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Symposium on 'The weaning process'

Weaning in Britain: practice, policy and problems

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The first 'age of man' is the suckling who receives a single food, either breast milk (preferably) or a modern infant formula. The weanling continues with the suckling's food but other foods have been introduced. These other foods are often referred to as 'solid foods', although initially they may be a mixture of powdered foods such as flours, sugar and dried milk or are a soft mush of mashed, minced and/or strained adult-style foods.

Other papers in the present symposium describe aspects of weaning in developing countries and in children of immigrants to Britain. The present review, therefore, deals mainly with indigenous British weanlings but draws on some messages from other communities. The review considers current practice, policy and problems.

PRACTICE

Secular trends

Table 1 summarizes various data relating to the liquid part of the weanlings' diet and the secular changes in the age of introduction of solid foods.

Between 1975 and 1980 there was a welcome increase in the percentage of babies breast-fed at 4 months, but there has been little change since then. On the other hand, it seems that most mothers who are breast-feeding at 4 months are sufficiently motivated to continue for some time. If the aim is to increase the number of breast-fed babies during weaning, the influence must be effected in the first month or so of life.

In the bottle-fed babies, there has been a welcome decrease in the number receiving unmodified whole cows' milk, but 42% were still receiving unmodified cows' milk instead of an infant formula or follow-on milk at the age of 9 months.

Comparison of the groups who were mainly breast- or bottle-fed showed that more breast-fed babies receive unmodified cows' milk as a bottle feed (Fig. 1). These babies receive little Fe from the liquid parts of their diet (breast milk or unmodified cows' milk), so a good source of available Fe is essential in the rest of the weanling's diet.

There was a substantial change in the age of introduction of solid food between 1975 and 1980, but little change since then. Nevertheless, the majority of mothers do not follow the current advice to delay weaning until 4 months. How well-based is this advice is unclear. The oft-quoted 4–6 months of age dates from the original report of the Department of Health and Social Security (1974). The choice of age is based more on experienced opinion than on hard scientific analysis. Young infants now receive breast milk or a modern

Table 1. *Secular changes in liquid part of the diet in weanlings and age of introduction of solid foods in Britain* (Data taken from Martin, 1978; Martin & Monk, 1982; Martin & White, 1988; White *et al.* 1992)

	Percentage of mothers breast-feeding from the age of 4 months (England and Wales)			
	4 months	6 months	9 months	
1975	15	10	< 5	
1980	27	23	12	
1985	26	21	11	
1990	25	21	12	
	Liquid part of diet received by bottle-fed babies (Great Britain)			
	4–5 months (% of infants)		9–10 months (% of infants)	
	1985	1990	1985	1990
Whey	43	32	12	18
Casein	46	61	16	33
Other	4	4	4	7
Cows' milk	7	3	67	42
	Percentage of infants given solid foods at different ages			
	6 weeks	3 months	4 months	
1975 (England & Wales)	40	85	97	
1980 (Great Britain)	14	52	89	
1985 (Great Britain)	11	62	90	
1990 (Great Britain)	9	68	94	

infant formula rather than the higher-protein, high-Na, higher-renal-solute-load cows' milk. Furthermore, manufactured weaning foods contain less protein, less salt and are often gluten-free. The risk of a high dietary renal solute load is, therefore, much less and so the time of weaning may not be so critical. Studies from Dundee suggest that early weaning is associated with more coughs and chestiness (Forsyth *et al.* 1993). It is not clear whether this indicates a greater susceptibility to infection or (more likely) an increased prevalence of allergic reactions.

Foods eaten

Table 2 summarizes selected intake data abstracted (and where necessary calculated) from a number of the tables in the Ministry of Agriculture Fisheries and Food survey of the diets of older infants (Mills & Tyler, 1992).

Commercial weaning foods, infant formula, and milk products each contributed one-fifth or more of total energy intake, cereal products 12 %, with all other categories of food 6 % or less of energy intake. There was a wide range of foods in these other categories. During the week of the survey most infants had received some meat (61 %), vegetables (66 %), potatoes (70 %) and fruit (67 %) as family food. The commercial weaning foods consumed would of course contain these foods as well. There is an overall picture of a very varied diet, therefore, but health visitors frequently meet older infants whose only diet is cows' milk plus a fruit or dessert preparation.

