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Fat Metabolism in Diabetic Children

By

L. Barta, Viola V. Szobotka and Márta V. Tóth

First Department of Paediatrics, University Medical School, Budapest

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There are many data [7,16] to show that sensitivity to insulin is enhanced by a diet rich in carbohydrates. It was, on the other hand, found [1] that the blood sugar decreasing effect of insulin did not essentially change in children kept on a fat rich diet.

The decrease of the blood-sugar level goes usually hand in hand with that of free fatty acids [17]; it is well-known that changes in the level of free fatty acids and blood ketone bodies are sensitive indicators of the insulin effect [10,11,23].

The present study was designed to yield information concerning the following points.

(i) The influence of a fat rich diet on lipid metabolism in diabetic children.

(ii) The influence of insulin on the blood free fatty acid level in diabetic children with whose actual condition a considerable rise in the triglyceride and total fatty acid level would be expectable.

(iii) How far is the insulin modified by dietary fat.

(iv) The connexion between the decrease of the blood free fatty acid level and that of blood sugar.

Material and Method

Twenty hospitalized diabetic children between 8 and 15 years of age were distributed into two groups. The sex ratio was identical in both groups. The children's metabolism was practically in equilibrium, the morning urine contained ketone bodies only exceptionally. All children were treated with promptly acting insulin.

The children of the first group after the morning dose of insulin were given potato prepared in fat. In caloric value this meal was equivalent to the usual breakfast and ten o'clock snack. The amount of potato was double that of fat (e.g. 100 g of potato with 50 g of fat), hence in caloric value the fat was five times more than the carbohydrate. The fat was administered to the same patient once in the form of lard and once in that of sunflower oil.

The second group received 100 g to 200 g of curd sweetened with 20 g of glucose. This meal represented approximately as many calories as the usual breakfast. Thus more than 50 per cent of the calories was supplied by fat so that, as compared to the usual high carbohydrate diet, the children were moderately loaded with fat. Earlier investigations [2] showed that the action of insulin was pronounced after the administration of curd with glucose.

Blood sugar was determined first on an empty stomach and at 30 min. intervals during 4 hours. Estimations of total fatty acids, triglycerides, free fatty acids and total ketone bodies were performed first from blood collected before, and then 2 1/2 and 4 hours after the meal. The methods used were HAGEDORN and JENSEN'S for blood sugar; SMITH and KIK'S [18] for total fatty acids; CARLSON and WALDSTRÖM'S [3] for triglycerides; DOLE and MEINERTZ'S [6] for free fatty acids; WERK et al. [22] for total ketones.

As a control, blood sugar and serum fat were estimated before breakfast and after the ten o'clock snack both in diabetic children kept on a standard diet and in metabolically intact children of the corresponding age groups. In addition, therapeutically well regulated diabetic outpatients were examined for fasting blood total fat and fatty acid level.

RESULTS

The free fatty acid and ketone levels always changed in the same sense (Fig. 1). Although there was no close correlation between the magnitude of the respective changes, there was a statistically significant tendency for high concentrations of free fatty acids to be associated with high concentrations of ketone bodies (Fig. 2a). Changes in the total fatty acid and triglyceride levels were likewise parallel, and high respective concentrations had a tendency to being associated in this respect also (Fig. 2b). The decrease of blood sugar was approximately the same whether the patient had been given fat or curd, but changes in this respect were considerably less marked in patients on a standard diet (Fig. 3a). This may have been due to that the patients had two meals during the experimental period.

The form of fat, whether lard or vegetable oil, did not influence the changes (Table I). The free fatty

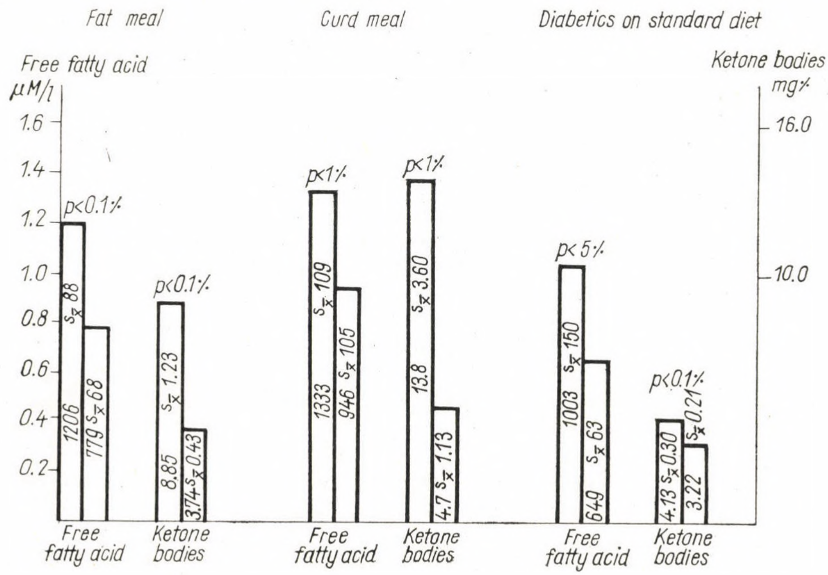

FIG. 1. Changes in the blood free fatty acid and ketone levels after the consumption of fat and curd

