We investigated the gastrointestinal handling and post-absorptive metabolic handling of [1,1,1-13C]tripalmitin and [1-13C]glycocholate during recovery from severe childhood malnutrition. Eight children were studied on three occasions: at admission (phase 1), during rapid catch-up growth (phase 2) and when weight-for-height had reached 90% of the reference (phase 3). Breath samples were obtained over a 24 h period and stools were collected over 3 d following the administration of each tracer. At admission, the lipid content of stool expressed as a percentage of ingested lipid was 6 (range 0.7–28.9) but less variation was shown between children at phase 2 (3.3 (range 0.9–4.1)) and phase 3 (1.4 (range 0.4–2.5)). The excretion of 13C in stool varied markedly between children at admission (11.1 (SD 5.4) % administered dose) and during rehabilitation (phase 2, 15.4 (SD 16.5) % administered dose; phase 3, 6.2 (SD 10.2) % administered dose). About 5 % of the absorbed label was recovered on breath at each stage (% absorbed dose; phase 1, 5.1 (SD 6.0); phase 2, 5.2 (SD 3.1); phase 3, 6.4 (SD 6.6)). None of the children exhibited significant bile salt malabsorption as a consequence of small intestinal overgrowth. Of the 13C measured in stool, more label was recovered in fatty acids than triacylglycerols during each of the three phases and this was interpreted to reflect a failure to absorb the products of digestion. The results show that not all the children had problems associated with the digestion and absorption of 13C-labelled tripalmitin in severe malnutrition and during recovery, which was not reflected in gross lipid balance across the gastrointestinal tract. Absorbed lipid was more likely to be deposited as adipose tissue than to satisfy the immediate needs for energy.

Children with severe malnutrition have extensive perturbations in lipid metabolism, as shown by marked loss of subcutaneous adipose tissue and profound fatty infiltration of the liver (Waterlow, 1948; Schneider & Viteri, 1974). However, there is only limited information on the physiological and metabolic mechanisms that underlie the gastrointestinal handling and further metabolic disposal of the triacylglycerols (TAG) that make up dietary lipid, either in the acutely malnourished state or during the period of rapid catch-up growth. The rate at which the weight deficit can be repleted during catch-up growth is directly related to the dietary energy consumed (Ashworth, 1969); this repletion might readily be achieved by fortifying the diet with lipid. It is likely that, at each stage of recovery, the amount and pattern of dietary fatty acids play an important role in the outcome. However, at present there is no consensus on the most appropriate fatty acid profile from one stage to another.

Malnourished children frequently suffer chronic diarrhoea, which may sometimes be identified as steatorrhoea. Balance studies in which either the total lipid content of stool (Holemans & Lambrechts, 1955; Gomez et al. 1956; Robinson et al. 1957; Dutra de Oliveira & Rolando, 1964) or the concentrations of individual fatty acids in stool (Underwood et al. 1967) have been used to characterise how dietary lipid is handled by the gastrointestinal tract. Using these approaches it is not possible to determine with confidence whether the lipid measured in stool is derived directly from the diet, or carries a contribution from endogenous sources, such as biliary and other secretions,
desquamated cells, or even the products of bacterial metabolism. In malnutrition, although stool lipid losses have been loosely characterised as malabsorption, there is indirect evidence for a contribution from impaired digestion, bacterial overgrowth of the small intestine (Lifshitz et al. 1970), excessive bile salt deconjugation, impaired resorption of bile salts and an increase in endogenous losses (Watson et al. 1977; Jackson & Golden, 1978; Durie et al. 1985), but these factors have not been directly related to the handling of lipid. Once absorbed, the hepatic partitioning of lipid between oxidation, export and other pathways appears to be impaired (Tanner, 1990), but the mechanistic basis of the problem remains unresolved.

