Biochemical aspects of malabsorption in marasmus: effect of dietary rehabilitation

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1. Sixty marasmic children were investigated for the absorption of xylose, proteins and fats. Their duodenal juice samples were also analysed for bile salts and microflora.

2. The marasmic children were then studied in three groups of twenty by allocating them to three different dietary schedules: a high-protein diet (30% of the total energy from protein), a high-fat diet (40% of the total energy from fat) and a high-carbohydrate diet (70% of the total energy from carbohydrate) for 2 weeks and the previous measurements repeated.

3. Whereas the high-fat diet resulted in improved fat absorption, along with an increase in total and conjugated bile acids, and the high-carbohydrate diet led to improved xylose absorption, the diet rich in protein resulted in an improvement in the absorption of all three dietary ingredients. It appears that a high-protein diet improves the overall absorption process by improving the intestinal environment as a whole, while high-carbohydrate and high-fat diets bring about adaptive changes related to the respective absorptive processes.

Malabsorption is a well-recognized phenomenon in protein–energy malnutrition (PEM) (Viteri *et al.* 1964) and a number of pathophysiological alterations have been described in PEM (Viteri & Schneider, 1974). It is, however, difficult to say whether these pathophysiological alterations and malabsorption are the cause or the effect of malnutrition.

Therapeutic treatment with diets rich in proteins and energy is the most common method of management of PEM. A high-protein diet is known to improve the absorption status (Viteri *et al.* 1973; Stanfield, 1976) as well as pancreatic functions in PEM. A few reports on the adaptive effect of a high-fat diet on bile acids and fat absorption (Gomez *et al.* 1954; Schneider & Viteri, 1974) and of a high-carbohydrate diet on pancreatic amylase (Reboud *et al.* 1960; Zoppi *et al.* 1972, 1973) are also available. However, a comprehensive study investigating separately the effects of a protein-rich, a fat-rich and a carbohydrate-rich diet on a large number of factors involved in the digestive and absorptive processes has not been undertaken. We have attempted to study this aspect in marasmic children.

MATERIALS AND METHODS

Sixty marasmic children admitted to the Paediatrics department of the Medical College, Rohtak, took part in the present study. All the children weighed less than 60% of 50th percentile of Boston Standards (Dugdale, 1971), were in the age-range 9–42 months and free from oedema and any major infection.

These children were investigated for: (a) the absorption of proteins by studying the rise in serum proline following an oral dose of 1·5 g casein/kg body-weight (Gould & Schwachman, 1956); (b) the absorption of fats by studying 24 h faecal fat excretion (Van de Kamer *et al.* 1949) in twenty cases and lipiodol absorption, noting the dilution of urine positive for iodine after an oral dose of 0·5 ml lipiodol/kg body-weight (Jones & diSant Agnese, 1963) in the remaining cases; (c) the absorption of xylose by measuring peak blood xylose level after an oral dose of 1·1 g xylose/kg body-weight (Roe & Rice, 1948); (d) duodenal juice bile acids by thin-layer chromatography (Anthony & Behar, 1964);

Table 1. *Weight, height and mid-arm circumference of marasmic children in the three groups*

(Mean values and standard deviations; twenty children per group)

		Age (months)	Wt (kg)	Height (m)	Mid-arm circumference (mm)
Group 1: high-protein diet	Range	6–36	3·0–8·0	0·55–0·80	70–130
	Mean	19·4	5·4	0·682	91
	SD	12·6	1·5	0·079	17
Group 2: high-fat diet	Range	8–36	3·5–8·0	0·57–0·815	70–120
	Mean	21·8	5·8	0·704	95
	SD	10·6	1·5	0·082	17
Group 3: high-carbohydrate diet	Range	7–42	3·0–9·0	0·56–0·85	75–135
	Mean	21·6	5·7	0·718	93
	SD	12·0	1·7	0·095	16

Mean values were not significantly different in any case.

(e) duodenal juice microflora (aerobes) by the standard loop technique of O'Sullivan *et al.* (1960).

