Experiment on Diabetes Mellitus under the Quantitative Diet with Varying Body Frame

M. Raja Sekar, N. Sandhya

Abstract— This paper deals with in-depth analysis of diabetes disease based on mathematical modeling. Proposed mathematical modeling is helpful in understanding sugar levels in the blood. The designed system is also useful in estimating insulin percentage for various diets. Fourteen different age groups are employed in the analysis. Fasting blood sugar level 80-110 mgmdl and upto 140 mgmdl followed by a meal have been used as the ranges for the calculations. Closed form solution method is used to solve the simultaneous differential equations.

Index terms: Diabetes mellitus, hyperglycemia, palatable diet.

1. INTRODUCTION

Diabetes refers to the condition in which excessive amounts of some substance ate excreted from the body. Symptoms for identifying this disease are excess amount of urine production. Another important symptom is feeling thirsty[1].

Other metabolic symptoms for this disease is producing large amount of colorless urine. Also the features like dry hand and constipation are useful in identifying this disease. The rare metabolic disorder leads to diabetes mellitus in which the body passes large quantity of colorless urine that contains more water causing thirsty, dry hands, constipation. This is due to the failure of kidney's function where in, water is to be re reabsorbed. The disorder of carbohydrate metabolism leads to diabetes mellitus.

This problem occurs mainly due to the issues raised in hormonal problems in pancreatic. Hyper glycemia is the main cause of blood sugar levels which takes place as of deposit of huge amount of sugar in the blood. There are various problems like retinopathy and stress may also lead to this disorder.

As a result of issues in arteries problems like polyuria may occur which leads to formation of sugar in the blood. These arteries problems results in occurring weight related issues and glycosuria related issues. This may also causes to occur problems like neuropathy and retinopathy. All these issues can be addressed by analyzing different kinds of cells like beta and alpha cells. As a result, micro aneurysms develop in the arteries when the cells function is distributed. This problem can be resolved by monitoring sugar levels in regular intervals and taking precautions as per sugar levels. Different categories of body frames can be analyzed by monitoring activities related to metabolism. Appropriate meal habits are helpful in controlling the percentage of sugar in the blood [2].

Wood and Gate proposed a methodology in the year 1970 that explained the effect of glucose on the diabetic patients. They formulated a mathematical model that describes the effect of pituitary gland on glucose levels in blood. Gate described a statistical method in which effect of thyroxin on diabetic patients are discussed. Brown formulated a systematic approach which explains glycosylation effect on human body [3].

Kan designed a methodology based on compartmental technique which relies on insulin levels at regular intervals. Bankr formulated a comparative procedure based on dydfunction to distinguish with and without mellitus. Cauchy introduced an analytical procedure which gives the relation between dysfunction and various disease patterns. Dev initiated system based on vascular related issues and glycemic control. Brith invented a procedure that describes viscosity effect of the blood sugar levels in diabetic and non-diabetic cases. Jingbee described a procedure which gives approximations of the glucose levels based on arterial segment properties in diabetic and non diabetic cases also. Gat proposed a scientific approach to detect sugar levels in lean and non lean diabetic patients. Raja introduced risk factor based approach which gives approximations associated with type I and type II diabetic cases. Richie discussed the procedure which gives close approximations of physical activities and diabetic assessments [4, 5].

In this paper we studied and introduced a systematic approach that describes proposition millets in diabetic patient diet. Proposed methodology also studied the behavior associated with fasting and non fasting diabetic cases. We studied calories intake of the diabetic patients at regular intervals. The duration of the interval may vary from 4 to 6 hours in between before breakfast and after breakfast. In this study we studied various types of body frames under different conditions. Our study also made some observations on insulin levels and sugar levels of mainly three categorical body frames [6].

2. FORMULATION

Proposed methodology is formulated by taking the parameters such as sugar level in blood, insulin level present in blood and calories consumed by diabetic patient. In this formulation we are treating x as blood sugar level, y as insulin level in blood, z as calories consumed by the diabetic patient[14]. Here the cases considered are blood sugar level