Further studies are needed to define more precisely the gastrointestinal handling and metabolic disposal of dietary TAG in malnutrition and during rehabilitation. One approach is to employ orally administered substrates labelled with $^{13}$C. We have previously determined the fate of label from orally administered $^{13}$C-labelled tripalmitin (TP), given as an emulsion in healthy children and patients with cystic fibrosis, by determining the proportion of label excreted in stool and in breath as $^{13}$CO$_2$ (Murphy et al. 1998). Patients with cystic fibrosis excreted more of the label in stool when compared with healthy children; this differences could have been the result of poor digestion of labelled TAG, which limits subsequent absorption (malabsorption). Alternatively, or in addition, the labelled products of digestion could have been malabsorbed because of a failure in the absorptive capacity of the gastrointestinal tract.

Intestinal malabsorption may also occur as the result of bile salt malabsorption and small bowel overgrowth. In a previous study (Schoeller et al. 1981) bile salts labelled with $^{13}$C were used to examine bile salt malabsorption and small bowel overgrowth in children with suspected malabsorption. The approach was based on the principle that, if anaerobic bacteria have colonised the small intestine, bacterial cleavage of the amide bond between the labelled glycine and cholate moiety would be cleaved and the glycine metabolised to $^{13}$CO$_2$ which is excreted on breath and/or that excess $^{13}$C in stool is indicative of bile acid malabsorption.

In the present study we report the gastrointestinal and post-absorptive handling of $^{13}$C-labelled TP and $^{13}$C-labelled glycodeoxycholate (GCA) in severely malnourished children and during rehabilitation. The purpose of the study was to determine the extent to which the treatment for severe childhood malnutrition may influence: (1) the total amount of $^{13}$C label excreted in stool, and whether gastrointestinal problems were associated with poor hydrolysis of TAG and/or absorption; (2) the proportion of absorbed labelled palmitic acid that is oxidised over 24 h; (3) bile salt malabsorption and small bowel overgrowth.

Materials and methods

Subjects

The Ethical Committee of the University Hospital of the West Indies gave approval for the study to be carried out. Eight Jamaican children (four girls, four boys) aged 7–23 months were recruited into the study after informed consent was received from their parents. The main criterion for selection and inclusion in the study was severe malnutrition according to the Wellcome classification (Wellcome Trust Working Party, 1970), i.e. less than 80 % weight-for-age and the presence or absence of oedema. Exclusion criteria were evidence of other obvious pathology, such as renal disease, heart disease, sickle cell disease or infection with HIV. All clinical decisions regarding care and treatment were taken by the attending physicians. On admission, the children were started immediately on a milk-based diet based on a commercial infant feed (Nan; Nestle, Vevey, Switzerland) with a water supplement to provide about 417 kJ/kg per d, 1·4 g protein/kg per d and 7 g lipid/kg per d. During rapid catch-up growth, the children were offered a milk-based formula that was made energy dense by the addition of coconut oil, and provided 625–750 kJ/kg per d, approximately 3 g protein/kg per d and 10 g lipid/kg per d.

Study design

Each child was studied on three occasions: within 48 h of admission, when acutely malnourished (phase 1); during rehabilitation, at the time when the child was gaining weight rapidly and had corrected 50 % of the weight deficit (phase 2); at late catch-up, when the child had reached at least 90 % of the expected weight-for-height (phase 3). Each study phase lasted for a period of 9 d, and on each occasion the children first received $[1,1,1-^{13}C]TP$, 20 mg/kg body weight (99 atom % excess (APE); Masstrace, Woburn, MA, USA), followed by a 3 d stool collection, a wash-out period of 3 d, and then $[1,1,1-^{13}C]GCA$ (as a Na salt), 10 mg/kg body weight (99 APE; Masstrace), followed by a stool collection for 3 d. On the day before the administration of the $^{13}$C-labelled compounds, breath and stool samples were collected to determine baseline abundance of $^{13}$C.

The $[1,1,1-^{13}C]TP$ was made up as an emulsion in a portion of the formula being consumed by the child, using sonication to incorporate the label. This emulsion was consumed as a single bolus by the subject. The $[1,1,1-^{13}C]GCA$ was solubilised in 5 ml water and given as a single dose immediately before the child was fed. For the duration of the study each child received at intervals of 2–3 h the same standardised feed from the same batch of commercial formula in order to minimise any possible differences due to changes in the background isotopic abundance of $^{13}$C.