After the initial studies the children were allocated to three different dietary schedules at random in three groups of twenty each.

Group 1. Twenty children were given a high-protein diet (30% of the total energy derived from protein, 20% from fat and 50% from carbohydrate). Calcium caseinate was used as the protein supplement.

Group 2. Twenty children were given a high-fat diet (40% of the total energy from fat, 15% from protein and 45% from carbohydrate). Ten of these children were given fat in the form of butter and the remaining ten in the form of purified groundnut oil. Faecal fat excretion (24 h) was studied in all these children.

Group 3. Twenty children were maintained on a high-carbohydrate diet (70% of the total energy derived from carbohydrate, 15% from protein and 15% from fat). These children were studied under three subgroups: (a) ten children received half the carbohydrate energy as sucrose and half mainly as starch, (b) six children were given lactose instead of sucrose, (c) four children in this subgroup received only starch as the main source of carbohydrate.

The diet consisted of milk, cereals, pulses, banana, eggs and Casilan (calcium paracaseinate) as the protein supplement, butter–groundnut oil as the fat supplement and starch–sucrose–lactose as the carbohydrate supplement.

All the children were given diets providing 630 kJ (150 kcal)/kg per d. Initially a diet equivalent to about 210 kJ (50 kcal)/kg per d (or as much as a child could tolerate) was given. The diet was gradually increased to the desired amount within 5–6 d. The diets were continued for 2 weeks after which the follow-up measurements described previously were conducted. An adequate supply of minerals and vitamins was provided to all the children during the rehabilitation period.

Statistical methods

The results of different groups (before diet *v.* after diet) have been compared using the paired *t* test, except for lipiodol absorption where the χ^2 test has been used. For comparing the anthropometric data of children in the three groups, an unpaired *t* test was used.

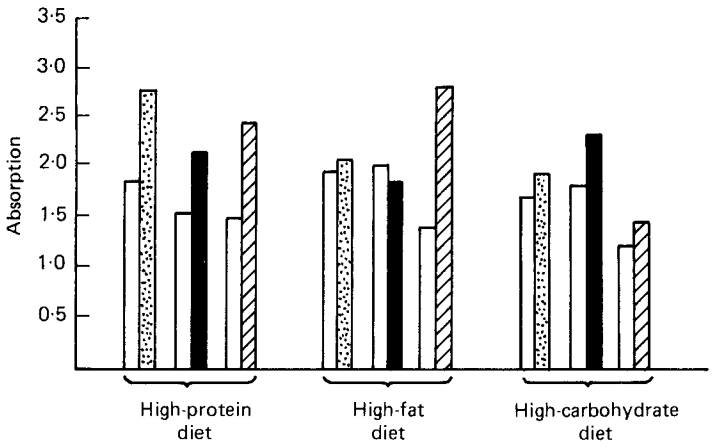

Fig. 1. Comparative effect of different diets on absorption of carbohydrates, protein and fat in marasmic children. (□), Before dietary therapy; (▨), rise in serum proline (μmol/l × 0·01); (■), peak blood xylose level (mmol/l); (▨), lipiodol absorption (urine dilution positive for iodine × 0·2) all after dietary therapy.

Table 2. *Effect of a high-protein diet on absorption in marasmic children*

(Mean values and standard deviations for twenty children)

	Protein absorption: rise in serum proline (μmol/l) after a casein dose			D-Xylose absorption: peak blood xylose levels (mmol/l) after a xylose dose			Lipiodol absorption: urine dilution positive for iodine*	
	Range	Mean	SD	Range	Mean	SD	< 1:4	> 1:4
Before dietary therapy	60·9–382·6	191·3	87·0	0·23–3·33	1·59	0·85	12	8
After dietary therapy	113·0–608·7	278·3	104·3	1·15–4·00	2·21	0·81	5	15
Statistical significance of difference: $P <$	0·001			0·001			0·01	

* Values expressed as number of cases.