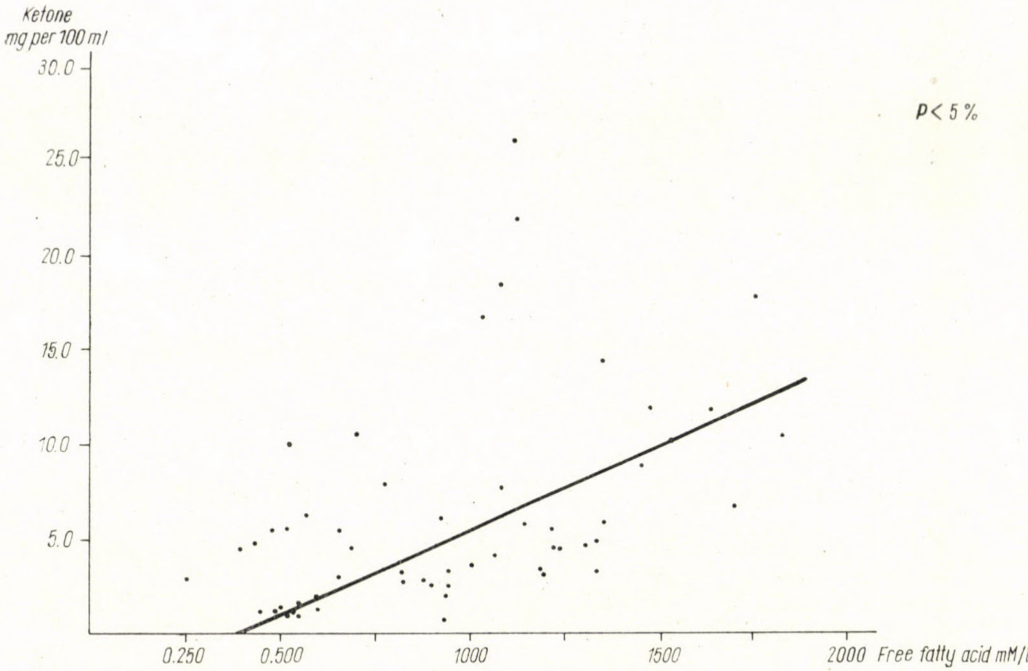

FIG. 2a. Correlation between the blood free fatty acid and ketone levels

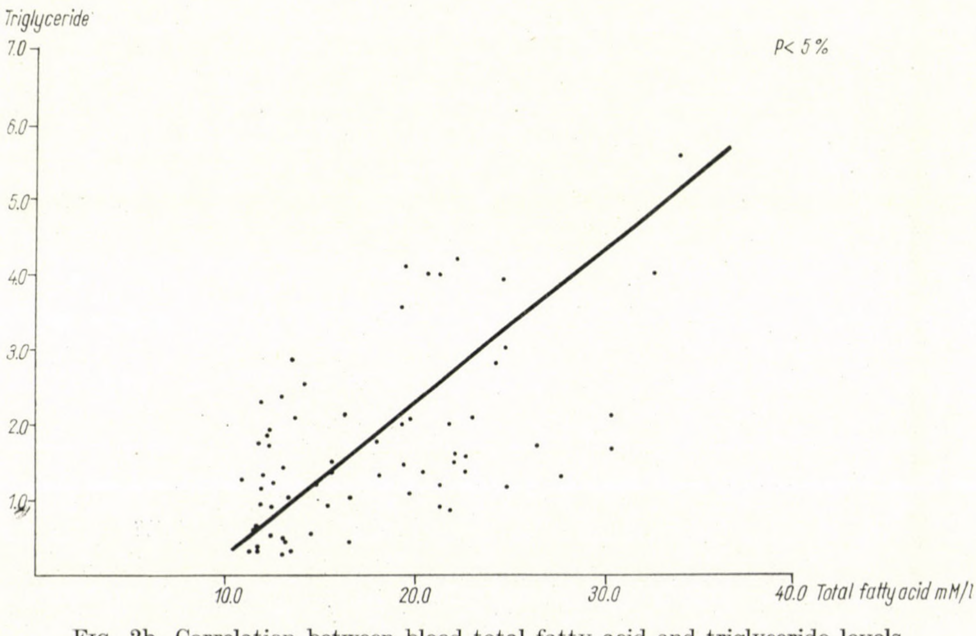

FIG. 2b. Correlation between blood total fatty acid and triglyceride levels