The main drink given to the infants affected the total nutrient intake (i.e. from all sources) as would be expected. Infants whose main drink was infant formula rather than cows' milk consumed less protein (and presumably less Na, but it is not possible to abstract

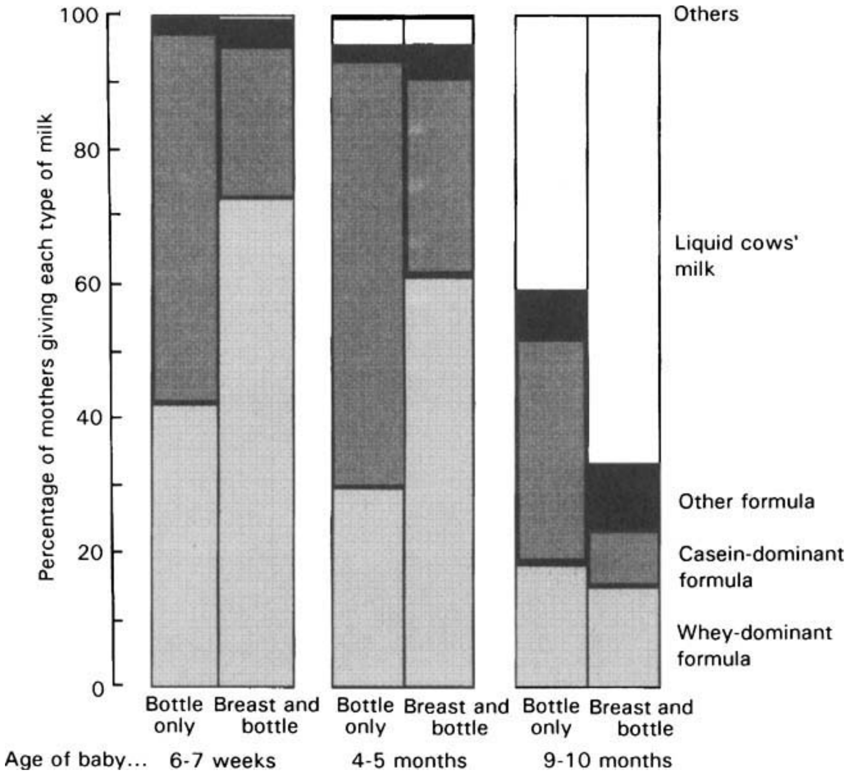

Fig. 1. The main type of non-human milk given to infants at three ages (6–7 weeks, 4–5 months, 9–10 months) by mothers who were bottle-feeding exclusively and by those who were also breast-feeding. (From White *et al.* 1990).

exact values from the data presented) and more Fe, retinol and vitamin D (reflecting the fortification of infant formula with these nutrients). Similarly, the choice of family or commercial weaning foods affected nutrient intakes. The group receiving predominantly family foods had more protein and fat but less Fe and vitamin D. They also received more sucrose and fibre.

Generally, therefore, infants living on infant formula and commercial weaning foods had no dietary disadvantage compared with those consuming adult or family foods; indeed their diet had a number of qualities which currently we regard as beneficial.

POLICY

A series of reports have recommended policies for weaning in Britain; the most recent was 2 years ago (Department of Health, 1994). The advice I give, which is broadly in line with the Department of Health (1994) report is shown in Tables 3, 4 and 5 (from Wharton, 1993). Solid foods should be introduced between 4 and 6 months of age; bottle-fed babies should receive an Fe-fortified formula until the age of 1 year. When in doubt give a vitamin supplement, particularly of vitamin D.

Table 2. *Nutrient intakes of older infants (6–9 months of age)* (Data taken from various Tables of Mills & Tyler, 1992)