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before breakfast and after breakfast[7,8]. This can be mathematically modeled by the following equations

$$\frac{\partial x}{\partial t} = -axy + bx_0 H(x_0 - x) \quad (1)$$

$$\frac{\partial y}{\partial t} = (fx)bx_0 H(x_0 - x) \quad (2)$$

All the coefficients appeared in equation1 and equation2 are must be treated as postive constants as modelled system is postive definite[9]. This definitivity depends on the parameters like gradients such as glucose level gradient, insulin gradient, intake level gradient. All these parameters are associated with modelled equations present in equation 1 and equation 2 may lead to form H step generated function[10,11]. Among all these gradients sugar level gradient forms the core part of the equation 1 and equation 2. The food source is the main cause for occurrence of blood sugar[13].The periodical deposit of the sugar in blood levels may lead to form the exponential curve. The source of the model can be represented by the term Z(t),

$$Z(t) = 0 \quad , t < t_0 \ \ and$$

$$Qe - \pi(t - t_0),\ t > t_0 \quad (3)$$

Where Q is the quantity of the meal

π can betreated delay value

t_0 is the time at which calories intake

Treatmenr for mathematical model presented by 1, 2 and 3 can be obtained with the help of modelled with the help of injections at periodic intervals

Mean lekage rate is represented by I(t) and is defined as,

$$I(t) = \frac{rt}{t - t_0} + b,\ \ t_0 \le t \le \bar{t} \quad ...(4)$$

3. ANALYSIS

All the equations present from 1 to 4 illustrate the concept of diabetic patient treatment methodology which gives all the gradient parameters associated with insulin level, sugar level and intake level.

Equations (1) and (2) describe the blood sugar and insulin levels. Changing the non linear terms then,

For $x > x_0,\ H(x_0 - x) = 0$ (*by step function*)

Then for $t \le t_0,\ z(t) = 0, I(t) = 0,$ *equation* (1) *and* (2) *becomes*

$$\frac{\partial x}{\partial t} = -axy \quad (5)$$

$$\frac{\partial y}{\partial t} = fx - fx_0 - yy \quad (6)$$

Solving (5) and (6) by simultaneous linear method with D=d/dx (the linear differential operator), the solution for x(t) and y(t) are,

$$where \quad m = -\frac{y \pm \sqrt{y^2 + 4axf}}{2} \quad for\ two\ values\ m1 - m2 \quad (9)$$

x(t) remains within the faasting level x0 range and y(t) remains as parallel solution response. For t>t0

z(t), then introducing (3) into (5) and using (9) we obtain x(t) and y(t) as

$$x(t) = c_6 e^{m1t} + c_7 e^{m2t} + x_0 \quad (10)$$

$$y(t) = c_8 e^{m1t} + c_9 e^{m2t} \quad (11)$$

$$where\ m = -\frac{f \pm \sqrt{j^2 + 4axf}}{2}$$

$$for\ two\ values\ m1 - m2$$

x(t) remains within the fasting level x0 range and y(t) remains as parallel solution response. For t>t0, z(t)=0, then introducing (3) into (5) and using (9) we obtain x(t) and y(t) as

$$x(t) = x_0 \frac{gQ(y - d)e - d(t - t_0)}{d^2 - jd} \quad (12)$$

$$y(t) = x_0 \frac{gQ(y - d)e^{-d(t - t_0)}}{d^2 - d} \quad (13)$$

The constants c1,c2,…,c9 are the arbitrary constants in the successive steps of complementary solutions of (1) and (2).

Substituting the sensitivity values $f = 0.01,\ x = 1.01,\ a = 3.7,$ $x_0 = 0.1,\ g = 0.3, y = 0.2 and\ d = 0.7$

$$x(t) = x_0 + \frac{gQ(y - d)e^{-d(t - t_0)}}{d^2 - d + a} \quad (14)$$

$$y(t) = \frac{gQ(y - d)e^{-d(t - t_0)}}{d^2 - d + a} \quad (15)$$

$$Since\ t > t_0 implies\ t_0 < t < b,$$

Time for the meal is determined with the help of equation 4 to equation 6. Half time of the meal can be determined from the equation5 to equation 9,

$$\int_{t_0}^{\infty} z(t)dt = \int_{t_0}^{\infty} Qe - d(t - t_0)dt \quad (16)$$

Assuming the selection of food with normal time consumption, let a person eats half meal in 10 minutes (1/6 hours), by equation (14), we obtain,

$$\frac{1}{3}\frac{Q}{d} = \int_{t_0}^{\infty} Qe - d(t - t_0)\ dt \quad (17)$$

The parameter Q in Equation 17 represents that meal in calories in which a diet principe based on Joslin's is used. In this equation P is the parameter which represents protien level present the diabetic patient. The parameter F represents fat level present in the diabetic patient body. Also the parameter C represents the carbohydrate level in human body.

$$x = x^{PD}, y = y^{PD}, D1 = D1^{PD}, D2 = D2^{PD},\ PD = Palatable\ diet.$$

The time parameter is divided into four different slots known as brekfast, noon, evening and late evening. Equations 10 to 17 can be summarized in the form of equation 18 and equation 19.

