Age and Sex Variations in the Prevalence and Onset of Diabetes Mellitus

MORTIMER SPIEGELMAN AND HERBERT H. MARKS

Statistical Bureau, Metropolitan Life Insurance Company, New York, N. Y.

IN this paper, there are presented estimates of the sex and age distribution of the existing diabetic population in the United States, of the new diabetics expected each year, and of those in the population who may eventually become diabetic.

PREVALENCE

In preparing the estimates which form the basis for this paper, use was made of the findings of the National Health Survey in regard to diabetes prevalence. This survey was conducted during the winter of 1935–1936 under the auspices of the U. S. Public Health Service.[1] It covered 2,500,000 white and colored persons living in 700,000 households in 83 cities and was so planned as to constitute a sample representative of the general urban population of the United States. Morbid conditions were recorded by trained enumerators as they were reported by a member of the household. Wherever possible, an effort was made to confirm the diagnoses by referring to the physician in attendance. Through the courtesy of George St. J. Perrott, Chief, Division of Public Health Methods, National Institute of Health, there have been made available unpublished data regarding diabetes prevalence which form the basis for this paper.[2] These data are shown in Table 1.

TABLE 1

Cases of Diabetes Mellitus per 1,000 Persons of Specified Sex and Age, National Health Survey, 1935–1936

	Males			Females		
Age	*Population Covered*	*Cases of Diabetes*	*Cases per 1,000 Persons*	*Population Covered*	*Cases of Diabetes*	*Cases per 1,000 Persons*
All ages	1,201,992	3,285	2.73	1,300,399	5,897	4.53
Under 15	303,207	105	0.35	299,607	124	0.41
15–24	206,696	129	0.62	239,673	136	0.57
25–34	196,845	178	0.90	228,456	247	1.08
35–44	191,157	385	2.01	204,368	646	3.16
45–54	151,540	680	4.49	151,468	1,309	8.64
55–64	87,647	873	9.96	95,107	1,731	18.20
65–74	46,380	702	15.14	55,787	1,328	23.80
75–84	15,067	212	14.07	19,790	341	17.23
85 and over	2,189	14	6.40	3,196	22	6.88
Unknown	1,264	7	5.54	2,947	13	4.41

Quality of the data: It is possible to obtain some light on the quality of the data by comparing them with another experience, namely, the Massachusetts

NOTE: The writers are indebted to Drs. Louis I. Dublin and Alfred J. Lotka for encouragement and advice in the conduct of this study.

survey made by Bigelow and Lombard during 1929–1931.[3,4] Inspection of Table 2 shows that, on the whole, the incidence of diabetes observed in the National Heath Survey was somewhat greater than that in the Massachusetts survey.* The largest deviation between the two experiences is found among males of ages 70 to 79, and here it would seem that the Massachusetts figure is too low, a situation which may arise from the chance fluctuation of the small sample involved. Although the prevalence of diabetes may have increased from 1929–1931 to 1935–1936, the higher rates of the later period may also suggest better reporting in the National Health Survey than in the Massachusetts survey. In any event, the differences between the two experiences, on the whole, are not very great. They essentially confirm each other.

TABLE 2

Cases of Diabetes Mellitus per 1,000 Persons of Specified Sex and Age, National Health Survey, 1935–1936, and Massachusetts Survey, 1929–1931

	Males		Females	
Age	National Health Survey 1935–1936	Massachusetts Survey 1929–1931	National Health Survey 1935–1936	Massachusetts Survey 1929–1931
40–49	3.1	4.2	5.5	5.0
50–59	6.8	6.6	13.1	15.1
60–69	12.8	10.3	21.8	17.2
70–79	15.8	10.4	22.7	19.0
80 and over	11.2	10.0	11.4	14.0

Commenting on the quality of the data from the National Health Survey, Mr. Perrott[2] said, "I am inclined to believe that if the informant knew a person had diabetes, she would usually report that fact, even though the person were able to work. On the other hand, some such cases were naturally missed. Also, there would be cases unknown to the informant. . . . It seems evident that any esimate of the amount of diabetes present, based on information of this type, would be an understatement."

