Reprinted from Odontologisk Revy, Vol. 12, 1961, No. 1

The Effect of a Low-Refined-Carbohydrate High-Protein Diet upon Nonfasting Blood Sugar[1]

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INTRODUCTION

There is published material regarding the effect of (1) low-carbohydrate, (2) high-protein, and (3) low-carbohydrate high-protein diets upon the *fasting* blood sugar and the *glucose tolerance pattern*. The conclusions, in the main, indicate that these dietary regimes lead to a reduction in the blood sugar concentration.

Two areas have received scant attention: (1) the effect of a low-*refined*-carbohydrate high-protein diet upon the fasting *low* blood sugar and upon the *flat* or *inverted* glucose tolerance pattern, and (2) the results of a low-*refined*-carbohydrate high-protein regime upon the *nonfasting* blood sugar.

This report will attempt to analyze the changes in *nonfasting blood sugar* following a three-day diet of a low-*refined*-carbohydrate high-protein type.

[1] This study was made possible in part by a grant from The American Society of Anthropometric Medicine and Nutrition.

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Submitted for publication 7.XI.1960.

REVIEW OF THE LITERATURE

In order to comprehend the design and results of this study, it is necessary to review briefly the present thinking regarding: (1) *the effect of diet upon blood sugar,* and (2) *the present status of nonfasting blood sugar.*

Effect of Diet upon Blood Sugar

It is recognized that blood *sugar* and blood *glucose* are not synonymous. Blood sugar contains glucose. In addition, there are *saccharoids* (Benedict's term for the quantities of non-glucose, nonfermentable blood substances). Some biochemical techniques measure only negligible quantities of saccharoids (SOMOGYI, NELSON, SHAFFER, and HARTMANN). Other procedures (Folin-Wu method) include appreciable quantities of saccharoids if whole blood is used and much smaller quantities when serum is employed. However, the two techniques measure essentially the same because of a greater concentration of glucose in serum [1]. In the interest of space, these terms will be used interchangeably. Where the difference is important, mention will be made of the specific technique employed. According to SUNDERMAN and his group [2], there is no method which as yet has been designed to measure only glucose in the blood.

Effect of Low-Carbohydrate Intake Upon Blood Sugar: Studies have been reported in both: (1) *lower animals,* and (2) *human beings.*

Lower Animal Studies: GARNER and ROBERTS [3] studied the 17-hour fasting blood sugar levels in a group of rats and hamsters who had been fed previously a low-carbohydrate and high-fat or high-protein diet. They concluded that the fasting blood sugar levels are consistently lower in animals on a low-carbohydrate regime than in those who were subjected to a high-carbohydrate dietary course.

The publications dealing with high-carbohydrate dietary intake are pertinent to this discussion also because, in a negative way, they support the findings observed with low-carbohydrate intake. For example, DOHAN and LUKENS [4] studied the effects of the administration of large amounts of glucose upon the experimental production of diabetes mellitus in cats. They showed the development of islet lesions which were related directly to the degree and duration of hyperglycemia. HOUSSAY and MARTINEZ [5] investigated the development of diabetes mellitus in rats. They observed that, in all of the 95 percent pancreatectomized rats fed a high carbohydrate diet, diabetes mellitus developed in seven months. In contrast, even after eight months, only 82 percent of rats supplied with a high protein diet proved to be diabetic. In another experiment, all rats were fed the same high carbohydrate diet but the quantity of food consumed was varied. All overfed rats developed diabetes mellitus within two months. All of the normally fed acquired diabetes mellitus within seven months. However, even after eight months, only 43 percent of the underfed rats had developed diabetes mellitus. The authors conclude that the excess dietary carbohydrate content exerts an unfavorable influence on the progression of diabetes mellitus since the diet contained only five percent fat and adequate protein.

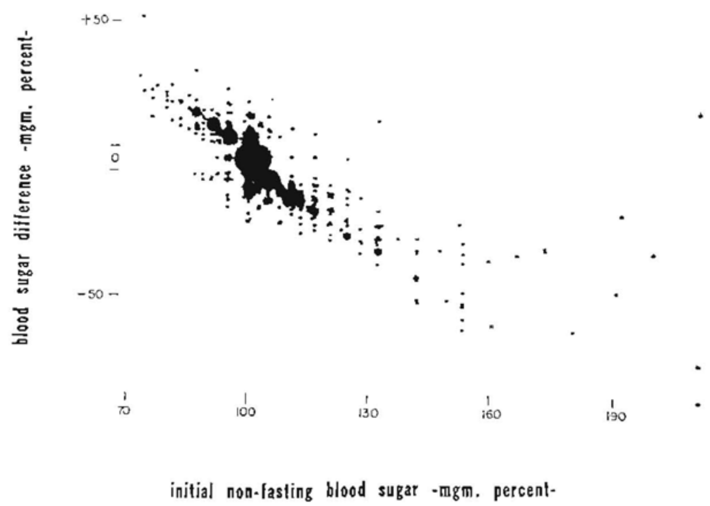

Figure 1. Comparison of nonfasting blood sugar (Folin method) initially (shown on the abscissa) and after a three-day low-refined-carbohydrate high-protein diet (demonstrated on the ordinate).