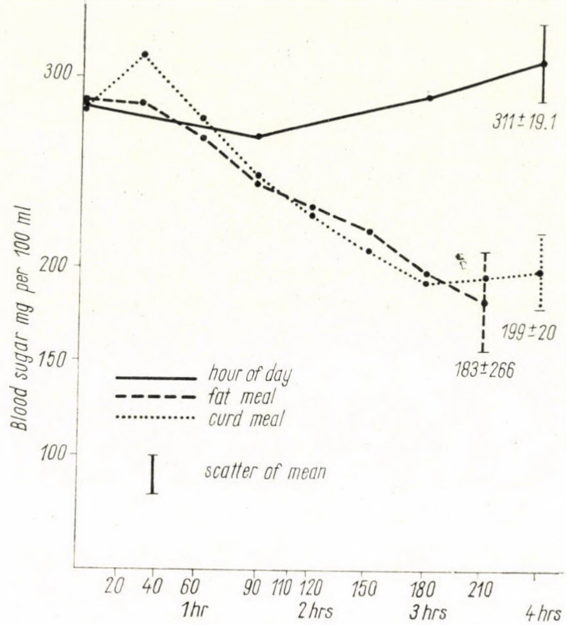

FIG. 3a. Changes in blood sugar after fat and curd consumption

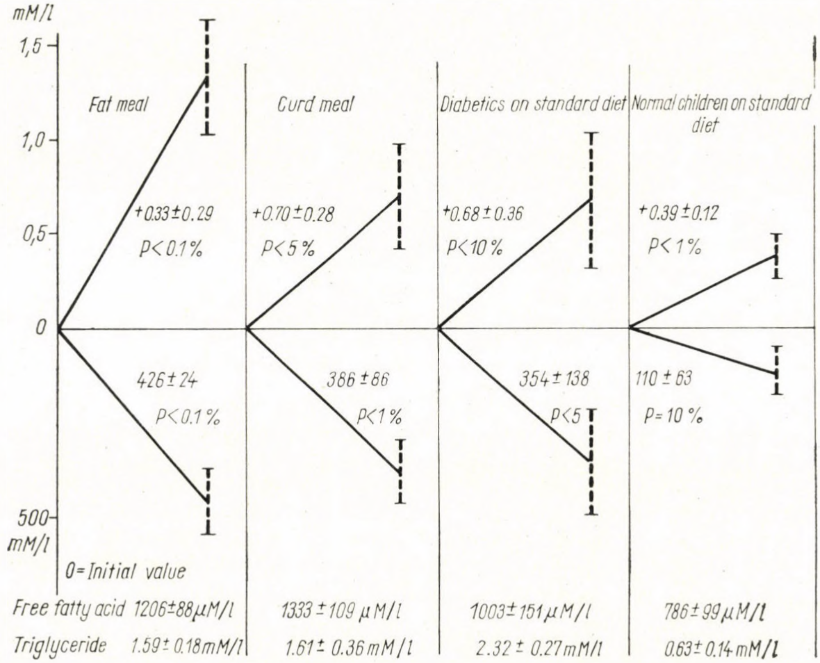

FIG. 3b. Changes in blood free fatty acid and triglyceride levels after fat and curd consumption