For the basic computations on the onset of diabetes according to sex and age, the data in Table 1 were used without adjustment. It is evident, therefore, that these data will provide minimum estimates of the situations considered. This is an important qualification of these estimates because in an appreciable number of cases diabetes exists in a form so mild that it may go undiagnosed or its diagnosis may be considerably delayed. As Joslin[5] has pointed out, "Diabetics developing the disease after the age of 60 exhibit it generally in mild form; the exact time of onset of diabetes in older patients is not as easily ascertainable as in younger diabetics because the condition develops more insidiously."

Fortunately, trial computations of these data show that any assumed percentage of understatement, even as high as 25 per cent, in the observed prevalence rates, provided it is invariant with sex and age, affects the onset rates emerging from our computations by practically the same percentage. It follows then that the rate of prevalence and annual onset and the chances of eventually becoming diabetic, as presented in the following pages, may be increased by any flat percentage considered appropriate to allow for any understatement in the observed data. No detailed consideration was given, however, to percentage allowances which

* For the purpose of this comparison, it was necessary to adjust the data of the National Health Survey by interpolation to the age grouping in which the data of the Massachusetts survey were presented.

TABLE 3

Diabetes Prevalence Rates, Diabetes Onset Rates (Rate at Which New Cases Arise among Non-Diabetics per Annum), and Chances of Eventually Becoming Diabetic, According to Sex and Age, United States, 1935–1936

Age	Diabetes Prevalence Cases per 1,000 Population National Health Survey		Diabetes Onset—New Cases per Annum per 100,000 Non-Diabetic Population		Chances per 1,000 of Eventually Becoming Diabetic	
	Males	Females	Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Under 15	0.4	0.4	*	*	22.1	41.5
15–19	0.6	0.6	*	*	22.4	42.0
20–24	0.7	0.7	2.8	3.8	22.6	42.3
25–29	0.7	0.8	5.8	10.0	22.8	42.6
30–34	1.1	1.4	11.0	19.6	22.8	42.6
35–39	1.6	2.4	16.4	31.9	22.7	42.2
40–44	2.4	4.0	24.6	53.7	22.4	41.3
45–49	3.8	7.1	39.6	82.2	21.9	39.4
50–54	5.3	10.5	71.6	130.6	20.7	36.2
55–59	8.6	16.1	101.7	179.5	18.1	30.7
60–64	11.8	20.9	114.8	198.1	14.8	23.8
65–69	14.1	23.0	125.1	201.2	11.3	16.6
70–74	16.6	24.9	113.3	162.4	7.7	10.0
75–79	14.5	19.1	99.0	115.0	4.6	5.2
80–84	13.2	13.5	65.9	66.5	2.0	2.0
85–89	6.4	7.1	20.1	19.7	0.4	0.4

* Onset rates were not computed at these ages in view of the small numbers involved in the basic data.

would vary with sex and age, because the results obtained from such allowances would not have a simple arithmetic relationship to those derived from the basic data.

Age and sex characteristics of diabetes prevalence rates: According to the National Health Survey, there were at least 3.67 diabetics per 1,000 persons in our urban communities in 1935–1936. Among males, 2.73 out of every 1,000 were diabetic, while among females the rate was appreciably greater, namely, 4.53 per 1,000. The rates for each sex rise steadily with increase in age, from low points, at ages under 15, of 0.35 per 1,000 males and 0.41 per 1,000 females to maxima in the age group 65 to 74 years, the rates here being 15.14 per 1,000 males and 23.80 per 1,000 females. At ages 85 and over, the rates for both sexes are somewhat over 6 per 1,000. The data supplied have been interpolated to provide diabetes prevalence rates for quinquennial age groups, as shown in Table 3, columns 2 and 3.

Along with the changes just described, there are correspondingly rapid changes in the sex ratio of diabetes incidence with increase in age. Thus, under age 25, the rates for the two sexes are not much different; at ages 25 to 34 years, the females are higher by 20 per cent, at ages 35 to 44 by almost 60 per cent, and at ages from 45 to 64, their rates are almost double those for males. After age 65, the differential between the two sexes diminishes, the females being higher by almost 60 per cent at ages 65 to 74, by about 20 per cent at ages 75 to 84, and practically the same as that for males at ages 85 and over.

