Enrichment of depot fat with odd and even numbered medium chain fatty acids

ROBERT B. ZURIER, ROBERT G. CAMPBELL, SAMI A. HASHIM, AND THEODORE B. VAN ITALLIE

Department of Medicine, St. Luke's Hospital Center, and Institute of Nutrition Sciences, Columbia University, New York City

ZURIER, ROBERT B., ROBERT G. CAMPBELL, SAMI A. HASHIM, AND THEODORE B. VAN ITALLIE. Enrichment of depot fat with odd and even numbered medium chain fatty acids. Am. J. Physiol. 212(2): 281-294. 1967. -Medium chain fatty acids shorter than laurate normally are absent in adipose tissue lipids. When these acids are present in dietary fats, they are transported via portal vein to liver where they are extensively metabolized. Transport of medium chain fatty acids into systemic circulation was achieved in rats with portacaval shunts. Enrichment of adipose tissue with medium chain fatty acids was effected by altering route of their transport to circumvent liver. Control animals and those with anastomoses were fed diets containing medium chain triglycerides of which the fatty acid constituents were C9 or C8 and C10 for periods up to 3 months. Fatty acid patterns by gas liquid chromatography were determined from samples of omental adipose tissue prior to and following portacaval shunting. Striking increases in proportions of C9 or C8 and C10 fatty acids of adipose tissue were noted in animals with portacaval shunts. By enriching depot fat with odd chain fatty acids such as pelargonate, it is possible to store appreciable quantities of fatty acids of which the terminal three carbon units are potentially glucogenic.

adipose tissue (omentum); portacaval anastomosis; pelargonate, caprylate; fatty acid transport

PLASMA FREE FATTY ACIDS (FFA) represent the transport form of lipid originating from adipose tissue and are readily available for oxidation or incorporation into lipid ester moieties of lipoprotein. Information concerning the transport and fate of FFA has been derived largely from studies of the behavior of long chain fatty acids. In contrast, medium chain fatty acids which differ markedly from the long chain fatty acids with respect to solubility and interaction with proteins usually are not constituents of the FFA transport system in the intact animal.

METHODS

Twenty-six male Sprague-Dawley rats weighing 250-300 g had been maintained on a nutritionally adequate stock diet deriving 26% of calories from fat (soy bean and corn oils: 50% linoleate), 54% from carbohydrate (wheat and corn meals), and 20% from protein (casein). The animals were separated into four groups depending on the sequence of portacaval anastomoses and medium chain triglyceride feeding. In group 1 (10 rats), an end-to-side portacaval anastomosis was performed on each animal. At operation a sample of omental fat was obtained. In a control group of rats of comparable weight (group 2; 8 rats) a sham operation was performed at which time omental fat also was obtained. Both groups of rats were placed in individual cages, allowed to convalesce, and were fed an experimental regimen consisting of a basic fat-free diet (Nutritional Biochemical Corp., Cleveland, Ohio), supplemented with an odd numbered medium chain (C9) triglyceride (tripelargonin). The diet, as modified, was adequate in vitamins and minerals and derived 17% of calories from protein (casein), 53% from carbohydrate (sucrose), and 30% from fat (tripelargonin).

The animals in groups 3 and 4 also were subjected to an initial sham operation, at which time samples of omen-
The fatty acid pattern of adipose tissue of the four groups of rats prior to and during feeding of tripelargonin and even numbered medium chain triglyceride.

### RESULTS

The fatty acid pattern of adipose tissue of the four groups of rats is shown in the second column of Table 1. It is apparent that the feeding for 1 month after portacaval anastomoses and tripelargonin feeding following portacaval shunting, the pelargonate content of the adipose tissue with odd and even numbered medium chain fatty acids prior to the shunting operation, and strikingly after operation.

The change in the long chain fatty acid patterns of adipose tissue in response to feeding of the experimental diets in the four groups of animals also is shown in Table 1. It is apparent that the feeding for 1 month of these regimens to sham-operated animals was associated with a drop in the proportion of linoleate and a concurrent rise in oleate of adipose tissue lipid. The enrichment of the adipose tissue with odd and even numbered medium chain triglyceride feeding following portacaval anastomoses, the adipose tissue was enriched slightly with medium chain fatty acids prior to the shunting operation, and strikingly after operation.

The fatty acid patterns of all the omental fat samples were determined by gas liquid chromatography following transmethylation of the extracted lipid with sodium methoxide.

### DISCUSSION

It has been possible to enrich adipose tissue glycerides with appreciable amounts of odd and even numbered medium chain fatty acids by shunting the portal venous blood of rats fed the parent triglycerides into the systemic circulation. Thus, if they are made to bypass the liver, medium chain fatty acids, though they are presumably unesterified, readily enter adipose tissue. Also, in this way, the adipose tissue can be enriched with odd num-

### TABLE 1. Fatty acid patterns (percent of total) of adipose tissue of four groups of rats prior to and during feeding of tripelargonin and even numbered medium chain triglyceride.