Human Studies: The relationship of low-carbohydrate diet has been studied with respect to the *fasting*, the *nonfasting* blood sugar and the *glucose tolerance test*.

LUNDBEK[6] examined 13 human subjects on a three-day high (512 grams) carbohydrate diet and on a three-day low (135 grams) carbohydrate regime. The *fasting* blood sugar for those on a high carbohydrate regime was found to range from 75 to 102 mg. percent with a mean of 89 mg. percent. In contrast, those subjects on a low carbohydrate intake demonstrated a fasting blood sugar range from 74 to 97 mg. percent with a mean of 88 mg. percent. However, no statistical analysis is included in the report.

HALDI and WYNN[7] studied the effect of carbobydrate intake upon the *nonfasting* blood sugar levels in 59 medical students. Under the conditions of this experiment (600 calorie breakfast, 127 grams versus 38 grams carbohydrate content) both one-hour and three-hour determinations were lower after the low carbohydrate breakfast (20 mg. percent lower at one-hour and 7 mg. percent at two hours).

A number of investigators have considered the *dextrose tolerance* after a period with a low carbohydrate dietary regime. HIMSWORTH[8], HIMSWORTH and MARSHALL[9], and CRAIG[10] all have demonstrated a reduction in dextrose tolerance after a low carbohydrate regime. This is generally explained on the basis of an impairment in insulin sensitivity. IRWING and WANG[11], however, studied 12 normal young male and female subjects. Dextrose tolerance was observed following daily diets of 100 versus 300 grams of carbohydrate. Within the limits of these dietary ranges, there was no ostensible difference in tolerance. WILKERSON and co-workers[12] confirmed tbese findings in a group of 57 nondiabetic men and women (18—59 years of age) using diets containing from 50 to 300 gms. of carbohydrate daily. These authors conclude that there is no need for high carbohydrate preparation for oral glucose tolerance tests in people who present no evidence of restricted food intake.

KRASNYANSKII[13] observed the variations in the blood sugar concentration in men during the course of a day. He noted that the blood sugar level exhibits a wavelike curve and the frequency and amplitude of the waves are directly related to the carbohydrate content of the food intake.

The conclusion to be drawn from these published reports is that fasting and postprandial blood sugar are lower following low-carbohydrate dietary periods than when high-carbohydrate foods are ingested. The other conclusion which may be made is that dextrose tolerance decreases after a low-carbohydrate period.

Effect of High-Protein Intake upon Blood Sugar: Major emphasis has been placed upon the use of high-protein intake in the treatment of diabetes mellitus. In this regard, two published reports are cited. ADLERSBERG[14] and GUBBAY[15] point out that a high-protein diet is better tolerated by diabetic patients because of the relatively slow processes of liberation of glucose from protein. In other words, blood sugar fluctuations are less under such a regime.

The observations with high-protein dietary intake are in accord, therefore, with the findings in connection with low- and high-carbohydrate intake. Thus, it is logical to turn next to the available material on low carbohydrate *and* high-protein intake.

Effect of Low-Carbohydrate High-Protein Intake upon Blood Sugar: It is difficult to delimit the publications which deal with the low-carbohydrate high-protein diet combination. Four representative published reports are included here which describe the general picture.

SWEENEY[16] studied the dietary effects upon the fasting blood sugar in a group of presumably normal male medical students. The students subsisting for two days upon a high-carbohydrate regime, demonstrated a

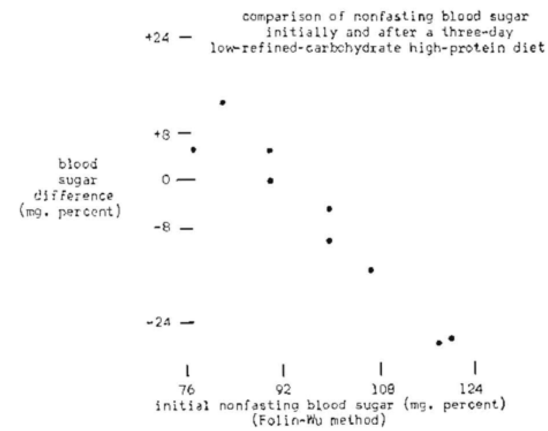

Figure 2. Comparison of nonfasting blood sugar (Folin–Wu method) initially (shown on the abscissa) and after a three-day low-refined-carbohydrate high-protein diet (demonstrated on the ordinate).

fasting blood sugar of 84 mg. percent in contrast to a fasting level of 69 mg. percent in the students on a two-day high-protein regime. CONN and NEWBURGH[17] examined the blood sugar response over a four to six-hour period following the administration of a protein meal versus a glucose-equivalent meal. The blood sugar levels with the high-protein intake varied from 72 to 86 mg. percent. In contrast, blood sugar values with the glucose-equivalent meal ranged from 60 to 170 mg. percent. FRYER et al.[18] point out, in a general way, that capillary and venous sugar levels are lowest during periods when a subject subsists on a low-carbohydrate and high-protein diet. POLLACK[19], also in general terms, recommends high-protein and low-carbohydrate diets in the treatment of diabetes mellitus. He discusses the reasons for such a regime and indicates that free sugars are rapidly absorbed and used whereas complex starches and proteins are more slowly assimilated. CLAYTON and RANDALL[20] studied 24 women (ages 17 to 29; weight 114.8 to 193.5 pounds) for a two-year period. The patients were subjected to high-protein versus high-carbohydrate breakfast meals of equal caloric value (450 calories). These investigators show that, postprandially, the blood sugar level rises in one-half hour almost four times as much following a carbohydrate versus a protein regime.