Age and sex distribution of diabetics: If it is assumed that the diabetes prevalence rates according to sex and age, as observed in the National Health Survey, prevailed in the general population of the United States during 1940, then there were *at least* 500,000 diabetics in the country during that year and their sex and age distribution was as shown in Table 4, columns 2 and 3. Males then constituted 38.5 per cent of the total cases and females 61.5 per cent. Over one-quarter of the total was under age 50, one-quarter was be-

TABLE 4

Estimated Number of Existing Diabetics, New Diabetics, and Potential Diabetics in the 1940 Population of the United States, by Sex and Age *

Age	Existing Diabetics		New Diabetics During 1940		Potential Diabetics	
	Males	Females	Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)	(7)
All Ages	196,400	313,000	18,800	31,100	1,376,000	2,497,000
Under 15	6,600	6,600	800†	800†	370,000	675,000
15–19	3,700	3,700	200†	200†	139,000	259,000
20–24	3,900	4,200	200	200	129,000	249,000
25–29	4,000	4,500	300	600	124,000	240,000
30–34	5,500	7,100	600	1,000	115,000	220,000
35–39	7,800	11,500	800	1,500	107,000	202,000
40–44	10,700	17,400	1,100	2,400	99,000	180,000
45–49	15,900	28,800	1,700	3,300	92,000	158,000
50–54	20,000	36,700	2,700	4,500	77,000	125,000
55–59	26,000	45,700	3,000	5,000	54,000	86,000
60–64	28,200	48,600	2,700	4,500	35,000	54,000
65–69	26,800	44,000	2,400	3,800	21,000	31,000
70–74	21,100	32,300	1,400	2,100	10,000	13,000
75–79	10,500	14,900	700	900	3,000	4,000
80–84	4,700	5,600	200	300	1,000	1,000
85+	1,000	1,400	...	....	....	....

* Based upon the rates shown in Table 3 and the United States census of population, April 1, 1940.
† Assumption based upon estimate of existing diabetics.

tween 50 and 60, and a little under half was at ages 60 and over. The peak, for quinquennial age groups, is found at ages 60 to 64 years, the males in this age group constituting 5.5 per cent of the total diabetic population and females 9.5 per cent. The average age of male diabetics was 55.6 years, and of the females, 56.7 years.

The foregoing estimate of a minimum of 500,000 diabetics in 1940 may be compared with several other estimates. In a review of diabetes incidence in the United States in 1930, Joslin, Dublin, and Marks [3] estimated the number of diabetics as 400,000 at the most. For this estimate, they made use of the diabetes prevalence rates, specific for sex and age, as observed in the Massachusetts survey. More recently, the U. S. Public Health Service issued an estimate of 660,000 diabetics in the United States in 1937, basing its figure upon the findings of the National Health Survey, with an adjustment for under-enumeration.[6] Their method involved multiplication of the crude overall diabetes prevalence rate observed in the Survey, by the total United States population for 1937. To adjust for under-enumeration, the result was then "multiplied by the ratio of the 1935 death rate [from diabetes] in the United States (Bureau of the Census) to the Health Survey death rate." Both of these steps may introduce a bias toward too high an estimate. In the first place, the crude overall diabetes prevalence rate of the Survey is influenced in an upward direction by the fact that the Survey population contains an appreciable excess of females who, by themselves, have a higher prevalence rate than males. The crude prevalence rate based upon the National Health Survey, therefore, is hardly applicable without downward adjustment to the total population of the United States in 1937, in which males exceeded females in number. Second, the use of the ratio of the 1935 diabetes death rate in the whole country to that found in the Survey may lead to an over-correction. Since the deaths reported in the Survey were obtained by questionnaire, it is possible that deaths from diabetes were understated to a greater extent than cases. The cases reported were alive

on the day of the census, whereas the deaths may have occurred at any time within the preceding year, with a consequent increase in liability to error in reporting. The Public Health Service estimate for the number of diabetics in the country as a whole may be too high for another reason: namely, that the National Health Survey, of which they made use, represents the situation in an urban population, whereas indications are that the prevalence of diabetes, age for age, is lower in rural than in urban areas.[3, 7]

