantial number of patients (both males and females) without family history belongs to the group 0 level of sugar in urine. Whereas, only a small portion of patients (13-16%) with family history belong to this group of 0 level. It is early to suggest anything, but it may be because the attack of diabetics may be sudden and severe in case of people with family history. In fact, an overwhelming majority of patients with a family history are at levels 2, 3, and four both meals and females. Further analysis relating to ordered contingency table (where the orderings are on levels of sugar in urine) can, of course, be done (see Cochran (1954), Maxell (1971)).

5. ANALYSIS BASED ON SUGAR LEVELS IN BLOOD

Since no sex differences are indicated in the finding above, we have combined the male and female group of the patient into one group. The average sugar level in blood fasting and non-fasting are given in table 2 including the value of *t* with 607 (d.f) to test the hypothesis of equality of means of the two groups with and without a family history. The standard error (S.E) is also provided with braces separately and for the combined mean.

Table 2
Blood Sugar Levels for groups with and without a family history

Condition	*Mean Blood Sugar Levels*		*Combined Mean*	*t*
	$W._{His.}$	$W.O._{His.}$		
Fasting	219.4	149.6	184.5	11.36
	73.2	55.3		
Non-Fasting	325.2	219.1	272.15	13.69
	92.3	77.5		

As can be seen from Table 2, the average sugar level for the groups with and without family history differs very significantly. Once again, we suspect that for patients with family history the attack is sudden and severe. This conclusion seems to be a general impression among physicians.

6. PATIENT'S AGE DISTRIBUTION

There are appears to be insignificant sex differences between patients with family history ($W._{His.}$) and without a family history ($W.O._{His}$). Therefore, the male and female groups were combined. The results are presented in Table 3.

Combining the first two and last two age groups χ^2 for testing any difference in age structure turned out to be 9.85. The critical value of χ^2 with 4 degrees of freedom is significant at 5% level. Diabetic seems to strike people with family history at a relative age.

Table 3
Age Structure of number of Patients with and without family history

Group	*Age Groups*							*Total*
	29 < 39	*39 < 49*	*49 < 59*	*59 < 69*	*69 < 79*	*79 <89*	*89+*	
$W._{His.}$	2	16	74	96	62	28	6	284
$W.O._{His.}$	2	42	104	86	66	10	8	318

7. RISK ANALYSIS

In this section, we attempt to investigate the severity of risks that people with and without a family history are exposed to the calculation of incidence rates, and risks are usually based on the much larger base of population and often also involve a follow-up period. Two recent reports are Rimm *et. al.*, (1995) found in 7735 men aged 40-59 spread over a period of two years 1978-1980. Perry *et. al.*, (1995) use Cox's proportional hazard model (see Cox (1972), Cox (1970)).

The research attempt differs in two fundamental ways comparing to previous work. First, we do not have a record of a large population base including people with diabetes for this part of Iraq from which the prevalence rate or the risks could be estimated. Secondly, Cox (1970) in a different context used differences of log-odds, whereas we shall be concerned with a ration of probabilities and not a difference of log-odds. Perhaps the difficulties can be made clear by introducing some notations as follows:

$W._{His}$ and $W.O._{His}$ are as defined before.

D = Diabetic

P(D) = Probability that an individual selected from the population (age may be restricted) will have diabetes.

Now what we can estimate from available data is P(D/H), i.e., the probability that an individual known to be diabetic has a family history. This probability is called conditional probability and follow Bayes' theorem. Thomas Bayes first employed the calculation of conditional probability in the eighteenth century.The theory follows a formula that describes how to update the probabilities of hypotheses when given evidence. It merely follows from the axioms of conditional probability but can be used to powerfully reason about a varied range of problems involving belief updates.

However, P(D/H), i.e., the probability that a person known to have a family history of diabetes is or will be diabetic is more directly useful to us. The probability estimate of P(D/H), in fact, gives the risk that individuals with family history of diabetes are exposed. To bridge the gap of passage from P(H/D) to P(D/H) we will have to use some extra information which is available for parts of Iraq. [see for example Fatani el al., (1987), Fatani el al., (1985) and Abu-Zeid and Al-Kassab(1992)]. Also, will have to use the assumption of random mating(see Levitan and Montague (1977)). The validity of the assumptions apparently rests on the fact that marriage is based on other social considerations and not on the family history of diabetes. For a good reason, this assumption of random mating has been made for many similar situations. However, the assumption leads to the following:

$$P(H) = 1 - [1 - P(D)^2] \quad (1)$$

$1 - p(\mathrm{D})^2$ gives the probability that neither the father nor the mother has diabetes.

