Dietary Intake in Diabetic Patients

By

Shoichi Yamagata and Akira Ohneda

*From the Medical Department of Prof. S. Yamagata, Tohoku
University School of Medicine, Sendai*

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Diabetes mellitus has been understood to be a metabolic disorder induced by hormone unbalance in whole endocrine organs, not always being produced by a single etiology. Since v. Mering and Minkowski¹⁾ reported a production of experimental diabetes mellitus in a depancreatized dog, Langerhans' islets of the pancreas have been thought to be an important organ in the etiology of diabetes mellitus. Recently, it has been proven that the central nervous system²⁾ as well as the anterior pituitary lobe,^{3,4)} adrenal glands,^{5,6)} thyroid gland⁷⁾ and alpha-cells in Langerhans' islets^{8,9)} play a major part in the development of diabetes mellitus. Moreover, obesity and heredity have also been exhibited as important factors in the etiology of diabetes mellitus by Mayer's obese mouse¹⁰⁾ and Okamoto's experimental hereditary diabetes.¹¹⁾

The etiologies of diabetes mellitus are generally divided into two groups, congenital and acquired. In the latter, it is obesity or diet that is important. Previously it has been reported by us¹²⁾ that a disordered carbohydrate metabolism was observed in rats fed with a high-protein, high-fat, and high-caloric diet.

How much is the dietary factor concerned with pathogenesis in human diabetics? Such reports as deal with dietary intake are rare, because of the difficulty in describing the amount of diet. Thus, the following survey was performed in order to know the importance of dietary intake in the etiology of diabetes mellitus.

MATERIALS AND METHODS

This study was performed on 127 diabetics who were admitted to our Department from June 1958 to April 1960.

The age at onset of diabetes mellitus was defined as the time when subjective symptoms developed, or if subjective symptoms failed to develop, the time when the first diagnosis was made. The maximum body weight prior to onset was taken as body weight before onset. Obesity was determined from the standard body

weight presented by Matsuki¹³⁾: Weights within $\pm 10\%$ of the standard body weight were considered to be normal, any weight more than $+11\%$ as obese, and any weight less than -11% as lean. Criteria on dietary intake are shown in Table I. This table was made in comparison with the report on the standard dietary intake in Japan.¹⁴⁾ In this table, dietary intake was classified into four grades, normal, increased, greatly increased and decreased. Dietary intake before the occurrence of diabetes mellitus was determined by the answer of the diabetics in comparison with the criteria described above. The amount of carbohydrate in the diet was decided from the intake of rice, bread or noodles. Since protein and fat are always contained in fish, meat, eggs, milk and so on, they were described as the intake of protein and fat. The total intake of calories was given as the sum of the intake of carbohydrate, protein and fat. Moreover, the intake of sugar was also noted.

In this study, diabetes mellitus was classified into two types, type I and type II.¹⁵⁾ The type I diabetics can be controlled solely by our dietary therapy, while type II diabetics require insulin administration in addition to dietary therapy.

TABLE I. Criteria of Daily Dietary Intake

Commodity	Decreased	Normal	Increased	Greatly increased
Boiled rice*	Less than 900g.	900 to 1400g.	1400 to 1800g.	More than 1800g.
Meat	Less than 30g.	30 to 70g.	70 to 100g.	More than 100g.
Fish	Less than 70g.	70 to 100g.	100 to 200g.	More than 200g.
Egg	Less than one	One to two	Three to five	More than five
Milk	Less than 180ml.	180 to 360ml.	360 to 900ml.	More than 900ml.
Oil and fat	Less than 10g.	10 to 20g.	20 to 30g.	More than 30g.
Cake	None	One to three	Three to five	More than five

* One hundred grams of boiled rice contain about 33 grams of carbohydrate.