TABLE I

Effect of fat consumption on the blood sugar, ketone and fat levels

	Blood sugar mg%		Free fatty acid μM/1			Total fatty acid mM/1		Triglyceride mM/1		Ketone mg%		Nature of fat
1	302	80	1330	796	631	22.16	24.70	1.58	3.91			Vegetable oil
	218	50	1639	909	773	19.40	33.92	1.47	5.61	11.4	7.9	Lard
2	170	132	514	340	437	22.78	26.60	1.33	1.72	5.6	4.8	Vegetable oil
	220	94	609	427	472	18.20	27.86	1.34	1.31			Lard
3	272	140	1200	950	900	15.65	19.26	1.37	3.55	3.1	2.5	Vegetable oil
	284	116	1268	960	946	15.76	16.31	1.51	2.17	4.6	2.5	Lard
4	268	70	1333	1133	933	32.50	37.15	4.02	6.20	3.3	0.7	Vegetable oil
	298	98	1085	1014	685	35.67	43.55			18.3	4.5	Lard
5	302	140	1228	928	600	20.38	16.65	1.39	1.05	4.6	2.1	Vegetable oil
	278	162	1068	1000	934	24.88	30.32	1.15	2.12	4.2	2.0	Lard
6	356	148	1828	1066	1057					10.5	3.6	Vegetable oil
	240	108	1762	815	573					18.0	6.2	Lard
7	280	370	1575		396	11.90	13.70	1.14	2.09	10.2	4.6	Vegetable oil
	340	270	1094		820	11.90	14.82	0,95	1.20	7.7	3.2	Lard
8	320	204	486	340	255	12.30	20.70	1.92	4.00	5.4	2.8	Vegetable oil
	260	208	930	650	656	11.90	13.57	2.32	2.85	6.1	3.0	Lard
9	320	518	1446		1384	18.03	24.31	1.77	2.82	8.9	3.9	Vegetable oil
	280	462	1473		1158	12.48	19.54	1.22	4.10	12.0	5.9	Lard
10	379	154	1043		1192	19.78	23.10	1.06	2.08	16.6	3.4	Lard
Mean value:												
$\bar{x}$	287	193	1206		779	19.15	23.88	1.59	2.92	8.85	3.74	
s			±386		±298	±6.99	±8.22	±0.73	±1.52	±5.05	±1.77	
$s_{\bar{x}}$			±88		±68	±1.69	±1.98	±0.18	±0.38	±1.23	±0.43	
Change												
$\bar{x}$				−426		+4.7		+1.33		−5.10		
s				±369		±4.1		±1.19		±4.10		
$s_{\bar{x}}$				± 84		±1.0		±0.29		±1.00		
				$p<0.1\%$		$p<0.1\%$		$p<0.1\%$		$p<0.1\%$		

Initial and extreme values are given in respect of blood sugar; zero-, two- and four-hour values in that of free fatty acids; initial and final values for other determination.

$\bar{x}$ = mean value s = standard deviation $s_{\bar{x}}$ = standard error of the mean

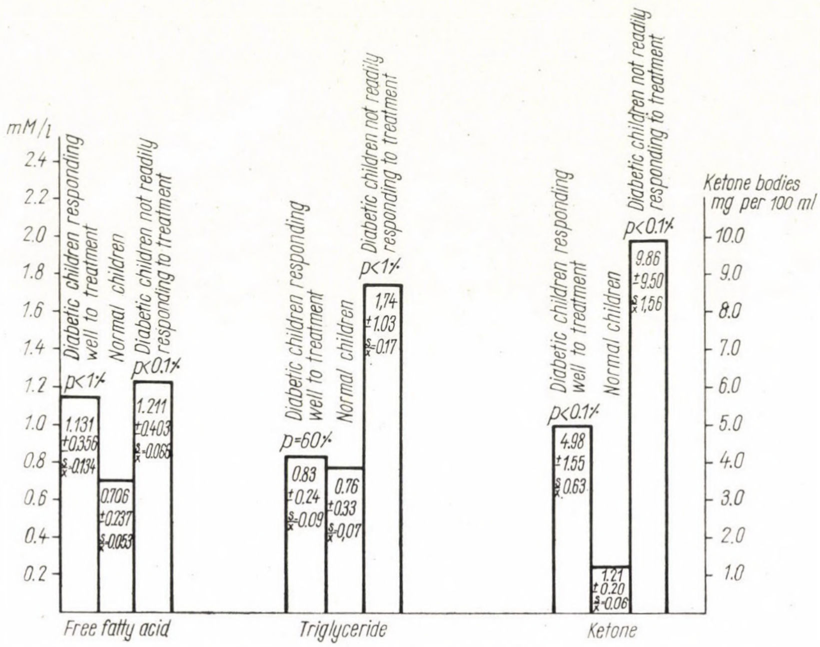

Fig. 4. Fasting blood free fatty acid, triglyceride and ketone levels in diabetic and non-diabetic children. p = Significance of difference between diabetic and normal children

acid and triglyceride levels were higher in diabetic than in healthy children. The difference was particularly pronounced in the patients not readily responding to treatment (Fig. 4).

Under the effect of insulin, a considerable rise in the triglyceride concentration did not prevent the fall of the blood sugar, free fatty-acid or ketone levels. Fig. 3b illustrates the deviations from the initial values of the triglyceride and free fatty acid levels during the various examinations. These changes invariably occurred in the opposite sense. The elevation of triglyceride concentration was generally significant, and was quite especially so after the administration of fat. The decrease of the free fatty-acid level was likewise significant, and likewise most pronounced after loading with fat; the difference between the various diabetic groups was less marked.