Following administration of the label, breath samples were collected, using a face mask, every 0·5 h for 6 h, then at 8 h, 10 h and 24 h. Samples of breath were transferred in duplicate into evacuated gas sample containers (Exetainers; Isochem, Finchampstead, Berks., UK) for analysis. The rate of $^{12}$CO$_2$ production by the subject was determined by indirect calorimetry (GEM; Europa Scientific Ltd, Crewe, Cheshire, UK) for a period of 15 min immediately before and after a feed. The individual rate of $^{12}$CO$_2$ production was used to determine the rate of $^{13}$C recovery from the enrichment of $^{13}$CO$_2$ on breath. It was possible to carry out measurements in four of the eight children. For those
Breath and stool analyses

The methodology for processing stools has been described previously (Murphy et al. 1995). The abundance of $^{13}$C in stool and as $^{13}$CO$_2$ on breath was analysed by continuous-flow isotope-ratio MS (ANCA-NT GSL; Europa Scientific Ltd). Total lipid was measured in samples of stool collected during the $^{13}$C-labelled TP studies by a modification of the method of Folch et al. (1957) with previous acidification. The TAG and fatty acid fractions extracted only from those stools with the highest level of $^{13}$C enrichment were separated by TLC. The $^{13}$C enrichment in total lipid and within the TAG and fatty acid fractions were analysed by continuous-flow isotope-ratio MS to determine the extent to which the label appeared unhydrolysed in stool, as TAG as the result of maldigestion, or appeared hydrolysed, as fatty acid as the result of malabsorption.

The $^{13}$C/$^{12}$C of the samples and of the reference was used to calculate the $\delta^{13}$C‰ of the sample applying the following equation:

$$\delta^{13}\text{C‰} = \left[\frac{(^{13}\text{C}/^{12}\text{C})_{\text{sample}}}{(^{13}\text{C}/^{12}\text{C})_{\text{standard}}} - 1\right] 	imes 10^3,$$

where the international standard is the Pee Dee Belemnite standard. The measured $\delta^{13}$C‰ was transformed to atom % (AP) with the formula:

$$\text{AP} = \frac{100}{(\delta^{13}\text{C}_{\text{sample}}/1000 + 1)^R} + 1,$$

where $R$ is the $^{13}$C/$^{12}$C of the international standard ($R = 0.0112372$) and $\delta^{13}$C$_{\text{sample}}$ is the $\delta^{13}$C value of the sample.

The calculated AP were converted to APE by subtracting the average background $^{13}$C abundance (+2 SD) from the $^{13}$C enrichment of the samples containing the label. The proportion of the orally administered $^{13}$C label which was recovered in total stool, as stool lipid, TAG and fatty acid was calculated from APE expressed as a percentage of label administered. The proportion of $^{13}$C label excreted on breath as $^{13}$CO$_2$ over the study period was calculated by area under the curve of $^{13}$C recovery on breath $v.$ time from the APE expressed as a percentage of absorbed label.

Presentation of results and statistical analysis

The results are reported as means and standard deviations. The data were analysed by ANOVA and differences between means were considered significant with $P < 0.05$. The post hoc Bonferroni adjustment was made to the significance levels because of repeated comparisons. Statistical analyses were performed using SPSS for Windows (version 9.0, SPSS Inc. Chicago, IL, USA).

Results

Subject details

The physical characteristics of the eight subjects who entered into the study are presented in Table 1. Based on the Wellcome classification (Wellcome Trust Working Party, 1970), three subjects were diagnosed as suffering from marasmus, one from undernutrition, two from kwashiorkor and two from marasmic kwashiorkor. All subjects had been treated with broad-spectrum antibiotics (on the assumption that all severely malnourished patients will have at least one focus of infection, even though this might not be clinically obvious), which included metronidazole for presumptive small bowel overgrowth. The subjects were studied within 2 d of admission (phase 1) except for one subject, who was studied 6 d after admission, and all the studies were completed within 2 months of hospitalisation. At admission the subjects were stunted with height-for-age being 87 % of the reference (Hamill et al. 1979). On average the children gained 1 cm by phase 3, and the degree of stunting was not changed in relation to their age (NS). The body weight of the subjects increased between each successive phase. There was an increase in weight of 0.9 kg from phase 1 to phase 2 and 0.9 kg from phase 2 to phase 3, whether expressed as an absolute increase (NS), or in relation to the age (weight-for-age; NS) or to the height of the subjects (weight-for-height; $P < 0.01$). For each phase the rate of weight gain was