An estimate prepared by one of us (M. S.) for Joslin in 1939 yielded a figure of 1,000,000 diabetics for 1950. This was based upon an assumption of an average duration of 20 years from onset of diabetes to death; the assumption now appears to have been rather optimistic for the general population.[8]

GROWTH OF THE DIABETIC POPULATION

The outlook for the next few decades is that the number of diabetics will increase at a much greater rate than the population, and that the problem of diabetes will gain in importance. If it is assumed that the course of the diabetes prevalence rates according to sex and age as observed in the National Health Survey remain unchanged, then it is expected that the number of diabetics will increase by 18 per cent in the decade from 1940 to 1950, while the total population may grow only by 9 per cent. Present indications are that our total population will be at a maximum about 1985, when it will be 22 per cent greater than it was in 1940*; however, over the same time, the diabetic population may increase by 74 per cent. The more rapid increase of the diabetic population than of the total population arises from two factors: first, the ever-increasing proportion of persons at the older ages; second, the more rapid increase in the number of females than of males at these ages.

In accepting the assumption that the course of the diabetes prevalence rates, according to sex and age, as observed in the National Health Survey, will continue to prevail without change, it is realized that no allowance is being made for the effect that organized efforts to make the general practitioner and the lay public more diabetes conscious may have upon future prevalence rates. It is quite likely that as these efforts become more successful, there will be an increase in diabetes case finding. Another factor that may raise the prevalence rates is the likelihood of further increases in the after-lifetime of diabetics beyond those already observed. It is obvious that by lengthening the life of diabetics, the proportion of them in our midst will increase. Still another consideration arises from the trend of our standard of living. As it continues to higher levels and is accompanied by a further increase in food consumption beyond the lessened physical requirements which result from our growing mechanization, the prevalence of diabetes may also show an upward trend. Although research is under way at present on the prevention of diabetes, the outlook for practical results appears too remote to warrant, at this time, the assumption of a favorable effect on future diabetes prevalence.

NEW DIABETICS

The data of the National Health Survey, together with information regarding mortality among diabetic patients of the George F. Baker Clinic during 1926 to 1929 reported by Joslin, Dublin, and Marks,[9] provide the material with which it is possible, by a suitable actuarial technique, to esti-

* These estimates are based upon the "medium" forecast of population published by Thompson and Whelpton in *Estimates of the Future Population of the United States, 1940–2000*, National Resources Planning Board, Washington, D. C., 1943, Table 7, p. 68.

mate the age and sex distribution of persons becoming diabetic during the course of a year.* Although the mortality experience among the patients of the George F. Baker Clinic relates to a period somewhat earlier than the Survey, it is believed suitable for the present computations. The fact that the mortality experience of the Baker Clinic antedates somewhat the period of the National Health Survey is an actual advantage, as there would naturally be a lag between the results obtained in a large metropolitan medical center and the corresponding situation in the country as a whole, where treatment is sometimes inadequate or carried out under adverse conditions. Furthermore, the years 1926 to 1929 are at a sufficiently late date to insure that there was at that time already familiarity with the management of diabetics on insulin therapy, and the drug was in wide use.

Age and sex characteristics of diabetes onset rates: The first result emerging from the computations was a series of diabetes onset rates specific for sex and age—that is, a table of figures showing, for each sex and age, the chances that a non-diabetic will acquire the disease within one year. The results are shown for quinquennial age groups in Table 3, columns 4 and 5. As indicated earlier, the results represent the situation at a minimum. Correction for understatement in the Survey would give proportionally higher figures at each age.