The conclusion to be drawn from studies concerning low-carbohydrate high-protein diets and blood sugar confirms the earlier observations with low-carbohydrate *versus* high-protein regimes. It appears that high-protein and low-carbohydrate both tend to produce less fluctuations in blood sugar than high carbohydrate diets. There is one point which deserves special note because of its bearing on the results of this report. Mention has already been made[17] that, following a carbohydrate meal, the blood sngar range increases so that more cases of both *hypo-* and *hyperglycemia* result.

Blood Glucose Criteria

In order to consider the problem of the present status of nonfasting blood sugar, it is necessary to consider: (1) *sugar homeostasis,* (2) *fasting versus nonfasting blood sugar,* and (3) *physiologic blood sugar levels.*

Sugar Homeostasis: A number of investigators[21-23] have indicated that, despite dietary intake, blood sugar levels remain surprisingly constant in the healthy individual. This is possible only through the interplay of a host of endocrine factors exquisitely attuned to permit sugars to be absorbed from the intestinal tract and utilized at a critical rate. The concensus among authorities is that the diurnal blood sugar fluctuations under physiologic conditions are, therefore, relatively small.

Fasting versus Nonfasting Blood Sugar: The question naturally arises as to what type of blood sample will provide the most diagnostic information about carbohydrate metabolism. There are some investigators who contend that the *fasting* blood sugar is the most critical measure. There are others who support the dextrose tolerance test. Finally, some authorities prefer *postprandial* blood sugar determinations.

SOSKIN[24] makes a plea for the use of the intravenous dextrose tolerance test as the best diagnostic reflection of the efficiency of blood sugar regulation by the liver under the influence of various endocrine glands.

On the other hand, a number of investigators support the postprandial determination as the most diagnostic sample. JOHN[25] studied 22,808 blood sugar determinations in presumably nondiabetic individuals under fasting and postprandial conditions. He indicates that a blood sugar sample two and one-half to three huors after a fairly heavy carbohydrate meal provides the most critical information. He observed that, from two and one-

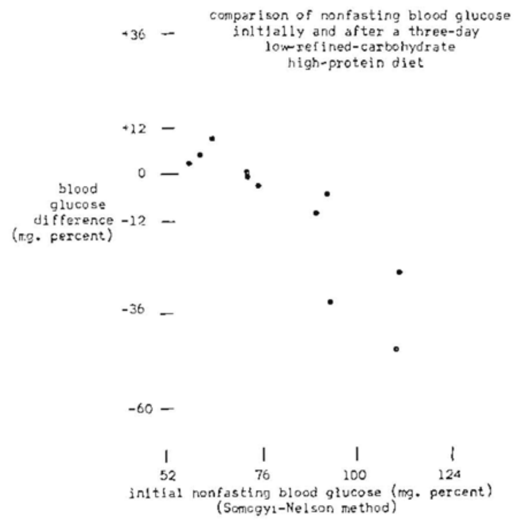

Figure 3. Comparison of nonfasting blood glucose (Somogyi—Nelson method) initially (shown on the abscissa) and after a three-day low-refined-carbohydrate high-protein diet (demonstrated on the ordinate).

half to six hours postprandially, blood sugar ranges from 70 to 120 mg. percent. In a subsequent report, JOHN[26] makes a plea for the three-hour postprandial blood sugar test as the best index of carbohydrate metabolism. SINDONI[27] contends that information regarding blood sugar metabolism is best obtained during a patient's physiologic activities. He states that the glucose tolerance test is, therefore, not a good procedure because it creates an artificial strain upon carhohydrate metabolism. Thus, it is not a true measure of the patient's metabolic capacity for food. He observed, in 20 normal nondiabetic patients, a fasting blood sugar of 91 mg. percent. After a test breakfest of 32 grams protein, 64 grams fat and 95.6 grams carhohydrate, the 30 minute level was 91.8, at one hour 84.4, at one and one-half hours 85.6, two hours 86.2, at three hours 89.2, and four hours 90.1 mg. percent. Thus, the fasting and nonfasting sugar levels are surprisingly similar. SOSKIN[24] also asserts that the *oral* dextrose tolerance test imposes an artificial strain upon the blood sugar regulating mechanism and that, as ordinarily used and interpreted, it is practically worthless.

It would appear, from the reports described in this section, that *fasting* and *nonfasting* blood sugar levels are very similar. Further, there is the feeling among some investigators that nonfasting blood sugar levels may be more representative of carbobydrate metabolism than fasting determinations or the findings derived from dextrose tolerance studies.