| Table 1. The physical characteristics of the subjects during the three study phases of rehabilitation from severe malnutrition† |
|-----------------|-----------------|-----------------|
|                  | Phase 1         | Phase 2         | Phase 3         |
|                  | Mean            | SD              | Mean            | SD              | Mean            | SD              |
| Weight (kg)      | 5·47            | 1·46            | 6·38            | 1·87            | 7·26            | 1·81            |
| Height (m)       | 0·64            | 0·07            | 0·64            | 0·07            | 0·66            | 0·06            |
| Height-for-age (%)| 86·5            | 7·7             | 86·4            | 6·0             | 87·1            | 6·5             |
| Weight-for-age (%)| 63·9            | 7·3             | 67·8            | 8·9             | 73·4            | 9·2             |
| Weight-for-height (%)| 75·9          | 14·1            | 90·1            | 10·4            | 98·8*           | 9·5             |
| Rate of weight gain (g/kg per d) | 1·17            | 6·73            | 11·77*          | 5·28            | 9·83*           | 6·02            |

Mean values were significantly different from those at phase 1: †$P < 0.05$. ‡$P < 0.01$.

† Phase 1, on admission to hospital of malnourished children; phase 2, during rapid catch-up growth; phase 3, when weight-for-height had reached 90 % of the reference value.
Mean values were significantly different from those at phase 1: *P < 0·05, **P < 0·01, ***P < 0·001.
† Phase 1, on admission to hospital of malnourished children; phase 2, during rapid catch-up growth; phase 3, when weight-for-height had reached 90 % of the reference value.
‡ For details of subjects and experimental procedures, see p. 706 and Table 1.

Baseline abundance of \(^{13}C\) in stool and breath

On the day before the \(^{13}C\)-labelled TP and GCA trials, background abundance of \(^{13}C\) was determined in a stool sample and samples of breath collected over 24 h (Table 3). The limits of detection (equivalent to) for excess \(^{13}Ci\) n sample and samples of breath collected over 24 h (Table 3).

<table>
<thead>
<tr>
<th>Metabolisable energy kJ/kg per d</th>
<th>Mean</th>
<th>SD</th>
<th>Mean</th>
<th>SD</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1</td>
<td>451</td>
<td>90</td>
<td>634</td>
<td>148</td>
<td>651*</td>
<td>186</td>
</tr>
<tr>
<td>Phase 2</td>
<td>634</td>
<td>148</td>
<td>651*</td>
<td>186</td>
<td>651*</td>
<td>186</td>
</tr>
<tr>
<td>Phase 3</td>
<td>651*</td>
<td>186</td>
<td>651*</td>
<td>186</td>
<td>651*</td>
<td>186</td>
</tr>
</tbody>
</table>

Mean values were significantly different from those at phase 1: *P < 0·05, **P < 0·01, ***P < 0·001.
† Phase 1, on admission to hospital of malnourished children; phase 2, during rapid catch-up growth; phase 3, when weight-for-height had reached 90 % of the reference value.
‡ For details of subjects and experimental procedures, see p. 706 and Table 1.

Excretion of lipid in stool

All the collections of stool were complete, other than the loss of a single stool sample from one subject during phases 2 and 3. During phase 1, the average lipid in stool was 2·4 (SD 3·6; range 0·4–11·2) g/d, or 5·9 (SD 9·4; range 0·7–28·9) % of the dietary lipid. During phase 2, the average lipid in stool was 1·7 (SD 0·9; range 0·4–2·9) g/d, or 3·3 (SD 2·4; range 0·9–4·1) % of the dietary lipid and was not significantly different between phases 2 and 3 or phases 1 and 2, which reflected an increased consumption of protein and carbohydrate during rehabilitation. The consumption of protein and carbohydrate was significantly increased at phase 2 compared with phase 1 (P < 0·001). Similarly, there was a significant increase in protein (P < 0·001) and carbohydrate (P < 0·001) at phase 3 compared with phase 1, but no difference was observed between phases 2 and 3. The amount of lipid consumed was not different amongst the three phases.