$$x^{PD} = C_1^{PD} e^{-t} \sin t + C_2^{PD} e^{-t} \cos t \quad (18)$$

$$y^{PD} = C_1^{PD} e^{-t} \cos t + C_2^{PD} e^{-t} \sin t \quad (19)$$

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Equations (12)-(16) gives values of x(t) and y(t) for non palatable and palatable diet during and after the breakfast

The new forms of (1) and (2) become

$$Dx = -\ddot{\alpha}xy + \beta Qe - \delta(t - t_0) \quad (20)$$

$$Dy = -\ddot{\alpha}xy + \delta\phi e - \gamma(t - t_0) \quad (21)$$

Solution of (18) and (19) give

$$x(t) = c_1 e^{-m_1 t} + c_2 e^{-m_2 t} + \ddot{\alpha}xy + \delta\phi e - \gamma(t - t_0) \quad (22)$$

$$y(t) = \frac{1}{\alpha x} c_1 e^{-m_1 t} + c_2 e^{-m_2 t} + \ddot{\alpha}xy \quad (23)$$

comparing (19) and (20) with (12) and (13) and substituting for m for (9) we get,

$$x^{PD} = C_1^{PD} e^{-t} \cos t + C_2^{PD} e^{-t} \sin t + \int_{t_0}^{\infty} Qe - d(t - t_0)\, dt \quad (24)$$

$$y^{PD} = C_1^{PD} e^{-t} \cos t + \int_{t_0}^{\infty} Qe - d(t - t_0)\, dt \quad (25)$$

Model for Q (input or source) with palatable diet for various body frames

I. Here the analasys is done on the basis of age and weight. Considered average is 34 and the weight is from 63 kg to 84 kg with average difference of 1.923 kg (in the increasing order and with body frames small, medium and large),

$$Q_M^{PD} = T_{sM}^{Ca} = 921.213 + (1.92) T_{sM}^{PFC} \quad (26)$$

Values of Q_M^{PD} are presented in table [1].

II. Women aged 25 years and above with weight 52 kg to 71.5 kg with average difference of 1.6231 kg (in the increasing order and with body frames small, medium and large).

$$Q_M^{PD} = T_m^{Ca} w = 53.243 + (5.076) T_{mM}^{PFC} \quad (27)$$

values of Q_M^{PD} are presented in table [2].

The parameters x(t) and y(t) represents glucose levels and insulin levels.These are obtained by introducing equations (23) and (24) into (21) and (22)successively for four different cases. In each case, the values of C_1^{PD} and C_2^{PD} are calculated for P: F: C using Joslin's principle. The glucose that is absorbed into the blood causes rapid secretion of insulin when carbohydrate quantity is increased.

4. RESULTS AND DISCUSSION

In this study compositions like carbohydrite, Fat and Protein present in the body have been analysed.

In the metabolic process of human body glucose plays an important role in digestion process. Energy demand can meet by the consumption of carbohydrate. The parameters x(t) and y(t) represents sugar and insulin levels present in the human body. These are represented by equations (21) and (22). Garphs are plotted from different categories of people like small, medium and large for men and women with varying body frames. For the sensitivity parameters

$a = 0.05,\ b = 0.98$ *and* $g = 3.23$, *the glucose tolerance has* $f = 0.5$ *and* $g = 1.962$

The glucose level varies depending on time duration. Glucose levels are observed periodically for each two hours. Here x_0 and y_0 are the varibles which represents glucose level in periodic intervals that are useful in making decision.

When $a > 0.05,\ b > 0.98,\ g > 4.32,\ j > 0.5,\ y > 1.961$

the response of x(t) and y(t) will be independent of time. The resulting increase in osmotic pressure causes dehydration of the cells. In addition, elevated blood glucose causes glucose to appear in the glomerular filterate of the kidney(rise of 2% plasma osmotic pressure makes a diabetic blood glucose rise to 500 mg %). For this situation, the re-absorption is incomplete. This situation leasds to hypoglycemia. Infusion of y(t) under pathological assumptions, P : F: C is categorized or the optimal ranges of palatable diet composition. The inputs for TPFC are calculated as QPD for two categories. The input of QPD is taken for four different feeding with palatable composition to overcome the rise of blood glucose levels.

I. The parameters associated with glucose and insulin are described in Figure (1). All the decision parameters are analysed for the persons whose age 25 years and above. All palatable composition of diet are analysed with the help of equations formulated in equatioan 1 and equation 3.