RESULTS

Ninety-one male and thirty-six female diabetics were investigated in this study. The age and sex of the diabetics are shown in Table II. The age at the

TABLE II. Age and Sex at This Study

Age	Type I		Type II	
	Male	Female	Male	Female
0 - 20	0	0	0	0
21 - 30	0	0	2	2
31 - 40	7	2	2	1
41 - 50	14	2	7	5
51 - 60	23	4	19	8
61 - 70	11	1	4	10
71 ~	1	1	1	0

TABLE III. Age and Sex at Onset of Diabetes Mellitus

Age	Type I		Type II	
	Male	Female	Male	Female
0~20	0	0	1	1
21~30	1	0	1	2
31~40	9	2	4	1
41~50	16	3	12	5
51~60	21	4	14	11
61~70	8	1	2	6
71~	1	0	1	0

TABLE IV. Body Weight and Age at or Prior to Onset of Diabetes Mellitus

Age	Lean	Normal body weight	Obese	Total
0~20	2	0	0	2
21~30	0	3	1	4
31~40	0	2	14	16
41~50	0	6	30	36
51~60	1	17	32	50
61~70	1	5	11	17
71~	0	1	1	2

occurrence of diabetes mellitus is shown in Table III. Most of the diabetics between 40 and 60 years of age are distributed in both Tables II and III. The age at onset showed a shift of several years earlier when compared with the age at this study. The body weight in the younger age group was normal or lean, while it was normal or obese in the older group (Table IV). Obese diabetics with a maximum body weight before onset of +11% to +20% of the standard weight occurred most frequently. Eighty-nine out of 127 diabetics (70.1%) were obese before onset. The body weight observed at this study is shown in Fig. 1. Obesity was seen in only 39 diabetics (30.7%) while the body weight in 62 diabetics (48.9%) was within the normal range, and in 26 diabetics (20.4%) was lean. A decrease in the body weight was observed more markedly in type II diabetics than in type I. There was no difference between the sexes in the body weight after onset. The changes in the body weight are shown in Table V. There were no diabetics who gained body weight after onset. Dietary intake is shown in Table VI. The intake of carbohydrate was within the normal range in almost all diabetics of both types, whereas an increased intake of protein and fat was observed in 35 out of 66 type I diabetics and 27 out of 61 type II diabetics. Thirty-eight out of 66 type I diabetics and 26 out of 61 type II diabetics took a greater total of calories than normal subjects. There was no significant difference in the intake of total calories between type I and type II diabetics.

There was no correlation between the dietary intake and hereditary relation-

Fig. 1. Fluctuation in body weight prior to and after onset.

TABLE V. Body Weight Prior to Onset and at This Study

Body weight prior to onset	Body weight at this study					
	Type I			Type II		
	Lean	Normal	Obese	Lean	Normal	Obese
Lean	1	0	0	3	0	0
Normal	7	10	0	8	9	0
Obese	1	23	24	6	20	15

TABLE VI. Dietary Intake and Diabetic Types

Dietary intake	Type I			Type II		
	Carbo-hydrate	Protein and fat	Total calories	Carbo-hydrate	Protein and fat	Total calories
Greatly increased	2	11	7	4	11	8
Increased	10	24	29	7	16	18
Normal	52	28	28	46	31	35
Decreased	2	3	2	4	3	0

TABLE VII. Dietary Intake and Heredity

Dietary intake	Diabetes with heredity			Diabetes without heredity		
	Carbo- hydrate	Protein and fat	Total calories	Carbo- hydrate	Protein and fat	Total calories
Greatly increased	4	7	4	2	15	11
Increased	4	9	12	13	31	35
Normal	19	11	12	79	48	51
Decreased	1	1	0	5	5	2

Fig. 2. Obesity and dietary intake.

ship as shown in Table VII. It is interesting that an increased dietary intake was observed rather in diabetics with a hereditary relationship than in those without it. The correlation between obesity and the dietary intake is shown in Fig. 2. The diabetics with a decreased body weight, although they were few in number, had a normal intake of carbohydrate, protein and fat, and calories. Many diabetics with a normal body weight were observed to take a normal amount of calories. However, that was not the case in those diabetics with an increased body weight. Normal intake of carbohydrate was observed in almost all of those obese diabetics, while an increased intake of protein and fat and of calories was observed in more than half of those diabetics with obesity. It may be supposed that obesity in diabetics is rather linked with an overintake of protein and fat and of total calories than of carbohydrate.

The intake of sugar or cake was normal or less in a number of cases of diabetics when compared with normal subjects, and this shown in Table VIII. Twenty-three out of 127 diabetics with an increased intake of sugar or cake took

TABLE VIII. Intake of Sugar

Intake of sugar	Type I		Type II	
	Male	Female	Male	Female
Greatly increased	2	0	2	2
Increased	6	1	6	4
Normal	33	7	18	15
Decreased	15	2	9	5

a large amount of other dietary stuff. Therefore there were none in which diabetes mellitus is followed solely by an increased intake of sugar or cake. The relation between the intake of calories and the occupation of the diabetics is shown in Table IX. An increased intake of calories was observed only in a small number of farmers or office workers, whereas there was an increased intake of total calories in many of those cases who were economically well off, such a university professor, an administrator of a company, and so on.

