A STUDY OF BLOOD SUGAR VALUES IN THE LOCAL POPULATION IN RESPONSE TO ORAL GLUCOSE

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SYNOPSIS

The present study attempts to start a collection of data on glucose tolerance measurements on the population of Singapore. The study was carried out on 23 subjects (19 males and 4 females) drawn mainly from the student, academic and non-academic staff population, their relatives and friends. A 50 g oral glucose load was used for the test. From the results obtained, the upper limits for normality appear to be 100 mg.% glucose at fasting, 180 mg.% glucose as the peak value whether at 30 or 60 minutes and 120 mg.% glucose at 2 hours after glucose administration.

INTRODUCTION

The present study was prompted by the need to establish blood-sugar values as criteria for the diagnosis of Diabetes mellitus here in Singapore. The glucose tolerance test is the classical biochemical test for detecting the diabetic state. Most of our clinicians assess the GTT values of their patients against data obtained for normal subjects by workers in the West. Not a few, however, base their criteria on the 1965 WHO report. The importance of assessing an individual's GTT values against data from tests on normal subjects conducted in an identical manner is, however, generally recognised. But due to the complete lack of appropriate control data this practice has not been adhered to. The present study attempts to start a collection of data on glucose tolerance measurements in the population of Singapore. It also provides some idea as to the range of GTT values obtained here.

MATERIALS AND METHODS

Subjects and Experimental Conditions

Subjects were drawn mainly from the students and academic and non-academic staff population of the University, their relatives and friends. They were accepted for the glucose tolerance test only if they were enjoying good health, were aglycosuric and did not have a family history of diabetes.

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Oral glucose tolerance test was carried out according to the following procedure:— Each subject was instructed to be on a normal diet of at least 200 gm. of carbohydrate per day for a minimum of 3 days prior to the test. The subject was asked to fast for 10 hours overnight before being given 50 gm. glucose to be taken orally. The test was carried out with the subject in the recumbent position. A saline drip was set and the blood drawn at various time intervals from an antecubital vein into centrifuge tubes containing small amounts of solid heparin to prevent coagulation. This method of sampling was used because an attempt was also being made to estimate insulin concentrations. Otherwise all that will be required could be easily obtained from a prick of the finger.

Blood samples were taken just before administration of glucose, then 10, 20, 30, 60, 90 and 120 minutes after glucose. 0·2 ml. aliquots were used for glucose estimation and plasma separated from the remaining blood within 15 minutes of sampling by centrifugation, and stored at—15°C for insulin estimations. Whenever possible, urine samples were taken at fasting, 30, 60, 90 and 120 minutes for glucose test.

CHEMICAL ANALYSIS

Blood glucose was estimated by pipetting 0·1 ml. blood into 0·9 ml. water in a centrifuge tube and deproteinizing with 0·5 ml. 5% $ZnSO_4$ and 0·5 ml. 0·3 n. $Ba(OH)_2$ according to the method of Somogyi (1945). After centrifugation, 0·1 ml. of supernatant was used for the estimation of glucose by the glucose oxidase method of Hugget and Nixon (1957) as modified by Randle (unpublished) in the preparation of the reagents. The glucose oxidase and the peroxidase reagents were prepared in concentrated form with neutral saturated ammonium sulphate solution and stored as stock solutions

at 4°C. Just before use, appropriate aliquots of the stock solutions are taken and diluted with the phosphate buffer of pH 7. Glucose standards were run with each set of estimations. The standards were prepared by diluting appropriate amounts of standard stock solution of glucose in water saturated with benzoic acid. There was no difference between glucose standards prepared in this way and that prepared fresh with water without benzoic acid.

Urine sugar was tested for with Benedicts Reagent or with Clinistix (Ames).

RESULTS

Table I shows some of the personal data of all the subjects studied. There were 19 males and 4 females with ages ranging from 19 to 57 years. Actual body weight rather than % ideal weights are shown in the table because there is at present no data on the standard weights of the population in Singapore from which ideal weights could have been calculated. The authors do not feel that weights for Chinese provided by the Weh Fung Insurance Company of Shanghai, China, in use since pre-war days, are necessarily valid in our local context even though it was used by McFadzean and Yeung (1968) for Hongkong Chinese. Subjects no. 22 and 23 are, however, noticeably overweight even by Western standards of weight measurements. Apart from these two subjects, the rest have been arranged in the table according to age and glucose tolerance.