An increase in diabetes onset with advance in age is apparent quite early in life; among young adults of ages 20 to 24 years, new cases arise annually at the rate of 2.8 per 100,000 for males and 3.8 per 100,000 for females. The onset rates mount with an accelerating rapidity up to about age 55—more so for women than for men. Thus, in the age group 55 to 59 years, males acquire the disease at a rate of 102 per 100,000 or about 35 times the rate at ages 20 to 24, while females of ages 55 to 59 have a diabetes onset rate of 180 per 100,000, or about 45 times that of ages 20 to 24. After age 55, the diabetes onset rates increase at a less rapid pace and reach a peak rate of 125 per 100,000 males at ages 65 to 69 years, and a rate of 201 per 100,000 females of the same ages. The decrease in diabetes onset rates thereafter is quite rapid; for example, at ages 80 to 84, the annual onset rates for both males and females were about 66 per 100,000 persons. In this connection, attention is again called to the uncertainty of the time of onset of diabetes at the older ages.

The relative susceptibility of males and females to diabetes may be measured by the ratio of the onset rate for females to that for males of the same age. Thus, the ratio of the onset rates for females to males increases to a maximum of 2.2 at ages 40 to 44 years, and thereafter decreases, so that a ratio of 1.6 is found at ages 65 to 69 years, while after age 75 the rates of onset in the two sexes are not very different. The great acceleration in diabetes onset among females on approach of the menopause is indicative of the endocrine changes that are characteristic of that period of life.

Age and sex distribution of new diabetics: On the basis of the foregoing diabetes onset rates specific for sex and age, it is estimated that at least 50,000 persons in the United States became diabetics during 1940; about three-eighths were males and a little under five-eighths were females. The distribution of the new diabetics during 1940 according to sex and age is shown in Table 4, columns 4 and 5. Somewhat more than one-quarter of the new diabetics acquired the disease at ages under 50 years; almost one-half fell into the

* A brief outline of the method employed is given in a note at the end of this paper.

relatively narrow range from 50 to 64 years; and the remaining quarter were at ages 65 and over when they became diabetic. The average age of the new diabetics in 1940 was somewhat over 54 years for both sexes.

If we assume that the course of the diabetes onset rates according to sex and age as found in this paper remains unchanged in the future, then the new diabetics in 1950 will be 18 per cent greater than in 1940, and those in 1985 will be greater by 67 per cent. These increases are much greater than those of the total population. As in the case of the estimates of the total number of diabetics, the increases in the annual number of new cases arise from the growth of total population, from the increasing proportion of older persons, and from the increasing proportion of females in the population.

EVENTUAL DIABETICS IN THE POPULATION

Chances of eventually becoming diabetic: With the annual diabetes onset rates specific for sex and age computed in the manner described, and with an appropriate life table, it is a relatively simple matter to compute the chances that a man or a woman of any age will eventually become diabetic. The life table used for this purpose was based upon the mortality experience of white persons in the general population of the United States during 1935, this year being sufficiently close to the period of the National Health Survey. The results of the computation are shown in Table 3, columns 6 and 7.

Two characteristics become apparent from an examination of these data. In the first place, up to age 50, the chances of eventually becoming diabetic for females are almost twice those for males. Second, the chances rise very slowly from birth to a maximum at age 30, fall gradually until about age 50, and then fall quite rapidly at the higher ages. Thus, among females, the chances of eventually becoming diabetic increase to a peak rate of 42.6 per 1,000 at age 30, then fall to 23.8 per 1,000 at ages 60 to 64, and to 10.0 per 1,000 at ages 70 to 74. In the case of males, the peak in the probability of eventually becoming diabetic is 22.8 per 1,000 at age 30, while in the age group 60 to 64 years, the figure is 14.8 per 1,000. In short, of our population under age 50, over 4 per cent of the females and more than 2 per cent of the males will become diabetic sometime during the course of their lives. These chances of eventually becoming diabetic are greater than the chances of eventual death from the disease since many diabetics die from other causes.

Age and sex distribution of the potentially diabetic population: An estimate of the age and sex distribution of eventual diabetics in the population at the census of 1940 is easily obtained. It simply calls for the multiplication of the numbers of the population (less those already diabetic), subdivided by sex and age, by the corresponding chances of eventually becoming diabetic. On this basis, it is found that at least 3,873,000 of those in the population of 1940 may eventually become diabetic; their age and sex distribution is shown in Table 4, columns 6 and 7. Of the total, 35.5 per cent are males and 64.5 per cent are females. About one-quarter of the number in the 1940 population who may eventually become diabetic will be found at ages under 15, and almost half are between the ages of 15 and 40.