Physiologic Blood Sugar Levels: The question naturally arises as to what the physiologic blood sugar range is during the 24-hour period. Secondly, the question must be answered as to how *age* effects blood sugar. With respect to diurnal changes, experiments are available both in: (1) *lower animals,* and (2) *human experiments.*

Lower Animal Studies: PITTS[28] studied the diurnal blood sugar rhythm of normally fed female white rats. He observed that the difference between the noon and midnight determinations was only a magniture of about 10 percent. Further, he noted that during 36–48 hours of fasting the same cycle persisted. By training rats to feed at different times with respect to their activity cycles, be demonstrated that the blood glucose changes parallel the feeding rather than the activity pattern. On the basis of this information, this investigator concludes that the diurnal blood sugar cycle is small and that it is probably due to feeding babits. GREISHEIMER and coworkers[29] found a sexual difference in the blood sugar changes in rats fasted for 42 hours. The total fall for females was 27.8 mg. percent (67 percent of this between 12 and 24 hours); that for males was 20.9 mg. percent (59 percent of this between 12 and 24 hours).

Human Studies: General observations have been made by MEYER[30]. He points out that the diurnal patterns for blood sugar in the human may be grouped into three categories. The first includes those individuals characterized by *decreasing* values in the morning with a maximum at noon. Other individuals demonstrate patterns with *increasing* values in the morning, a maximum before noon and a second maximum in the afternoon. Finally, there are those who show completely disorganized cycles with increases and decreases throughout the 24 hour period. Though the author makes no mention as to the possible cause or causes, it might well be related to the varied eating habits among different individuals. JONAS et al.[31] studied the diurnal blood sugar curves in six nondiabetic individuals. He observed a rise approximately one hour after each meal and a return to within the fasting level about two hours postprandially. The overall fluctuations ranged from 75–155 mg. percent.

A number of interesting experiments have been performed with regard to blood sugar and starvation. Though they are not directly pertinent to this discussion, they do demonstrate that physiologic blood glucose levels lie within a critical and narrow range. LENNOX[32] studied the blood sugar levels in eight individuals who fasted for 16 days. Before the fasting state, the blood sugar determinations averaged 90 mg. percent. During the first week of the fasting period, the blood sugar declined. However, following this period, the levels rose again to approximately the prefasting range. SLOTOPOLSKY[33] confirms the previous observations and adds that the return to normal values occurs between the fifth and tenth fasting days. CHABRABARTY[34] investigated 407 cases of slow starvation not complicated by disease in the Bengal Famine of 1943–45. During the starvation period, the dextrose tolerance test showed a delayed rise in blood sugar with the peak occurring in approximately three hours. In contrast, during convalescence, the glucose tolerance pattern rose to a peak at approximately one hour with a return to the original levels within three hours.

GREISHEIMER[35] studied the blood sugar changes with regard to sex. Fifty-four adults (28 women and 26 men) were fasted for 60 hours. Blood was drawn at 12, 36, and 60 hours for blood sugar determinations (Shaffer–Somogyi method). She shows that the initial fall in blood sugar was greater in the female for the first 12–36 hours. After 60 hours, there was only a five percent difference in the total decrease in each group (25.6 percent female and 20.6 percent male).

Several studies attempt to relate the fasting to nonfasting blood sugar levels. SWEENEY[36] observed eight medical students. Four were examined under a regime of a regular diet and four were deprived of food for 24 hours prior to the study. Blood samples were drawn every two hours. The mean daily *fasting* blood sugar was found to be 80.2 mg. percent with a range of 77–94 mg. percent. In contrast, the mean daily *nonfasting* blood sugar was 92.8 mg. percent with a range of 74.2–151 mg. percent. Thus, it can be observed that the mean is lower and the spread smaller under fasting conditions. MACY[37] studied blood sugar in 936 females ranging in age from three months to 79 years. No preparatory diet was recommended nor was a standard meal given. She found that the mean fasting level proved to be 93 mg. percent. She also observed that the level rose to 105 mg. percent within one hour and then progressively declined to 98 mg. percent by three hours. Thus, the mean changes were indeed small throughout a three-hour postprandial period.

Age and Blood Sugar: There is still considerable discussion as to whether blood sugar is physiologically higher in elderly persons. JOHN[38] studied the *fasting* blood sugar levels in 1,000 nondiabetic persons. The range of fasting blood sugar was found to be 80–110 mg. percent. He also noted a very slight but uniform increase with each decade from a mean of 91.8 mg. percent in the first decade to 107.4 mg. percent in the eighth decade. KINSELL et al.[39] agree with John that there is a physiologic increase in the blood sugar concentration with advancing age. As evidence he points out that fasting "true blood sugar" is not uncommonly observed in ranges of 130–140 mg. percent. DEREN[40], on the other hand, disagrees with the concept that fasting blood sugar is higher in elderly persons. He found, from a study of the oral dextrose tolerance test in 50 subjects over 55 years of age, that the mean fasting blood sugar is 88.4 mg. percent.

GILLUM et al.[41] observed the effect of age upon *postprandial* blood sugar from an examination of 577 presumably normal men and women above the age of 50. All subjects consumed a carbohydrate meal two hours prior to the blood sugar determinations. The mean value obtained for presumably nondiabetic individuals was 101 mg. percent in contrast to his normal fasting standard of 76–96 mg. percent. From this he concluded that the physiologic postprandial blood sugar level is slightly higher in elderly individuals.