RESULTS

Some difficulties were encountered in the dietary therapy experiments since many children could not tolerate the desired amount of diet as they developed diarrhoea and were excluded from the study. Generally the high-protein diet was well accepted. The high-fat diet was accepted by only 60% of the cases studied. The maximum difficulty was encountered with respect to the high-lactose diet which was tried in twenty-two cases but only six were able to tolerate it. The high-sucrose diet was initiated in sixteen cases but six of them were unable to tolerate this diet.

The weight, height and mid-arm circumference of marasmic children in the three groups are given in Table 1. The children in the three groups did not differ significantly with respect to any of these indices ($P > 0·05$).

The effect of different diets on the absorption of different dietary ingredients is shown in Tables 2–4 and Fig. 1. The high-protein diet led to marked improvement in the absorption of proteins, xylose and lipiodol.

The high-fat diet did not result in any significant improvement in the absorption of

Table 3. *Effect of a high-fat diet on absorption in marasmic children*

(Mean values and standard deviations)

Major source of fat	Protein absorption: rise in serum proline (μmol/l) after a casein dose			D-Xylose absorption: peak blood xylose level (mmol/l) after a xylose dose			Fat absorption: 24 h faecal fat excretion (g)		
	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD
Butter (*n* 10)									
Before dietary therapy	121·7–234·8	181·7	33·0	1·33–3·73	2·03	0·89	1·9–9·4	4·9	3·2
After dietary therapy	121·7–260·8	188·0	44·3	1·50–2·33	1·85	0·28	1·6–7·1	3·2	1·8
Statistical significance of difference: $P <$		NS			NS			NS	
Groundnut oil (*n* 10)									
Before dietary therapy	60·9–460·9	219·1	139·1	0·33–4·00	2·13	1·61	1·5–7·3	4·7	2·3
After dietary therapy	113·0–391·3	236·5	95·7	0·83–2·93	1·93	0·77	1·0–5·5	3·5	1·6
Statistical significance of difference: $P <$		NS			NS			0·01	
All cases (*n* 20)									
Before dietary therapy	60·9–460·9	200·4	100·5	0·33–4·00	2·08	1·28	1·9–9·4	4·8	2·7
After dietary therapy	113·0–391·3	212·3	76·5	0·83–2·93	1·89	0·56	1·0–7·1	3·35	1·7
Statistical significance of difference: $P <$		NS			NS			0·05	

NS, not significant.

Table 4. *Effect of a high-carbohydrate diet on absorption in marasmic children*

(Mean values and standard deviations)

Main source of carbohydrate	Protein absorption: rise in serum proline (μmol/l) after a casein dose			D-Xylose absorption: peak blood xylose level (mmol/l) after a xylose dose			Lipiodol absorption: urine dilution positive for iodine*	
	Range	Mean	SD	Range	Mean	SD	< 1:4	> 1:4
Sucrose (*n* 10)								
Before dietary therapy	43·5–365·2	176·5	95·7	0·67–2·73	1·76	0·03	6	3
After dietary therapy	121·7–321·7	188·0	60·9	1·30–3·33	2·33	0·71	5	4
Statistical significance of difference: $P <$		NS			0·01		NS	
Lactose (*n* 6)								
Before dietary therapy	147·8–207·4	182·6	45·2	1·33–2·73	1·98	0·78	2	3
After dietary therapy	173·9–260·9	214·3	33·0	1·53–3·13	2·43	0·37	3	2
Statistical significance of difference: $P <$		NS			0·05		NS	
Starch (*n* 4)								
Before dietary therapy	130·4–382·6	208·7	117·4	1·67–2·67	2·04	0·48	1	3
After dietary therapy	147·8–347·8	214·3	92·2	1·67–2·67	2·33	0·47	1	3
Statistical significance of difference: $P <$		NS			NS		NS	
All cases (*n* 20)								
Before dietary therapy	43·5–382·6	184·8	85·1	0·67–2·73	1·88	0·71	9	9
After dietary therapy	121·7–347·8	201·2	61·5	1·30–3·33	2·36	0·58	9	9
Statistical significance of difference: $P <$		NS			0·05		NS	

NS, not significant.