Discussion

The blood free fatty acid level is usually higher in children than in adults. The fasting values obtained by us in both the healthy and the diabetic children agree well with the values determined by Corvilain et al. [4] with Dole's method [6]; Persson et al. [15] with the method of Trout et al. [21]; and by Davidson

TABLE II

Fasting values

		Own observations	Davidson and Kaye [5]	Persson et al. [15]	Sterky et al. [20]	Corvilain et al. [4]
Serum glyceride mM/litre	Diabetic children not readily responding to treatment	1.74±0.17 (26)				
	Diabetic children responding well to treatment	1.02±0.12 (12)			0.73±0.03 (103)	
	Non-diabetic children	0.76±0.07 (20)			0.68±0.03 (118)	
Blood free fatty acid level, μM/litre	Diabetic children not readily responding to treatment	1211±66 (29)				
	Diabetic children responding well to treatment	1004±107 (12)	1120±420 (15)	1172±99 (10)	815.5±31.9 (42)	
	Non-diabetic children	706±53 (20)	1080±290 (17)	739±92 (6)	555.1±27.5 (36)	699±199
		8–15 years ± standard error of mean	2–13 years ± standard deviation	11–19 years ± standard error of mean	school children ± standard error of mean	4 months–10 years ± standard deviation

and KAYE [5] with GORDON's method [9], although the values found by STERKY et al. [20] in compensated patients were considerably lower. The fasting triglyceride level of our compensated patients was, similarly to the findings of STERKY et al. (20), but slightly above that of the controls, whereas a considerable rise was observed in the group not readily responding to treatment (Table II).

According to the behaviour of

blood sugar, the effect of insulin was more pronounced in children given fat or curd than in those kept on a standard diet, whereas there was no essential difference in the free fatty acid level. It follows that if the effect of insulin is judged on the basis of changes in the free fatty acid level, results are the same whether the blood sugar remains unchanged or becomes lower. It is clear from Fig. 3 that the rise of the triglyceride level did not affect the fall of free fatty-acid concentrations. A comparison on the fat and curd meals was especially instructive; the decrease of blood sugar level was approximately equal in both cases, that of the free fatty acid level was more marked after the fat meal, while the elevation of the triglyceride level was nearly twice as high after the fat meal as after the curd.

It is thus evident that a rise of the triglyceride level does not neutralize the effect of insulin, even if the patient is kept on a diet rich in fat and poor in carbohydrate.

Fats have undoubtedly a ketogenic, anti-insulin effect, although we have observed rising total fatty acid and triglyceride levels together with an intensive insulin action. This contradiction is, however, only apparent. Ketosis ensues if the effect of insulin is inhibited or weakened, for instance in the case of some infection, or if it ceases for a time, for instance between two doses. Carbohydrate deficiency promotes the development of ketosis. Following the administration of fat, the organism consumes its own sugar reserves, becomes deficient in sugar, and this makes the patient susceptible to ketosis even while receiving insulin [13, 14, 12, 19, 8]; it is clear that the disposition to ketosis must become still more pronounced after insulin has ceased to act. The effect of insulin, on the other hand, is not essentially influenced by a rise of the triglyceride and total fatty acid levels as long as the organism has an adequate supply of sugar. The considerable elevation of the triglyceride level was accompanied in our cases by a considerable fall of the free fatty acid level. It would follow that despite the marked susceptibility to ketosis, a fat rich diet does not weaken the effect of insulin in hyperglycaemic, non-ketotic children.

While in patients kept on a normal diet there was hardly any change in the blood sugar level, it dropped considerably after the consumption of curd, whereas the nature of the diet made no difference in the fall of the free fatty acid level. Diminution of the free fatty acid level is, accordingly, independent of the fall of blood sugar in insulin treated diabetic children.

Acknowledgement

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Summary

According to our experimental observations the blood free fatty acid and triglyceride levels change in opposite directions in insulin-treated diabetic children. A rise of the triglyceride level did not diminish the decrease in free fatty acid. Changes in the free fatty acid, ketone and blood sugar levels failed to indicate a contra-insulin effect after the consumption of fat in hyperglycaemic children. The decrease of the free fatty acid level was independent of changes in the concentration of blood sugar. Changes in the blood free fatty acid and ketone level went parallel, without a significant correlation between the height of these levels and the magnitude of the changes. The nature of the consumed fat (vegetable oil or lard) did not influence the observed metabolic changes.

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Dr. L. Barta
Bókay J. u. 53
Budapest VIII. Hungary