The individual GTT values obtained for all the subjects studied are shown in Table II. All subjects were aglucosuric throughout the test. Fasting glucose values were below 100 mg.% in all cases and ranged from as low as 60 mg.% to 94 mg.%. In the majority, the glucose value reached a peak within one hour of glucose administration, to as high as 177 mg.% in a particular case, but

TABLE I

PERSONAL DATA OF ALL SUBJECTS STUDIED

No.	Name	Sex	Race	Age	Height	Weight (lbs.)
		Subjects with normal glucose returns.				
1	T. K. H.	M	Chi.	21	5′ 8¼″	143
2	T. W.	M	Chi.	24	5′ 5½″	120
3	W. Y. G.	M	Chi.	24	5′ 7 ″	145
4	T. T. S.	M	Chi.	26	5′ 5 ″	120
5	C. C. M.	M	Chi.	27	5′ 4¾″	138
6	S. D.	F	Ind.	28	5′ 5¾″	144
7	H. L.	M	Chi.	29	5′ 3¼″	112
8	S. S.	M	Ind.	34	5′ 5 ″	138
9	C. H.	M	Chi.	36	5′ 6 ″	133
10	K. S.	M	Ind.	44	5′ 5½″	139
		Subjects with delayed glucose returns				
11	P. R.	F	Ind.	19	5′ 0 ″	114
12	J. L.	M	Chi.	23	5′ 7 ″	120
13	N. P. L.	M	Chi.	24	5′ 11″	125
14	Y. E. H.	M	Chi.	25	5′ 2½″	102
15	M. B. E.	M	Chi.	25	5′ 6 ″	126
16	C. L. F.	F	Chi.	26	5′ 3 ″	110
17	M. S.	M	Ind.	28	5′ 6¾″	148
18	A. L.	F	Chi.	42	5′ 0 ″	105
19	T. C. G.	M	Chi.	44	5′ 6 ″	158
20	W. A. F.	M	Chi.	47	5′ 2½″	117
21	P. L.	M	Ind.	57	5′ 5 ″	125
22	C. K. L.	M	Chi.	25	5′ 10″	198
23	M. R.	M	Eur.	38	5′ 5¼″	166

Chi. = Chinese
Ind. = Indian
Eur. = Eurasian.

TABLE II

BLOOD GLUCOSE CONCENTRATIONS OF ALL SUBJECTS DURING A 50 GM ORAL GTT

Subjects	Blood glucose in mg./100 ml.						
	0′	10′	20′	30′	60′	90′	120′
1. T. K. H.	81	136	166	150	115	81	77
2. T. W.	92	124	128	143	125	85	72
3. W. Y. G.	65	75	108	101	91	90	67
4. T. T. S.	71	96	120	139	101	97	78
5. C. C. M.	78	—	—	116	98	92	80
6. S. D.	83	86	107	120	114	106	82
7. H. L.	74	94	136	140	155	117	80
8. S. S.	72	100	105	111	100	78	54
9. C. H.	78	88	107	116	109	98	84
10. K. S.	90	112	133	143	161	139	93
Mean ± SEM	78±4	101±7	123±7	128±5	117±7	98±6	77±2
S. D.	±11	±20	±21	±15	±22	±19	±8
	Subjects with delayed glucose returns (non-obese)						
11. P. R.	84	—	—	115	114	118	115
12. J. L.	74	107	143	155	135	100	87
13. N. P. L.	82	88	116	134	158	131	96
14. Y. E. H.	81	93	113	141	177	148	114
15. M. B. E.	86	115	137	145	133	147	119
16. C. L. F.	82	100	128	142	143	100	119
17. M. S.	84	90	95	97	128	109	104
18. A. L.	81	92	128	140	152	128	94
19. T. C. G.	81	107	138	158	144	118	104
20. W. A. F.	90	121	123	100	147	116	114
21. P. L.	60	99	114	124	131	135	106
Mean ± SEM	82±3	102±3	123±3	132±6	142±5	123±5	107±3
S. D.	±11	±9	±9	±19	±16	±16	±10
	(Obese)						
22. C. K. L.	92	103	113	125	147	145	103
23. M. R.	94	108	124	134	140	142	115
Mean ± SEM	93±1	105±2	119±6	130±5	144±4	141±2	109±6
Subjects 1-21(non-obese)							
Mean ± SEM	81±2	102±4	123±3	130±4	131±4	114±5	93±3
S. D.	±8	±17	±14	±20	±24	±21	±14