* Values expressed as number of cases.

Table 5. *Effect of a high-protein diet on conjugated and free bile acids in the duodenal juice samples of marasmic children*

(Mean values and standard deviations for twenty children per treatment)

	Conjugated bile acids (mg/ml)			Free bile acids (mg/ml)		
	Range	Mean	SD	Range	Mean	SD
Before dietary therapy	0·60–2·60	1·22	0·48	0·24–1·30	0·58	0·29
After dietary therapy	0·86–3·00	1·80	0·58	0·04–0·96	0·30	0·23
Statistical significance of difference: $P <$		0·001			0·001	

Table 6. *Effect of a high-fat diet on conjugated and free bile acids in the duodenal juice samples of marasmic children*

(Mean values and standard deviations)

	Conjugated bile acids (mg/ml)			Free bile acids (mg/ml)		
Main source of fat	Range	Mean	SD	Range	Mean	SD
Butter (n 10)						
Before dietary therapy	0·56–3·20	1·82	0·80	0·08–1·56	0·83	0·44
After dietary therapy	1·52–4·16	2·92	1·00	0·48–1·52	0·94	0·33
Statistical significance of difference: $P <$		0·001			NS	
Groundnut oil (n 10)						
Before dietary therapy	0·76–3·40	1·72	0·79	0·44–0·88	0·66	0·14
After dietary therapy	1·04–3·76	2·15	1·02	0·44–0·96	0·64	0·13
Statistical significance of difference: $P <$		0·02			NS	
All cases (n 20)						
Before dietary therapy	0·56–3·40	1·77	0·79	0·08–1·56	0·75	0·33
After dietary therapy	1·04–4·16	2·54	1·04	0·44–1·52	0·79	0·29
Statistical significance of difference: $P <$		0·01			NS	

proteins and xylose but there was improvement in fat absorption, especially when groundnut oil was used as the source of fat. Similarly, the high-carbohydrate diet resulted in improvement in the absorption of xylose without affecting protein and fat absorption. The number of cases with an overall improved absorption status markedly increased after the high-protein diet but this was not true for other diets.

The concentration of conjugated and free bile acids in marasmic children, before and after dietary rehabilitation with different diets, is shown in Tables 5–7 and Fig. 2. The high-protein diet resulted in a significant increase in the concentration of conjugated bile acids (CBA) and a significant decline in the concentration of free bile acids (FBA) but the levels of total bile acids were not affected significantly. The high-fat diet resulted in a significant increase in the concentration of total bile acids as well as CBA but had no significant effect on the level of FBA. The high-carbohydrate diet had no significant effect on the concentration of either CBA or FBA. There was a significant decrease in the aerobes of duodenal juice after

Table 7. *Effect of a high-carbohydrate diet on conjugated and free bile acids in the duodenal juice samples of marasmic children*

(Mean values and standard deviations)

Main source of carbohydrate	Conjugated bile acids (mg/ml)			Free bile acids (mg/ml)		
	Range	Mean	SD	Range	Mean	SD
Sucrose ($n = 10$)						
Before dietary therapy	0·52–2·64	1·38	0·74	0·20–0·56	0·41	0·12
After dietary therapy	0·92–2·72	1·66	0·62	0·32–0·60	0·51	0·18
Lactose (n 6)						
Before dietary therapy	1·16–2·56	1·86	0·47	0·32–0·80	0·49	0·18
After dietary therapy	0·80–2·15	1·70	0·51	0·20–0·68	0·39	0·18
Starch (n 4)						
Before dietary therapy	1·50–2·10	1·75	0·27	0·40–0·65	0·55	0·15
After dietary therapy	1·60–2·20	1·78	0·28	0·35–0·65	0·50	0·15
All cases (n 20)						
Before dietary therapy	0·52–2·64	1·60	0·60	0·20–0·80	0·46	0·14
After dietary therapy	0·80–2·72	1·70	0·52	0·20–0·68	0·47	0·15

Mean values were not significantly different in any case.