SUMMARY

1. Using the diabetes prevalence rates according to sex and age as observed in the National Health Survey, it is estimated that there were *at least* 500,000 diabetics in the United States in 1940. Almost two-fifths of the diabetics were males and over three-fifths were

females. One-half of the total diabetics were at ages 60 and over.

2. During the next few decades, the number of diabetics in the United States will increase at a much greater rate than the total population. From 1940 to 1950, an increase of 18 per cent may be expected in the number of diabetics, while the total population is expected to grow only by 9 per cent.

3. At least 50,000 persons in the United States became diabetic during 1940; about two-fifths were males and three-fifths females. Not quite half were under 55 at the onset of their diabetes; somewhat more than one-quarter became diabetic between ages 55 and 64; and one-quarter were at ages 65 and over when they developed the disease.

4. Of our population under age 50, over 4 per cent of the females and more than 2 per cent of the males will eventually become diabetic.

NOTE ON METHOD

This note outlines the procedure followed in arriving at the diabetes onset rates.

In a stationary (life table) population let

l_x = number who live to attain age x

r_x = proportion of persons at age x with diabetes

$l_x^a = r_x \cdot l_x$ = number of diabetics attaining age x

i_x = number becoming diabetic during the year of age x to $x+1$

q_x^a = chance, per head, that a diabetic just attaining age x will die *from any cause* within the year of age

d_x^a = number of deaths *from any cause* at age x to $x+1$ among diabetics in the stationary population

Then

$$(1)\quad l_x^a + i_x - d_x^a = l_{x+1}^a$$

Assuming that the new diabetics at age x to $x+1$ were exposed to the risk of death as diabetics at that age for one half year on the average, and further, that their mortality was not different from that of those already diabetic, we have

$$(2)\quad d_x^a = q_x^a \left(l_x^a + \tfrac{1}{2} i_x\right)$$

Substituting (2) in (1) and solving

$$i_x = \frac{l_{x+1}^a - l_x^a(1 - q_x^a)}{1 - \tfrac{1}{2} q_x^a}$$

The chance that a non-diabetic of age x will become diabetic within the course of the year of age is

$$p_x^a = \frac{i_x}{l_x - l_x^a}$$

The chance of eventually becoming diabetic at or after age x is

$$\frac{\sum_{t=0}^{t=\infty} i_{x+t}}{l_x - l_x^a}$$

The life tables used were those for white males and white females in the general population of the United States in 1935.

REFERENCES

1. Perrott, G. St. J., Tibbitts, C., and Britten, R. H. The National Health Survey—Scope and Method. *Pub. Health Rep.*, 54:1663, 1939.
2. Personal communication.
3. Joslin, E. P., Dublin, L. I., and Marks, H. H. Studies in Diabetes Mellitus; II. Its Incidence and the Factors Underlying Its Variations. *Am. J. M. Sc.*, 187:433, 1934.
4. Bigelow, G. H., and Lombard, H. L. *Cancer and Other Chronic Diseases in Massachusetts.* Boston: Houghton Mifflin, 1933.
5. Joslin, E. P., Root, H. F., White, P., and Marble, A. *Treatment of Diabetes Mellitus.* Philadelphia: Lea & Febiger, 1940, p. 32.
6. U. S. Public Health Service. The Magnitude of the Chronic Disease Problem in the United States. National Health Survey, 1935–1936. *Sickness and Medical Care Series, Bulletin No. 6, 1938.*
7. Joslin, E. P., Dublin, L. I., and Marks, H. H. Studies in Diabetes Mellitus; III. Interpretation of the Variations in Diabetes Incidence. *Am. J. M. Sc.*, 189:163, 1935.
8. Joslin, E. P., Root, H. F., White, P., and Marble A. *Loc. cit.*, p. 23.
9. Joslin, E. P., Dublin, L. I., and Marks, H. H. Studies in Diabetes Mellitus; VI. Mortality and Longevity of Diabetics. *Am. J. M. Sc.*, 195:596, 1938.