Mean values were significantly different from those at phase 1: *P < 0·05, **P < 0·01, ***P < 0·001.
† Phase 1, on admission to hospital of malnourished children; phase 2, during rapid catch-up growth; phase 3, when weight-for-height had reached 90 % of the reference value.
‡ For details of subjects and experimental procedures, see p. 706 and Table 1.

Table 3. Abundance of \(^{13}C\) (atom %) in stool and breath samples collected at baseline before the \(^{13}C\)-labelled tripalmitin (TP) and glycocholate (GCA) trials at each study phase in children during rehabilitation from severe malnutrition†‡

<table>
<thead>
<tr>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TP</strong></td>
<td><strong>GCA</strong></td>
<td><strong>TP</strong></td>
</tr>
<tr>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Baseline stool (^{13}C)</td>
<td>1·0876</td>
<td>0·0023</td>
</tr>
<tr>
<td>Baseline breath (^{12}C)</td>
<td>1·0901</td>
<td>0·0033</td>
</tr>
</tbody>
</table>

Mean values were significantly different from those at phase 1: *P < 0·05, **P < 0·01, ***P < 0·001.
† Phase 1, on admission to hospital of malnourished children; phase 2, during rapid catch-up growth; phase 3, when weight-for-height had reached 90 % of the reference value.
‡ For details of subjects and experimental procedures, see p. 706 and Table 1.
significantly different from that for phase 1. During phase 3, the average lipid in stool was 0.9 (SD 0.6; range 0.2–2.4) g/d, or 1.4 (SD 0.7; range 0.4–2.5) % of the dietary lipid. Less than half the lipid was excreted in stool during phases 2 and 3 when compared with phase 1, although the differences were not statistically significant.

\[ \text{[13C]Tripalmitin: excretion of 13C in stool} \]

Following a single oral dose of [1,1,1-\textsuperscript{13}C\textsubscript{3}]TP in phase 1, the individual stools with the greatest 13C enrichment were passed within 2 d of the study period (Fig. 1). The average peak enrichment of 13C label in stool was 1.1405 (SD 0.0465) APE and by the third day levels of 13C enrichment in individual stools were not different from baseline. During phases 2 and 3, both the time course and the peak enrichments (phase 2, 1.1508 (SD 0.0777) APE; phase 3, 1.1306 (SD 0.0306) APE) were not different from phase 1. Using GC-isotope-ratio-MS methodology as described previously (Stolinski et al. 1997), palmitic acid represented the major fatty acid in those stools with the highest enrichment of 13C. This finding would indicate that the 13C label was restricted to the fatty acid species consumed by the children, i.e. as palmitic acid that had been given as a TAG. The total excretion of 13C in stool as a percentage of the administered dose was not different between phase 1 (11.1 (SD 10.2) %), phase 2 (15.4 (SD 16.5) %) and phase 3 (6.2 (SD 10.2) %), with a wide range observed amongst children (phase 1, 1.3–26.4 %; phase 2, 2.9–44.0 %; phase 3, 0–30.6 %), (Table 4). When all study periods were considered together, there was a weak association between total lipid and the amount of 13C label in stool (R 0.48; P < 0.05).