declining to less than 120 mg.% in the next hour. Some subjects had a more rapid decline in the glucose level than others. 10 subjects (nos. 1-10) had less than 10 mg.% above the fasting level at the 2 hour period. The other 13 subjects showed a delayed return, with 5 of the subjects (nos. 12, 13, 17, 18 and 20) having only a slight delay with glucose values less than 20 mg.% above fasting. Subjects no. 15 and 16 had high 2 hour values. For subject no. 15 this is probably due to a high 90′ value whereas for subject no. 16 there appears to be a 'kick back'. Subject no. 11 had an unusually flat curve which had no apparent clinical explanation.

Table II also shows the mean blood glucose concentrations of the subjects studied. The results were analyzed according to whether the subjects were obese or non-obese (by weight), with the latter group further subdivided according to whether the 2-hour glucose value fell within 10 mg.% of the fasting level (designated as normal and delayed glucose returns). There was a significant difference ($p < 0{\cdot}01$) in the mean glucose levels between subjects with normal and those with delayed glucose returns at 60, 90 and 120 minutes after oral glucose. The mean glucose values of both the obese subjects which also showed delayed

glucose returns, were comparable to those of the non-obese subjects of similar glucose tolerance.

Table III shows the mean GTT results of the subjects grouped according to age and to glucose tolerance. Age does not appear to modify significantly the GTT values especially if comparison was made between the older and younger subjects of similar glucose tolerance. There were, however, only 5 subjects above the age of 40 years including the 1 subject above 50 years of age. Attempts at increasing the number of subjects in these age groups proved unsuccessful. The various people approached were either too busy, or if they were individuals who were on retirement, did not fancy the idea of undergoing a glucose tolerance test. The use of 'hospital normals' i.e. patients in the wards suffering from disease other than diabetes proved an utter failure. Their GTTs were abnormal.

DISCUSSION

A 50 g. glucose load was used because this is the amount commonly used by our clinicians here. The number of subjects studied was limited by the difficulty in getting healthy subjects to volunteer for the glucose tolerance test. The number of tests that could be carried out per session was also limited by our attempts to obtain venous blood for estimating plasma insulin concentration in response to glucose load at the same time. The results obtained were, however, comparable to those obtained by other workers (Table IV).

The normal fasting blood sugar was less than 100 mg./100 ml. in all subjects as had been shown by most studies (Joplin and Wright, 1968). Only one of the twenty one non-obese subjects exceeded 90 mg./100 ml. Whereas both the obese subjects exceeded this value. The number of obese subjects is too small however to draw any valid conclusions.

The mean +2 S.D. of the 1-hour level was 158 mg./100 ml. when only subjects with a normal glucose return were considered (Table II). This value was raised to 179 mg./100 ml. if subjects with delayed glucose returns were also included. This is higher than values obtained by other workers though comparable to the peak value obtained by Buchanan and McKiddie (1967) at 30 minutes. For the establishment of GTT data, peak glucose values may be of more relevance than 1-hour values, as the maximum was reached in several subjects within 30 minutes.

TABLE III

THE MEAN GTT VALUES OF NON-OBESE SUBJECTS GROUPED ACCORDING TO AGE AND GLUCOSE TOLERANCE

Age of Subjects		Blood glucose in mg./100 ml.						
		0′	10′	20′	30′	60′	90′	120′
		Subjects with normal glucose returns						
Below 30 years Subjects 1-7	Mean	78	102	127	130	114	95	77
Mean age 26 yrs. (21-29 yrs.)	SEM	±3	±10	±9	±7	±8	±5	±2
	S. D.	±8	±21	±20	±16	±20	±12	±5
Above 40 years Subject 10		90	112	133	143	161	139	93
		Subjects with delayed glucose returns						
Below 30 years Subjects 11-17	Mean	82	99	122	133	141	122	108
Mean age 24 yrs. (19-28 yrs.)	SEM	±1	±4	±7	±8	±8	±8	±4
	S. D.	±4	±8	±16	±18	±19	±19	±12
Above 40 years Subjects 18-21	Mean	78	105	126	131	144	124	105
Mean age 48 yrs. (42-57 yrs.)	SEM	±6	±6	±5	±6	±4	±4	±4
	S. D.	±14	±11	±9	±21	±8	±8	±7