CHESROW and BLEYER[42] measured the *glucose tolerance pattern* in 39 nonambulatory and 41 ambulatory patients between the ages of 60 and 109. They observed a delay in the return of the curve to within normal limits. On the basis of their findings, they recommend that the glucose tolerance test be prolonged to three hours in patients over 60. Thus, indirectly, it is indicated that the glucose tolerance patterns are higher in elderly persons. BRANDT[43] studied the carbohydrate tolerance test among an elderly group of patients and observed that it correlated strongly with age. Because of the great frequency of higher blood sugar levels in the aged, he recommends that different standards be used for normality in the old versus the young. Others, including ALBANESE et al.[44], PETRIE and his coworkers[45], HOFFSTATTER et al.[46], MARSHALL[47], SPENCE[48], NISSEN and SPENCER[49], and HALE-WHITE and PAYNE[50] all voice the same opinion.

The consensus is that blood sugar is normally higher in elderly subjects. However, these conclusions are based only on the more frequent occurrence of higher blood sugar levels in older people. In other words, these conclusions are being justified on the basis that what the greatest number possess is physiologic. This concept can be seriously questioned. For example, 95 percent of the population demonstrate dental caries. On the basis of this logic, dental caries must then be regarded as physiologic.

Objections to the Dextrose Tolerance Test: Criticism has been directed against tolerance testing as a reliable index of carbohydrate metabolism because of the variations in serial findings. These have been explained away in part on the basis of differences in gastric emptying and intestinal absorption. FREEMAN et al.[51] subjected a group of 35 presumably healthy male individuals to two glucose tolerance tests one week apart. The average variation in fasting blood sugar was found to be 9 mg. percent. At one hour the differences were as great as 31 mg. percent with a maximum difference of 90 mg. percent. On the basis of such observations, these investigators conclude that the oral glucose tolerance test cannot be regarded as highly diagnostic. UNGER[52] performed two-hour glucose tolerance tests in 152 presumably healthy subjects without hyperglycemia (blood sugar less than 130 mg. percent 90 minutes postprandially). They observed that 54.6 percent of their patients exceeded the Mosenthal two-hour standard of 100 mg. percent. The conclusion is then drawn that the test, as commonly performed and interpreted, is variable and that modest elevations of the two-hour samples are not specific for a diagnosis of diabetes mellitus. The explanation that is offered is that the differences are due to delayed gastric emptying time. MYERS and MCKEAN[53] and EVENSEN[54] support Unger by claiming that gastric emptying time is a variable which modifies the glucose tolerance pattern. Further, JORGENSEN[55] regards intestinal absorption as another variable which explains the inconsistencies observed in the oral glucose tolerance test.

Objections to Fasting Blood Sugar: In the main, the objections to the use of the fasting blood sugar as an index of carbohydrate metabolism are very much the same as the criticisms directed against the dextrose tolerance test[25, 27]. In other words, fasting conditions represent an artificial situation. Therefore, they do not allow a true estimate of the patient's metabolizing food potential. KINSELL and other panelists[39] cite the recent event of a five percent detection of new diabetics in five Boston hospitals by using one hour postprandial blood sugar determinations on patients who had been tested negatively by fasting determinations. CHESROW and

BLEYER[56], in a study of 1,000 patients between 60–110 years of age, found that only 17.1 percent of the diabetic group and none of the pre-diabetics had a high fasting blood sugar.

Objections to Postprandial Blood Sugar: Actually, there are no specific publications to indicate that the postprandial blood sugar is a poor measure of carbohydrate metabolism. Mention is often made that postprandial variations exist by virtue of different diets. However, those investigators who compare fasting blood sugar versus dextrose tolerance versus post-prandial blood sugar appear to prefer the latter. Certainly, those who measure postprandial blood sugar under standard dietary regimes claim that this may well be the best diagnostic tool for the appraisal of carbohydrate metabolism.

METHOD OF INVESTIGATION

Six hundred and eighty-three ambulatory Caucasian patients were studied with regard to carbohydrate metabolism as measured by venous sugar analysis (Folin Method[57]).

Table 1. *Age and sex distribution.*

	Male		Female		Undetermined sex		Total	
	no.	%	no.	%	no.	%	no.	%
10–29	20	2.93	35	5.12	1	0.15	56	8.20
30–49	113	16.54	124	18.16	1	0.15	238	34.85
50–69	135	19.77	173	25.33			308	45.10
70–89	28	4.10	39	5.71			67	9.81
undetermined	5	0.73	7	1.02	2	0.29	14	2.05
total	301	44.07	378	55.34	4	0.59	683	100.00*

* approximate

Table 1 shows the age and sex distribution. Generally, the sample is divided almost equally between the two sexes. On the basis of age, the greatest number of patients proved to be in the 50–59 year category though subjects ranged from the second to the ninth decades. Of the sample of 683 subjects, the age was not determined in twelve, the sex not recorded in two, and both age and sex not listed in two. Therefore, in subgroup analyses, 14 individuals are not included. The mean ages for the male and female group proved to be 50.95 and 50.79 years with standard deviations of 14.15 and 14.94 respectively.