The etiological factors such as heredity, obesity, and an increased dietary intake are summarized in Table X. There were 24 diabetics who did not have any of the etiological factors mentioned above and the remaining had at least one of these factors. Heredity was proven in 30 diabetics or 24%, an increased intake of calories in 63 diabetics or 50%, and obesity in 89 diabetics or 70%.

TABLE IX. Dietary Intake and Occupation

Occupation	An intake of total calories				Total
	Decreased	Normal	Increased	Greatly increased	
Farmer	0	7	3	2	12
Office worker	1	32	19	2	54
Marchant	0	16	10	5	31
Doctor	0	3	0	2	5
Clergyman	1	2	0	0	3
Professor of university Administrator of company	0	3	15		22

TABLE X. Etiology of Diabetes Mellitus

Factors	Type I	Type II	Total
Heredity	3	2	5
Overeating	5	3	8
Obesity	17	10	27
Heredity and overeating	1	0	1
Heredity and obesity	2	6	8
Overeating and obesity	20	18	38
Heredity, overeating and obesity	10	6	16
None	8	16	24

DISCUSSION

Heredity is the most basic among the various etiological factors of diabetes mellitus. But as Joslin¹⁶⁾ said, "Search must be made for precipitating factors which help to bring out the inherited disposition, since the disease is rarely present at birth".

Obesity and/or overeating is one of the most important precipitating factors. Obesity is greatly influenced by dietary intake. However, there have been very few reports on dietary intake in diabetic patients, because of the difficulty in describing the amount of diet. We have reported that animals fed with a high-protein, high-fat, and high-caloric diet showed a decreased glucose tolerance and revealed a subdiabetic state.¹²⁾ This survey was made in order to know whether increased dietary intake and obesity play an important role in human diabetes or not.

The common age at onset was in the fourth or sixth decade as shown in Table III. This fact suggests that diabetes mellitus is based on acquired factors as well as heredity. Joslin¹⁶⁾ stated that obesity is by far the most important of all these factors, and he made an analysis of 1000 diabetics. The maximum weights of only 19 per cent were above the standard weight zone in diabetics aged ten years or younger, whereas 79 to 89 per cent of these cases from 31 years onwards were overweight. In our own series, the maximum weight of almost all adult diabetics was in or above the standard weight zone at or prior to onset. The maximum weight at or prior to onset was found to be above the standard zone in 70 per cent of all our series, and this fact suggests that obesity plays an important part in the occurrence of diabetes mellitus. Although Joslin¹⁶⁾ stated that in female Jewish diabetics obesity was more marked than in male patients, there was no correlation between obesity and sex in this study. Moreover, no correlation between obesity prior to onset and diabetic types was found. Body weights in almost half of both types, type I and type II, were decreased after onset of diabetes mellitus. Two different types of diabetes mellitus, insulin dependent and non-insulin dependent, have been distinguished for many years¹⁷⁾ and though the former is not obese, the latter is usually associated with obesity. Our results, however, suggest that a classification based on constitution is not essential, because obesity was found in a great number of both types at or prior to onset and because a decrease in body weight occurred according to the severity of diabetes mellitus.

How is obesity induced? Although obesity and heredity are closely linked, obesity is mostly influenced by dietary intake. Indeed, dietary intake in obese diabetics increased in comparison with diabetics with decreased weight (Fig. 2).

An intake of protein and fat, and of total calories is more closely connected with obesity than is carbohydrate intake. The fact that increased dietary intake or obesity plays an important role in the development of human diabetes,