In Fig. 2, the proportion of 13C in the TAG and fatty acid fractions of those stools with the greatest enrichment (as % administered dose) is shown for each phase. For TAG, 13C label was recovered as TAG in three patients at phase 1 (0.7 (SD 1.6; range 0–4.7) %), with even less label appearing as TAG in stool during phase 2, apart from one child who excreted 7 % of the label in stool (0.9 (SD 2.8; range 0–7.0) %; NS), or phase 3 (0.02 (SD 0.05; range 0–0.18) %; NS). For fatty acids, the excretion of 13C label in stool at phase 1 was 6.0 (SD 7.3; range 0–23.0 %) and declined during rehabilitation in phase 2 (4.8 (SD 3.7; range 2.5–11.8) %; NS) and phase 3 (3.3 (SD 3.8; range 0–11.8) %; NS). During phase 1, on average nine times as much appeared as fatty acid compared with TAG (NS). Almost all the label was in the form of fatty acid rather than TAG during phase 2 (P < 0.001) and phase 3 (P < 0.05).

\[ 1,1,1-\textsuperscript{13}C\textsubscript{3}\text{tripalmitin: breath 13CO\textsubscript{2} excretion measurements} \]

The recovery of 13C label on breath as 13CO\textsubscript{2} was expressed as a percentage of absorbed label (dose administered − label recovered in stool), in order to take

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Stool 13C</th>
<th>Breath 13CO\textsubscript{2}</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Phase 1</td>
<td>Phase 2</td>
</tr>
<tr>
<td>1</td>
<td>4.1</td>
<td>44.0</td>
</tr>
<tr>
<td>2</td>
<td>26.4</td>
<td>13.1</td>
</tr>
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<td>3</td>
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<tr>
<td>4</td>
<td>1.3</td>
<td>4.4</td>
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<td>5</td>
<td>17.3</td>
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</tr>
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<td>6</td>
<td>6.7</td>
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<td>7</td>
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<tr>
<td>8</td>
<td>4.0</td>
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<tr>
<td>Mean</td>
<td>11.1</td>
<td>15.4</td>
</tr>
<tr>
<td>SD</td>
<td>5.4</td>
<td>16.5</td>
</tr>
</tbody>
</table>

* Phase 1, on admission to hospital of malnourished children; phase 2, during rapid catch-up growth; phase 3, when weight-for-weight had reached 90 % of the reference value.
† For details of subjects and experimental procedures, see p. 706 and Table 1.
into account differential losses of $^{13}$C label within stool, in individual children and at different stages (Table 4). The time course and magnitude of excretion of $^{13}$C label in breath over 24 h were similar between the phases (Fig. 3). On all occasions the excretion of label on breath as $^{13}$CO$_2$ achieved maximum enrichment between 2 and 5 h following the administration of the label. There was a return to background levels of abundance by 24 h in almost all children. At phase 1, the enrichment of $^{13}$C in breath at peak excretion was 1.0958 (SD 0.004) APE and was not different to phase 2 (1.0932 (SD 0.0054) APE) and phase 3 (1.0925 (SD 0.0046) APE). When expressed as area under the curve in phase 1, the percentage of absorbed $^{13}$C label excreted on breath was 5.1 (SD 6.0; range 0–15.2), not different from phase 2 (5.2 (SD 4.5; range 1.7–10.7), or phase 3 (6.4 (SD 6.6; range 1.4–21.2)).

$[1-^{13}C]$ glycocholate

Following the administration of $[1-^{13}C]$GCA in phase 1, there was a small increase in $^{13}$C enrichment in stool from baseline within 24 h for three of the eight patients, ranging...
from 1·0886 to 1·0916 APE, equivalent to <4 % of the administered dose. In one subject, enrichment of 13C on breath was 1·0931 APE, equivalent to 6·2 % of the administered dose at phase 1. At phase 2, less of the 13C label was excreted on breath (1·0917 APE), 2·5 % of the administered dose, and this amount was not different from the natural abundance of 13C at phase 3 (1·0902 APE). These results demonstrate that the administered [1·13C]GCA was not malabsorbed or further degraded to any substantial extent. The data are taken to mean that none of the children exhibited significant bile salt deconjugation as a consequence of small intestinal overgrowth.

**Discussion**

**Gastrointestinal handling**

In the present study we have examined the extent to which the treatment for severe malnutrition may influence the gastrointestinal handling of dietary lipid in children. By collecting stool, we have been able to determine the balance of labelled lipid across the gastrointestinal tract. By following the fate of label from orally administered 13C-labelled TP we have examined the digestion and absorption and further oxidation of palmitic acid contained in TP, and from orally administered 13C-labelled GCA we have been able to assess the extent to which bile salt deconjugation might contribute to any impairment of digestion or absorption.