<table>
<thead>
<tr>
<th>Fatty Acid</th>
<th>All Groups (n)</th>
<th>Group 1 (10)</th>
<th>Group 2 (8)</th>
<th>Group 3 (9)</th>
<th>Group 4 (6)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Prior tofeeding of exptl. diets</td>
<td>1 Month after portacaval anastomoses and tripelargonin</td>
<td>1 Month after sham operation and tripelargonin</td>
<td>1 Month after sham operation and even numbered medium chain triglyceride</td>
<td>1 Month after portacaval anastomoses and 3 months after even numbered medium chain triglyceride</td>
</tr>
<tr>
<td>C6:0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C8:0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C10:0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C12:0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C14:0</td>
<td>1.7±0.2</td>
<td>1.4±0.6</td>
<td>1.7±0.6</td>
<td>1.3</td>
<td>3.1±0.6</td>
</tr>
<tr>
<td>C16:0</td>
<td>25.1±4.0</td>
<td>28.0±5.7</td>
<td>29.7±5.8</td>
<td>31.0</td>
<td>32.6±1.7</td>
</tr>
<tr>
<td>C18:0</td>
<td>8.1±3.1</td>
<td>11.1±4.7</td>
<td>10.3±2.8</td>
<td>7.6</td>
<td>12.9±1.8</td>
</tr>
<tr>
<td>C18:1</td>
<td>5.1±0.8</td>
<td>3.1±0.8</td>
<td>2.7±0.4</td>
<td>3.5</td>
<td>2.7</td>
</tr>
<tr>
<td>C18:2</td>
<td>30.7±4.2</td>
<td>29.5±4.3</td>
<td>36.9±4.1</td>
<td>38.4</td>
<td>38.1±3.3</td>
</tr>
<tr>
<td>Other</td>
<td>1.3±0.8</td>
<td>1.2±0.6</td>
<td>1.2±0.9</td>
<td>0.8±0.8</td>
<td>1.2±0.9</td>
</tr>
</tbody>
</table>

Data are means ± se; numbers of observations are noted in parentheses.
bered fatty acids of which the terminal three carbon units are potentially glucogenic.

In contrast, studies of the distribution of albumin-bound 14C-labeled palmitate in rats 15 min after intravenous injection have disclosed a general uptake of the label by liver, muscle, and other organs. It is of particular note that adipose tissue had no detectable radioactivity (6). This was the case in the fed as well as the postabsorptive animal. On the other hand, injected chylomicrons were taken up primarily by adipose tissue in the fed animal. It appears that re-esterification of long chain free fatty acids and their incorporation into lipoprotein may be necessary before such fatty acids can be stored in adipose tissue (5, 8, 10).

The fatty acids derived from orally administered medium chain triglyceride are transported via the portal vein in the unesterified form (14, 15, 29), while those derived from long chain triglycerides are transported in lymph as lipid ester moieties of chylomicrons (4-17). The medium chain fatty acids are extensively oxidized by the liver and feeding medium chain fats does not lead to any appreciable deposition in adipose tissue lipids of the intact animal (11, 24, 27). In the present study, the small amounts of medium chain fatty acids found in the adipose tissue of the sham-operated animals may be related to a slight degree of chylous transport of medium chain acids in triglyceride form (23). There was more decanoate (10:0) than caprylate (8:0) in the sham-operated rats in group 4 despite the fact that decanoate (10:0) than caprylate (8:0) in the sham-operated rats in group 4 despite the fact that decanoate may have been transported from the liver to the adipose tissue as a constituent of plasma lipoprotein.

Medium chain triglycerides are hydrolyzed in the intestine faster than long chain triglycerides (3, 9, 13) and are absorbed under circumstances which adversely affect long chain glyceride absorption (16, 18, 29). This may be due to the fact that the products of hydrolysis of medium chain triglycerides are more soluble than those derived from long chain triglycerides (7), permitting absorption directly through the gut mucosa and into the portal capillary bed without re-esterification. The same mechanism may apply for entry of medium chain fatty acids into the adipose tissue cell. Indeed, adipose tissue displays cellular processes characteristic of pinocytosis (21), and it has been suggested that pinocytosis may be involved in the absorption of fat by the intestine (26).

Another mechanism may be considered. As chain lengths of fatty acids decrease, the fatty acid-albumin bond is weakened (1, 12). It is conceivable that when a medium chain FFA, such as pelargonic, comes in contact with the membrane of the adipose tissue cell, this bond is easily broken, facilitating entry of the fatty acid to the cell. In any event, the greater affinity which serum albumin has for long chain fatty acids than for medium chain fatty acids is a pronounced physicochemical difference which, in part, may help to account for the different behavior of these fatty acids in biological systems.

We are indebted to Drs. William Lesko and Yasheika Kimoto of the Microsurgery Laboratory, Mt. Sinai Hospital, New York City, who did the portacaval shunts. We also gratefully acknowledge the technical assistance of Mrs. Pauline Mao.

REFERENCES