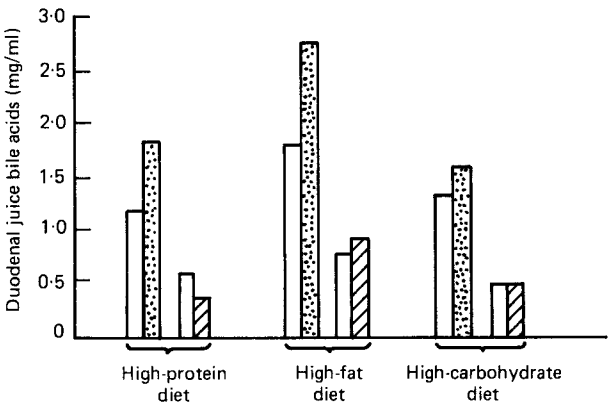

Fig. 2. Comparative effect of various diets on conjugated bile acids and free bile acids of duodenal juice of marasmic children. (□), Before dietary therapy; (▨), conjugated bile acids; (▨) free bile acids after dietary therapy.

the high-protein diet. All fourteen cases on the high-protein diet were found to be devoid of aerobic growth in duodenal juice after dietary therapy whereas initially only six of the fourteen duodenal juice samples were sterile.

DISCUSSION

A high-protein diet is reported to improve the absorption status in malnourished children (Viteri *et al.* 1973) but diets rich in fat and carbohydrate affect the absorption of only fats and carbohydrates respectively (Gomez *et al.* 1954; Reboud *et al.* 1960; Schneider & Viteri, 1974). The findings of the present study indicate that a protein-rich diet leads to an overall improvement in the absorption status of marasmic children whereas fat-rich and

carbohydrate-rich diets improve the absorption of fats and carbohydrates respectively without any effect on the absorption of other dietary ingredients (Tables 2–4). The protein-rich diet appears to work through an overall anabolic response whereas the other diets seem to act by way of adaptation. The contention is further supported by the effect of different diets on the factors involved in digestion and absorption.

A decline in bacterial growth after therapeutic treatment with diets adequate in protein has been reported in malnourished children (Mata *et al.* 1972). In the present study too, the high-protein diet resulted in a significant decline in the bacterial flora of duodenal juice and the aerobic organisms completely disappeared after this diet. Such an effect, however, was not noted with any other diet.

A significant increase in the concentration of CBA has been noted after a high-fat diet. (Schneider & Viteri, 1974). We noted a significant increase in the concentration of CBA not only with the high-fat diet but also with the high-protein diet (Tables 5 and 6). FBA, however, decreased only after the protein-rich diet. This could be because of a marked decline in micro-organisms of duodenal juice (which are known to deconjugate bile acids) after the protein-rich diet. The increase in bile acids after the high-fat diet may be attributed to increased synthesis from exogenous and endogenous cholesterol. The comparatively greater increase in bile acids with the butter-containing diet of the present study may result from the higher cholesterol content of butter compared with groundnut oil. Another possible cause of the increase in bile acids following the protein-rich and fat-rich diets may be decreased faecal loss because of improved fat absorption.

In addition to these factors the high-protein diet might also improve the functional status of mucosal cells, although morphological changes may take longer to return to normal. An improvement in pancreatic functions has also been observed after such a diet (Thompson & Trowell, 1952; Gomez *et al.* 1954; Barbezat & Hansen, 1968; Mezey & Potter, 1976; Mehta *et al.* 1984*a*).

The present work suggests the importance of the protein-rich diet in the treatment of marasmic children. We observed delayed absorption of amino acids in the marasmic children (Mehta *et al.* 1984*b*). This could explain why the diet with a high protein content is able to induce a better anabolic response compared with diets low in protein. It is therefore suggested that marasmic children should be maintained on the high-protein diet during the initial phase of treatment after which diets with normal protein content can be used for further clinical recovery.

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