Now, $\mathrm{P(D/W._{His.})} = \dfrac{\mathrm{P(W._{His.}/D)P(D)}}{\mathrm{P(W._{His.})}}$ and $\mathrm{P(D/W.O_{His.})} = \dfrac{\mathrm{P(W.O._{His.}/D)P(D)}}{\mathrm{P(W.O._{His.})}}$

Consequently, $$\frac{\mathrm{P(D/W._{His.})}}{\mathrm{P(D/W.O._{His.})}} = \frac{\mathrm{P(W._{His.}/D)P(W.O._{His.})}}{\mathrm{P(W.O._{His.}/D)P(W._{His.})}} \qquad (2)$$

From Table 1 we can estimate, $\mathrm{P(W._{His.}/D)} = \dfrac{(66+76)}{301} = \dfrac{142}{301} = 0.427$

Consequently, $$\mathrm{P(W.O._{His.}/D)} = 1 - \frac{142}{301} = \frac{159}{301} = 0.528$$

From relationships 1 & 2 we can estimate the relative Risk (with & without) as follows:

$$\frac{\mathrm{P(D/W._{His.})}}{\mathrm{P(D/W.O._{His.})}} = \frac{142}{159} \times \frac{[1-\mathrm{P(D)}]^2}{1-[1-\mathrm{P(D)}]^2}$$

So, roughly the risk of diabetes for people with family history is more than eight times bigger than the risk of diabetes in individuals without a family history.

There is a general feeling among physicians that P(D) or the rate of prevalence of diabetes worldwide is changing over time.

The prevalence rate of diabetes for all age-groups worldwide was estimated to be 2.8% in 2000 and 4.4% in 2030. The total number of diabetic people is expected to increase from 171 million in 2000 to 366 million in 2030. The prevalence of diabetic disease among men is higher than women. It is evident that the significant increase in diabetes proportion of people with age more than 65-years-old. (The American Diabetes Association. 2004)

A general feeling among physicians that the prevalence rate P(D) in the middle east region is higher than the rest of the world. In some area like Saudi Arabia, the prevalence rate may exceed 20%. If we consider the prevalence rate between 0.05 as an example, then the calculation of the severity of the diabetic risk can be shown as follows.

$$\frac{\mathrm{P(D/W._{His.})}}{\mathrm{P(D/W.O._{His.})}} = \frac{142}{159} \times \frac{(0.95)^2}{1-(0.95)^2} = \frac{128.155}{15.5025} = 8.27$$

To cover this possibility Table, 3 provides the relative risk $\dfrac{142}{159} \times \dfrac{[1-\mathrm{P(D)}]^2}{1-[1-\mathrm{P(D)}]^2}$ for different value of P(D) the prevalence rate.

Prevalence (P(D))	*Severity of Risk*
0.03	14.22
0.04	10.50
0.05	8.27
0.06	6.78

8. CONCLUSION

The survey carried out, although limited, nevertheless demanded a significant amount of time and effort not only from the researcher but also from health service personnel.

From a methodological viewpoint, the research has been an exercise in operations research detective work, attempting to reach a justifiable conclusion from scanty and oblique data. This work would appear to be the characteristic of health service research where the complexity of the system does not match the lack of richness in information sources.

However, it can be argued that Operations Research is the art of making the best use of available information and it is hoped that this research at least clarifies the issue of the influence of family history on diabetes.

The main findings of this research performed on the selected sample were: (1) the high significance of relationships between the genetic factor (family history) and level of sugar. (2) the risk of diabetes for people with family history is more than eight times bigger than the risk of diabetes in individuals without a family history in Bagdad- Iraq if we assume the prevalence rate is 5%.

Diabetes mellitus is a disease with critical long-term consequences. The situation is not only facing health of individuals but also, facing the health authorities, and resource allocation around the world. In the U.K. the treatment of this illness cost 4-5% of total healthcare expenditure alone. It is a grave matter as the prevalence rate is extraordinarily expanding with time which consequently will produce millions of diabetes in the world. Few studies have included the indirect costs of diabetes, such as the outcome of early retirement and premature death and time lost from work. Ultimately, diabetes problems may be disabling or even life-threatening. Diabetes may have possible complications which include Cardiovascular disease, Nerve damage, Kidney damage, Eye damage, Foot damage, Skin conditions, Hearing impairment, Alzheimer's disease. It is vital to get healthy messages about what we eat and lifestyle to communities, so they can improve their understanding what they are eating and how to be more physically active. This culture, in the way to help people to defeat the frightening diabetic disease.

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