is consistent with the experimental results previously reported by us.¹²⁾ Himsworth¹⁸⁾ stated that the incidence of diabetes can be related to the amount of fat in the diet. Himsworth and Marshall¹⁹⁾ reported that the diabetics prior to onset chose diets of greater calory value and that the diet of diabetics contained the same proportion of protein, a diminished proportion of carbohydrate and an increased proportion of fat in comparison with normal subjects. Horn and his co-workers²⁰⁾ reported that animal protein produced a decreased glucose tolerance. Griffiths²¹⁾ described the production of hyperglycemia by injecting intraperitoneally into rabbits uric acid, which was the metabolite of protein. These results suggest that protein and/or fat have diabetogenicity, and may provide an interpretation for the fact that the incidence of diabetes mellitus is high in Europeans and Americans who are meat-eaters, whereas it is low in incidence in Japanese who generally eat rice and vegetables. Although diabetes mellitus is supposedly produced by a diet rich in sugar since Dohan and Lukens²²⁾ succeeded in production of diabetes mellitus by the administration of excessive glucose, an increased intake of sugar was observed in only 23 out of 127 diabetics of our series. Joslin¹⁶⁾ stated that the consumption of sugar in the United States has been stationary in recent years, whereas diabetes mellitus had increased. Indeed, in our study diabetics who took excessive sugar generally took a high-caloric diet. Therefore, even an increased intake of calories has an important significance in the etiology of human diabetes mellitus.

How does increased dietary intake induce diabetes mellitus? It is well known that diabetes mellitus is mediated by an overloading and exhaustion of Langerhans' islets of the pancreas, which exhaustion is derived from increased dietary intake. Recently it has been generally accepted that insulin is released from the islets not only by the glucose loading but also by protein or fat loading.²³⁾ Therefore, overeating will result in the stimulation of the islets and then at last will lead to their exhaustion.

Increased dietary intake may have diabetogenicity mediated by obesity, in which state active lipogenesis results in an accelerated supply of insulin. Indeed, the high rate of lipogenesis was demonstrated on obese human subjects as compared with normal controls by Gordon.²⁴⁾ The fact that an abnormal increase in body weight occurs just prior to the appearance of the first manifestation of the disease, supports that opinion.

It has been reported by Kotake and his co-workers²⁵⁾ that a high-protein, high-fat diet leads to production of xanthurenic acid, which is mediated by a deficiency of vitamin B₆, and that xanthurenic acid induces damage to the beta-cells in the islets of the pancreas. If a high level of xanthurenic acid in the blood can be proven in obese subjects or in human subjects with an increased intake of protein and fat, this theory will become important in the etiology of diabetes mellitus.

Lastly, an elevated function in the anterior pituitary lobe and in the adrenal

cortex was observed by this author¹²⁾ in rats fed with a high-protein, high-fat diet, in which glucose tolerance was slightly decreased. Diabetes mellitus might be produced by the heightened function of the endocrine glands derived from an increased dietary intake.

The causes of diabetes mellitus are shown from the standpoint of heredity, overeating, and obesity in Table IX. Only 19 per cent of our series did not have these factors at all, while at least one of these causes was proven in the remaining 81 per cent. It seems worthy to emphasize that obesity and/or overeating are observed at an increased incidence in all diabetic patients. Statistical studies showed that a high incidence of diabetes mellitus was observed among obese subjects in comparison with normal adult subjects in the standard weight zone.²⁶⁾

These results obtained in our study support the supposition that acquired factors such as obesity and overeating play an important role in the etiology of human diabetes.

SUMMARY

Dietary intake was studied in 127 diabetic patients who were admitted to our Department.

The age at onset of diabetes mellitus was distributed mostly between the fourth and sixth decades.

The maximum weights at or prior to onset of this disease were above the standard zone of weight in 89 diabetics (70.1%) while they were below it in 4 diabetics (3.1%). The body weights of 39 diabetics (30.9%) after manifestation of this disease were over the standard zone of weight whereas they were below the standard zone of weight in 26 diabetics (20.4%).

Neither correlation between dietary intake and diabetic types nor between dietary intake and heredity was observed. There was a correlation between dietary intake and obesity, and an increased intake of protein and fat and of calories was found in a number of obese diabetics.

Any correlation between consumption of sugar and the etiology of diabetes mellitus was not observed.

An increased intake of total calories was observed in many of those cases who were well off economically, such as a university professor, an administrator of a company, and so on.

In connection with the etiological factors, heredity was proven in 30 diabetics or 24 per cent, an increased intake of calories in 63 diabetics or 50 per cent, and obesity in 89 diabetics or 70 per cent. Twenty-four diabetics (19 per cent) did not have any of the above mentioned etiological factors at all.

The results obtained in this study suggest that obesity and an increased dietary intake play an important role in the etiology of human diabetes mellitus.

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