Each patient presented in the clinic between 9:00 and 12:00 A.M. after a customary breakfast meal. A venous sample was drawn and a non-fasting blood sugar determination made immediately by the Folin technique. The scores so obtained will hereafter be referred to as based on a *regular diet.*

The patient was then instructed with regard to diet. He was informed that, for the next three days, to consume as much meat, fish, fowl, vegetables, whole grain (as breads, cereals, vegetables), eggs, nuts, and butter as desired. The patient was also permitted weak tea, decaffeinated coffee, natural condiments, and water ad libitum. Specific instructions were given not to eat sugar and refined sugar products, white flour foods, fruit and fruit juices, milk and milk products (except butter), preserved meats, hydrogenated fats, and alcohol. The only dietary supplement given the patient for the three-day period was vitamin C in the form of 75 mg. tablets of rose hips. Hereafter, in the interest of conservation of space, this regime will be referred to as *basic* or *preparatory diet* (preparatory to blood tests). In order to be as certain as possible that the instructions were followed, the patient was given a form on which all foods eaten were to be recorded during the three-day period.

Finally, the patient was instructed to return on the fourth day between 9:00 and 12:00 A.M. after breakfast based on the recommendations above. At this second visit, a venous sample was again drawn and a blood sugar determination made immediately by the Folin procedure.

RESULTS

The findings will be considered in two ways: (1) *general characteristics,* and (2) *subgroup analyses.*

General Characteristics

The mean initial blood sugar for the 683 patients proved to be 105.95 mg. percent with a standard deviation of 20.31 mg. percent. This can be interpreted to mean that approximately two-thirds of the patients, specifically 68 percent, ranged from 85.64 to 126.26 mg. percent. This is quite in accord with postprandial determinations described earlier in this report. Three days after subsisting on the preparatory diet, the mean blood sugar proved to be 101.42 mg. percent with a standard deviation of 10.36 mg. percent. This can be interpreted to mean that approximately two out of every three individuals ranged from 91.06 to 111.78 mg. percent. It can, therefore, be observed that there was a decrease in the mean blood sugar. Further, more of the individuals clustered about the mean after the three day preparatory regime.

Table 2 outlines the changes in nonfasting blood sugar which occurred in the 683 patients during the three-day interval. Approximately one-fifth

Table 2. *Effect of three-day low-refined-carbohydrate high-protein diet upon nonfasting blood sugar.*
(Folin Method [57])

Initial blood sugar (regular diet)	Final blood sugar (three-day low-refined sugar high-protein diet)	Number of patients	Percentage of patients
>100	greater than initial blood sugar	12	1.76
>100	unchanged blood sugar	7	1.02
>100	<100	46	6.74
>100	less than initial blood sugar but still >100	86	12.59
>100	100	133	19.47
100	>100	29	4.25
100	100	126	18.45
100	<100	51	7.47
<100	100	101	14.79
<100	greater than initial blood sugar but still <100	38	5.56
<100	>100	26	3.80
<100	unchanged blood sugar	9	1.32
<100	less than initial blood sugar	19	2.78
	total	683	100.00

(18.45 percent) of the patients had initial nonfasting blood sugar levels of 100 and the same findings after the three-day diet. It can also be noted that approximately one-third of the subjects with levels initially *greater* than 100 mg. percent either decreased to or at least approached 100 mg. percent during the three-day period. Also, it is noteworthy that one-fifth (20.35) of the subjects with initial blood sugar levels *below* 100 mg. percent increased to or, at least, approached 100 mg. percent in three days. In other words, over half of the individuals (52.41 percent) with levels other than 100 mg. percent initially were found to have levels exactly of 100 mg. percent or approaching that value during the dietary period. These data indicate that there is a tendency on the part of the blood sugar to "find" a level of 100 mg. percent under this dietary regime.

The scores obtained for the 683 patients initially and after the dietary regime are pictorially reported in Figure 1. Shown along the abscissa are the initial blood sugar findings. The difference between the initial scores and the findings three days later are charted on the ordinate. The largest darkened area represents the collection of dots signifying the 126 patients with initial and final nonfasting levels of 100 mg. percent. It is very clear from this graph that there is a definite line of regression. The coefficient of correlation was found to be −0.8399. Thus, the evidence seems reasonable that, under this dietary program, patients with blood sugar *above* 100 mg. percent tend to be reduced to or about 100 mg. percent. Also, it appears that those scores *below* 100 mg. percent tend to rise to or about 100 mg. percent.

The question arose as to whether blood sugar changes would significantly differ if the low-refined carbohydrate high-protein diet were to be continued for longer than three days. To answer this question, 28 subjects were studied initially (regular diet), three days later (basic diet) and several days to weeks later maintaining the same basic dietary regime. Values of 115.93 ± 29.49, 103.00 ± 12.25, and 103.46 ± 9.22 were found respectively. Thus, it appears that blood sugar levels tend to migrate toward 100 mg. percent beyond the three day diet period. However, the major changes appear during the first three-day interval.

Subgroup Analyses

Attention will be directed to an analysis of the nonfasting blood sugar levels initially and three days later in terms of: (1) *sex*, (2) *age*, and (3) *age and sex*.

Sex: Calculation of the mean blood sugar initially (with regnlar diet) shows a mean nonfasting blood sugar of 107.20 mg. percent for men and 104.90 mg. percent for women with respective standard deviations of 19.93 and 20.66 percent. Three days later the values proved to be 102.25 ± 7.64 and 100.74 ± 10.99 respectively for the male and female groups.