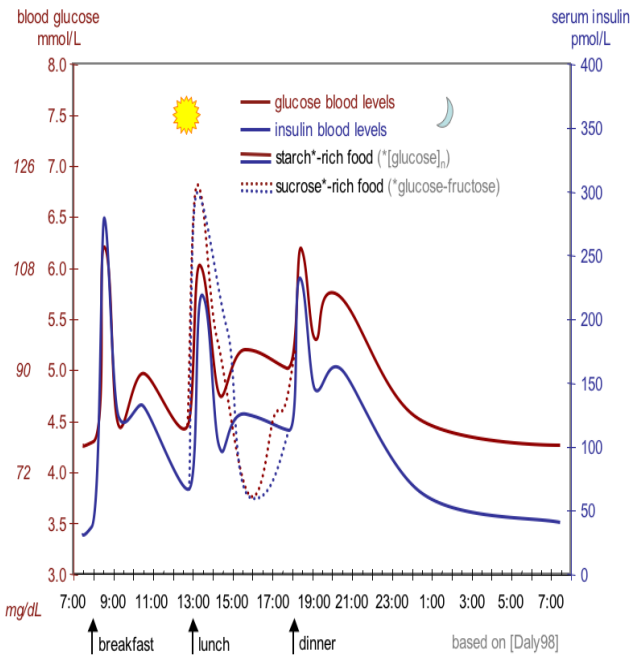

Fig1. Glucose blood level versus Insulin blood level

Analysis of P:F:C: (Time slots are divided into equal slots and each slot is associated with decision parameters) for fourteen samples.

For different body frame,

P : F: C; 64:76:150-85100:242gms [1612-2191] cal

For medium body Frame of small sample,

P : F: C; 60 : 80 : 160 -85 :100 : 260 GMS [1626-2293] cal

From large body frame,

P : F : C; 65 : 85 : 175-85 :110 : 270 gms [1631- 2341] cal

Figures (3) and (4) describe the blood glucose and insulin levels nearly to normal range under platable composition of diet for women aged 25 years and above

Palatable input range of P : F : C : (For four equal meals) for fifteen samples.

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For small body frame,
50 : 71 : 129-64 : 91 : 196 gms [1421-1992] cal
For large body frame,
P: F:C, 55: 81:152- 53 : 100 : 220 gms [1489-2132] cal

5. CONCLUSION

Model proposes the stimulation of blood glucose and insulin levels to the extent of normal ranges and the sensitivity values nearly to optimal values. The secretion of these two hormones may be balanced to a large extent (except the case of diabetic coma and vascular excitation) under the ratio of protein, fat and carbohydrate for the chosen quantities as presented in the tables. Also the rate of recovery of low blood sugar and the decay of insulin can be estimated under the palatable diet. It is evident that the time and palatable composition chosen play a significant role in distinguishing the diabetic and normal persons. Hence the palatable composition along with sensistivity quantities will become most important part in the classification of parameters. The model takes the valid physiolological ranges for the variation of time, the palatable quantity and the sensitivity values as depicted in the figures.

Men(M)	2	3	4	5	6	7
1	186	1412	301	1543	498	1542
	291	1331	302	1491	321	1631
	301	1531	309	1541	324	1704
	276	1731	345	1631	333	1698
	312	1691	351	1561	335	1561
	294	1574	324	1643	342	1497
	312	1452	331	1721	326	1541
	331	1543	301	1632	336	1491
	350	1761	321	1543	340	1532
	345	1671	331	1643	321	1632
	341	1856	306	1598	343	2012
	327	2231	314	1542	351	1954
	390	1961	312	1498	392	2001
	401	2141	309	1542	321	1974

Table [1] : Palatable Diet for Men aged 25 years and over [calculations are in round figures]

1. Weight 55 kg to 88 kg and Height 5’2’’ to 6’3’’
2. T_{SM}^{PFC}
3. T_{SM}^{Ca}
4. T_{MM}^{PFC}
5. T_{IM}^{PFC}
6. T_{IM}^{C}

Women(M)	2	3	4	5	6	7
1	245	1302	301	1443	401	1042
	255	1221	302	1391	298	1431
	259	1431	309	1241	321	1604
	310	1531	345	1131	311	1598
	298	1491	351	1361	318	1461
	294	1472	324	1443	323	1397
	276	1392	331	1421	313	1341
	321	1443	301	1332	312	1291
	340	1661	321	1443	311	1431
	315	1571	331	1543	300	1532
	321	1656	306	1498	323	2002
	337	2131	314	1242	341	1854
	340	1861	312	1398	311	2101
	350	2141	309	1442	301	1874

Table [2] : Palatable diet for women aged 25 years and over (calculations are in round figures)

1. Weight 49 kg to 76 kg and Height 5’11’’ to 6’
2. T_{SM}^{PFC}
3. T_{SM}^{Ca}
4. T_{MM}^{PFC}
5. T_{IM}^{PFC}
6. T_{IM}^{C}

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