Generally, for this group of children, the lipid content of stool was not greatly abnormal in malnutrition or during recovery, at about 5 g/d. However, a single value gives no sense of the capacity of the bowel to handle lipid in relation to the magnitude of the dietary intake, or the age and size of the subject. Expressing lipid in stool as a percentage of lipid intake in terms of lipid balance showed that lipid excreted in stool was about 6 % that of the lipid consumed in malnutrition, but varied between 1 and 29 %. During rehabilitation the values decreased to 3 and 1 % of the lipid consumed at phases 2 and 3 respectively, with less variation observed between children. In normal healthy children, aged between 6–11 years, we have found that stool lipid varies between 1 and 4 % of the lipid consumed (Murphy et al. 1991). The results of the present study reinforce the experience of other researchers that, in severely malnourished children, the lipid content of stools may be very variable.

Studies of stool lipid balance are based on the assumption that lipid measured in stool is dietary in origin, rather than the result of endogenous losses into the bowel, and no allowance is made for any colonic bacterial metabolism that may exert an influence on the lumen contents. One reason for giving 13C-labelled palmitic acid as a labelled TAG was to probe the fate of luminal lipid. Palmitic acid was chosen as it is one of the principal fatty acids found in those oils (i.e. maize and coconut oils) consumed by the subject during treatment. However, as it was not possible to rule out an important contribution from other lipases at different levels of the bowel, for example bacterial metabolism in the colon (Segal et al. 1990), we would be most likely to attribute the limitation to a degree of pancreatic insufficiency. However, as it was not possible to rule out an important contribution from other lipases at different levels of the bowel, for example bacterial metabolism in the colon (Segal et al. 1990), we cannot conclude that there was no impairment of pancreatic function. In addition, there could have been continued TAG hydrolysis in stool after defaecation, although attempts
were made to limit further hydrolysis by immediately freezing samples and maintaining storage conditions at −20°C. We also determined the extent of bile salt malabsorption by measuring the excretion of 13C label in stool following oral administration of [1-13C]GCA. The recovery of 13C label in stool was less than 1 % of the dose, except for one subject, in whom the recovery was about 4 %. From these data we conclude that there was no evidence of bile salt deconjugation.

Metabolic disposal

Once absorbed, the partitioning of the labelled fatty acids towards either oxidation or retention within the body was determined by measuring the recovery of 13C label in breath as 13CO2. The greatest recovery of label was on average about 15 % of the dose absorbed, and on average about 5 % of the absorbed dose was oxidised at each stage of rehabilitation.

There are not many reports with which to compare these results. In healthy children in the UK, following orally administered 13C-labelled TP, the recovery of 13C label on breath was on average 33 %, ranging from 15 to 43 % of the absorbed dose (Murphy et al. 1998), much greater than that for the malnourished children at any stage of recovery. In another study, a small percentage of the label (about 5 % of the absorbed dose) was recovered in breath as 13CO2. The greatest recovery of label was on average about 3–4·5 % to 5–7 % during the different periods of recovery. Thus, even when allowance is made for a substantial underestimate of the proportion of absorbed lipid that is oxidised, the overall interpretation is not altered, that most of the lipid ingested was retained in the body over the time course of the study.

In conclusion, the results of the present work indicate that during malnutrition not all the children had problems associated with the handling of dietary lipid and 13C-labelled TP. There were some children with a greater degree of impairment, which was not reflected in gross lipid balance. In these children there was some improvement in the digestion and absorption of 13C-labelled TP during rehabilitation. Poor gastrointestinal handling of 13C-labelled TP was more likely to be associated with a failure to absorb the products of digestion. The absorbed lipid was more likely to be deposited as adipose tissue than used to satisfy the immediate needs for energy. The extent to which different fatty acids in the diet might be handled differently, both within the gastrointestinal tract and in further metabolism, needs to be determined, as there could be clinical advantages in reviewing the type of lipid used to increase the energy density of feeds during treatment.

Acknowledgements

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References