Age: Table 3 summarizes the mean and standard deviation values with regular diet and after three days on a preparatory regime in terms of the age factor. In the first group of 55 subjects studied (10–29 years), the mean nonfasting blood sugar decreased from 98.62 to 98.29 mg. percent with a reduction in standard deviation from 11.96 to 5.59 mg. percent.

Table 3. *Blood sugar changes following a three-day low-refined-carbohydrate high-protein diet.*
(Folin Method [57])

Age groups	Regular diet mean	Regular diet standard deviation	After three-day low-refined-carbohydrate high-protein diet mean	After three-day low-refined-carbohydrate high-protein diet standard deviation	P
10–29 years					
total (55)*	98.62	11.96	98.29	5.59	.500
30–49 years					
total (237)	106.34	20.96	100.85	10.99	<.001
50–69 years					
total (308)	106.31	22.08	102.11	12.72	<.005
70–89 years					
total (67)	109.49	14.55	101.82	6.15	<.001

* number of subjects in parentheses

Table 4. *Blood sugar changes following a three-day low-refined-carbohydrate high-protein diet.*
(Folin Method [57])

Age and sex groups	Regular diet mean	Regular diet standard deviation	After three-day low-refined-carbohydrate high-protein diet mean	After three-day low-refined-carbohydrate high-protein diet standard deviation	P
10–29 years					
male (20)*	102.60	15.43	99.70	9.95	>0.400
female (35)	96.34	8.91	98.49	6.51	>0.200
30–49 years					
male (113)	108.47	22.25	103.11	9.89	<0.025
female (124)	104.40	19.59	98.80	11.57	<0.010
50–69 years					
male (135)	105.97	22.11	102.29	10.72	>0.050
female (173)	106.58	22.12	101.97	14.11	<0.025
70–89 years					
male (28)	107.39	11.49	100.79	5.06	<0.010
female (39)	111.00	16.37	102.56	6.79	<0.005

* number of subjects in parentheses

Thus, it appears that, though the mean has not changed appreciably, more of the cases cluster about the mean after the preparatory regime. However, an analysis of the difference of the means discloses that there is no statistically significant change ($P=.500$). The means for the 237 subjects in the next decade group (30–49 years) are 106.34 ± 20.96 and 100.85 ± 10.99. Here one can observe that the overall scores have approached 100 mg. percent both on the basis of the mean values and the reduction in the standard deviation. The significance of the difference of tbe means is clearly shown by a $P<.001$. It is noteworthy that, in the third and fourth age groups (50–69 and 70–89 years), the mean and standard deviation have once again decreased and the differences are significant.

Age and Sex: Finally, an analysis has been made on the basis of both sex and age as shown in Table 4. Once again, though the means and standard deviations indicate an approach to 100 mg. percent, the changes are not significant in the youngest age group. However, the significance increases, and the trend toward 100 mg. percent continues in the older age and sex categories.

DISCUSSION

The data thus far presented will be considered in the light of: (1) *general characteristics,* (2) *subgroup analyses,* and (3) *the method of laboratory testing.*

General Characteristics

The evidence from these 683 subjects indicates that there is a tendency for the nonfasting blood sugar to approach 100 mg. percent under the conditions of a high-protein and low-refined-carbohydrate diet. This is underscored by the reduction in the mean and standard deviation, by the very clearcut line of regression, and the high negative correlation.

It is, of course, hazardous to draw conclusions as to what normal nonfasting blood sugar should be from these data. However, the evidence at least suggests that 100 mg. percent might well be the ideal physiologic score.

The most interesting observation from this three-day dietary regime is that blood sugar levels below 100 mg. percent increased. These results, together with those mentioned above, make it feasible to speculate that: (1) protein and carbohydrate (other than refined) contribute measurably to blood sugar homeostasis, and (2) the delicate hormonal regulation of blood sugar functions more efficiently in a low-refined carbohydrate high-protein environment.

Subgroup Analyses

A study of the sex differences seems to indicate that the nonfasting blood sugar in the female is ordinarily much closer to 100 mg. percent than observed in the male. Also, these data tend to suggest that, with dietotherapy, the female responds with levels which more closely approximate 100 mg. percent. These data also suggest that 100 mg. percent may be the physiologic point.

The values summarized in this report suggest that, with increasing age, the response to diet is more pronounced. This may very possibly be due to the fact that nutritional imbalance is more serious in the aged. Thus, the imbalance may well not have been persisting long enough to produce clearcut changes in blood sugar in the young. Whether this is the entire explanation or only part of it cannot be concluded from this particular study. In any case, the observations just made with respect to age also seem to prevail in the age and sex analysis.

Method of Laboratory Testing

Attention should be directed to the fact that blood sugar in the 683 subjects was determined by the Folin technique[57]. It was thought important to establish whether similar patterns would be derived by studying blood sngar and blood glucose hy other methods. Accordingly, nine (1) protein and carbohydrate (other than refined) contribute measurably subjects were investigated as previously described except for the blood sugar levels which were done by the Folin-Wu method[58]. Also, eleven subjects were studied by means of the Somogyi-Nelson technique[59-61].