TABLE IV

ORAL GTT IN NORMAL SUBJECTS

Author	Particulars		Venous blood glucose mg./ 100 ml.							
			0′	10′	15′	20′	30′	60′	90′	120′
Buchanan and Mckiddie (1967)	50 g. glucose Glucose est:—	Mean	91		122		129	101	82	74
	Hagedorn Jensen 34 subjects	±1 S. D.	±10		±41		±26	±29	±21	±13
	Age 15-65 (mean 34) Weight 84-114%	Criteria for norm.	<110				<180			<120
Hale *et al* (1968)	50 g. glucose	Mean	65				91	72	60	58
	Glucose est:— glucose oxidase	±S. E.	±2				±4	±5	±5	±3
	14 subjects	Range	(50-76)				(57-110)	(40-102)	(20-102)	(35-80)
	Age 30-57 (mean 40) Weight 99-109%									
Joplin and Wright (1968)	50 g. glucose	Mean + 2S.D.	84				142	148		103
	45 subjects	Criteria	< 90					<150	<130	<110
	Age 18-52	for norm.								
Our own studies	50 g. glucose	Mean	81	102		123	130	131	114	93
	Glucose est:—	±1 S. D.	±8	±17		±14	±20	±24	±21	±14
	glucose oxidase	±S. E. M.	±2	±4		±3	±4	±4	±5	±3
	21 subjects									
	Age 19-57 (mean 32) non-obese.	Range	(60-94)	(75-136)		(95-166)	(97-158)	(91-177)	(78-148)	(54-119)
		Criteria for norm.	<100				peak <180			<120
Seltzer *et al* (1967)	Glucose 1·75/kg.	Mean	75	86		108	113	98	88	82
	Glucose est:—	±S. E. M.	±1	±2		±3	±4	±6	±3	±2
	Somogyi-Nelson 21 subjects									
	Age 23-54	Criteria								
	Weight 115%	for norm.	<100					<160		<110

A few occurred at 90 minutes in subjects with delayed glucose returns of >20 mg./100 ml. (Table I). The mean peak glucose value was found to be 141 mg./100 ml., when peak values for each subject irrespective of time was considered. 2 S.D. brought this value to 177 mg./100 ml. If the calculation of the mean peak value was confined to only subjects with a normal glucose return, only a small reduction in the value to 175 mg./100 ml. was obtained. Therefore there was no difference between 1-hour and peak values and 180 mg./100 ml. should be considered to be the upper limits of normality. The consideration of peak values would be possible only if complete GTTs were done. Otherwise the 1-hour values considered with the fasting and 2-hour values could be of value for detecting abnormality in glucose tolerance. From the present study, if 160 mg./100 ml. was to be considered as the upper limit for normality as has been used by several workers (Conn, 1958; Pyke, 1968; British Diabetic Association, 1968), 3 of the subjects would have had to be considered as abnormal, 2 of whom had normal glucose returns. All these subjects were aglucosuric. It is not possible in this study to come to a conclusion as to whether subjects with peak values between 160 to 180 mg./100 ml., but with GTT values otherwise normal, should be considered as "probable" diabetics.

A delayed glucose return with a normal GTT rather than a high peak value may be of greater value in the early diagnosis of diabetes. Several of the subjects in the present study, however, had delayed glucose returns of >10 mg.% though none had 2-hour levels which exceeded 120 mg./100 ml. That this could be diagnostic of "probable" diabetes has been suggested by Hales (1968). If this should be so, it is rather surprising that so large a proportion of the subjects studied should be prone to diabetes.

There is insufficient data from the older age group to draw any valid conclusions from this study as to whether age has any effect on glucose tolerance. If, however delayed glucose returns was an indication on decreased glucose tolerance, then age does have an effect on glucose tolerance. The proportion of subjects above 40 years of age with this type of glucose tolerance was higher than that found in the younger subjects. That glucose tolerance decreased with increasing age has also been shown by several other studies (Joplin and Wright, 1968).

In conclusion, the upper limits of normality for a 50 g. oral glucose tolerance test as shown by this study appears to be 100 mg.% glucose at fasting, 180 mg.% glucose as the peak value whether at 30 or 60 minutes and 120 mg.% glucose at 2 hours after glucose administration.

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