Table 5 shows that blood sugar and glucose mean values were lower

Table 5. *Blood sugar and glucose changes following a three-day low-refined carbohydrate high-protein diet.*

	Regular diet		After three-day low-refined-carbohydrate high-protein diet	
	mean	standard deviation	mean	standard deviation
blood sugar (9*) Folin–Wu method [58]	98.22	14.99	91.33	4.12
blood glucose (11*) Somogyi–Nelson method [59-61]	81.27	18.88	71.82	9.18

* number of subjects in parentheses

following the three-day diet. Also, Table 5 points out that the range shrinks considerably during the same three-day interval. An examination of Figures 2 and 3 emphasis the same line of regression previously reported for the 683 subjects.

SUMMARY

1. Nonfasting blood sugar analyses of 683 patients were made initially (during a period of regular diet) and three days after a high-protein and low-refined-carbohydrate regime.
2. Evidence is presented to show that, under this dietary course, the nonfasting blood sugar tends to seek a level at or about 100 mg. percent.
3. From the data presented in this report, it appears that the changes which occur with this dietary regime become more significant with increasing age.
4. It would appear, at least presumptively, that 100 mg. percent may well be the ideal (physiologic) nonfasting blood sugar level according to the methods employed in this study.

SAMMANFATTNING

Avsikten med undersökningen är att analysera hur fasteblodsockret förändras efter 3 dagar på en äggviterik kost innehållande mycket litet raffinerade kolhydrater.

I litteraturöversikten ges till en början en översikt av hur kosten påverkar blodsockret. Tidigare undersökningar tyder på att en kost rik på äggvita och med en låg kolhydrathalt tenderar att åstadkomma mindre fluktuationer i blodsockret än en kost rik på kolhydrater. Författarna konstaterar vidare att blodsockerhalten är förhållandevis konstant hos den friska individen under fysiologiska förhållanden. De diskuterar också vilken typ utav blodprov, som ger den bästa informationen beträffande kolhydratmetabolismen. Somliga undersökare anser att det är bäst att mäta fasteblodsockret, medan andra föredrar den s. k. sockerbelastningstesten. Andra auktoriteter anser slutligen att den postprandiala blodsockerbestämningen är att föredraga. Mot alla metoderna kan emellertid en viss kritik riktas, och författarna använder själva i sin undersökning det s. k. nonfasting blood sugar level. Vid undersökningen fastställdes blodsockerhalten hos 683 patienter mellan kl. 9—12 på förmiddagen efter deras vanliga frukostmål. Det anges ej i undersökningen hur lång tid efter måltiden

som provet togs. Patienten instruerades att för de påföljande tre dagarna äta så mycket kött, fisk, fågel, grönsaker, bröd, cerealia, ägg, nötter och smör, som han önskade. Patienten fick också dricka svagt te, dekoffeinerat kaffe och vatten ad libitum samt använda naturliga kryddor. Han fick också särskilda instruktioner att inte använda socker eller raffinerade sockerprodukter, vitt mjöl, frukt, fruktjuice, mjölk eller mjölkprodukter med undantag av smör, konserverat kött, »hydrogenated fats» och alkohol. Det enda tillägg som patienten fick var C-vitamin. För att försäkra sig om att patienten följde instruktionerna fick han ett formulär, på vilket han skulle skriva upp, allt vad han åt under denna tredagarsperiod. Slutligen fick patienten order om att återkomma den fjärde dagen mellan kl. 9 och 12 efter frukost. Vid detta andra tillfälle togs ett nytt blodprov och sockerbestämningen gjordes som i den första undersökningen genom Folins metod. Den initiala blodsockerkoncentrationen för de 683 patienterna var 105.9 mg%. Efter 3 dagar på den äggviterika kosten var motsvarande värde 101.4 mg%. Det visade sig att ungefär $^1/_5$ av patienterna hade ett blodsockervärde av ungefär 100 mg% både före och efter försöket och att $^1/_3$ av patienterna med värden högre än 100 visade värden som sjönk till omkring 100 mg%, och ytterligare $^1/_5$ av patienterna med initiala blodsockervärden under 100 mg% ökade sina värden till omkring 100. Dessa resultat tyder enligt författarna på att under den ifrågavarande kostregimen tenderar blodsockerkoncentrationen att hålla sig vid ungefär 100 mg%. Iakttagelsen att låga blodsockervärden ökade till omkring 100 mg% är enligt författarna det mest intressanta resultatet. Detta skulle tyda på, att äggvita och andra kolhydrater än de raffinerade på ett mätbart sätt bidrager till blodsockrets homeostas, och vidare att den hormonella regleringen av blodsockret fungerar mera effektivt på en kost, som är rik på äggvita, och som innehåller små mängder raffinerade kolhydrater. Vid en uppdelning av materialet visade det sig, att männen har en något högre blodsockerkoncentration än kvinnorna både före och efter försöket. Vad åldern beträffar har åldersgrupperna mellan 30—70 år högre blodsockervärden än både de yngre och de äldre åldersgrupperna. Förändringarna, som inträffar, i samband med försöket synes vara mera uttalade för de äldre åldersgrupperna än för de yngre.

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