	Energy (MJ)	Protein (g)	Fat (g)	Starch (g)	Sugar (g)	Fe (mg)	Zn (mg)	Retinol (µg)	Vitamin D (µg)
All infants (6–9 months)									
From all food: Total	3·5	28	34	39	73	10	5	621	5
% from: Milk products	20	30	27	–	19	2	24	16	2
Commercial weaning foods	23	20	12	48	32	59	22	12	11
Infant formulas	23	18	29	–	30	22	24	48	82
Groups of infants									
From all foods									
Main milk groups (6–12 months)									
Breast		21	31			3	4	519	1
Infant formula		26	35			11	5	801	9
Cows' milk		35	38			7	5	462	1
Main solid food groups (6–9 months)									
Commercial	3·1	22	30			10	4		6
Both	3·5	28	33			10	4		5
Family	3·4	32	35			5	5		1
Social groups (6–9 months)									
ABC1	2·7	27	32	37	66	9	4	601	4
C2BE	3·4	28	33	38	72	9	4	617	5
Only child	3·5	28	34	38	74	10	4	648	5
With siblings	3·4	27	33	37	71	9	4	592	5

Table 3. *A policy for solid foods in the weanling's diet* (From Wharton, 1993)

Why	To add or to replace total energy and protein received from liquid diet To provide certain micronutrients that may be required, particularly Fe, vitamin D (depending on sunlight), and Zn if breast-fed and Cu (if receiving ordinary cows' milk) For development of chewing action as opposed to suckling only
When	4–6 months; very few will need anything other than breast milk or an infant formula before 4 months. Almost all will need extra 'solid' foods after the age of 6 months
What food?	Cereal-based weaning foods are most commonly used initially and the majority of the commercially-available ones are gluten-free. Then proceed to baby meals, family foods etc. Beware of weaning diets that contain fruit, puddings, and vegetables only Dishes containing meat are a good source of Fe and are particularly useful for breast-fed children. The Fe in green vegetables is more easily available if meat or poultry is included with them and/or there is a good supply of vitamin C, from a baby fruit juice at the same time.

Table 4. *Liquid foods for the older infant* (From Wharton, 1993)

- Breastfed
    - Mothers may continue to breast-feed their older infants. If growth is satisfactory there are few nutritional problems, but the supply of Fe, vitamin D, Zn and possibly pyridoxine should be considered
    - The small amount of Fe in breast milk is well absorbed and so is Zn. Eventually some extra source of Fe and Zn (from the diet) and vitamin D (from the sun or diet) will be necessary
    - Solid foods may interfere with the absorption of Fe from breast milk. Fruit juices are not essential but will aid the absorption of Fe from vegetable sources
- Bottle-fed
    - Infant formula
        - Continued use of an Fe-fortified infant formula until the age of 1 year is advised
        - Compared with cows' milk, formulas provide more Fe and vitamin D. The lower concentrations of protein, Na and saturated fat are possible (but unproven) advantages
        - Fruit juices are not essential
    - Follow-on milk
        - May be used instead of an infant formula from the age of 6 months. It has no proven advantages over an Fe-fortified infant formula, but if a mother wishes to change from an infant formula before her child is 1 year old then a follow-on milk is much more preferable than cows' milk
        - Fruit juices are not essential
    - Whole cows' milk
        - Not suitable for infants under 1 year of age. It contains little Fe and vitamin D. It may lead to intestinal blood loss in some children. Formulas based on cows' milk, when fortified with Fe, seem effective in preventing anaemia. If despite all advice the mother uses whole cows' milk, well-diluted fruit juices may help to ensure an increased water intake, and a vitamin D supplement is required
    - Semi-skimmed and skimmed milk
        - They should not be used in infancy. They are potentially dangerous because of their much higher renal-solute load relative to their energy content. The lower energy intake from these milks may not be compensated for by another source of energy

PROBLEMS

Weight faltering

Most paediatricians have the impression that weight faltering due to unsuitable weaning practices is now less common than it was, but it has not been possible to get specific figures to support the impression.

When weight faltering, not due to an underlying physical disease, occurs then the more common diagnoses are inappropriate use of adult healthy-eating concepts, or a behavioural problem. A few mothers mistakenly give a diet which is low in fat and high in fibre (and, therefore, bulky with low energy density) so that there is inadequate energy for growth

Table 5. *Vitamin supplements in older infants* (From Wharton, 1993)

All pregnant women should receive a supplement of vitamin D during the second and third trimesters unless her professional advisor is confident she is receiving an adequate intake from her diet or the sun. Winter pregnancies and Asian mothers living in northern latitudes are at a higher risk of a poor vitamin D status

All children should receive vitamin supplements (vitamin D 7–10 μg daily) until the age of 2 years and preferably until the age of 5 years unless the professional advisor is confident the child is receiving an adequate intake from the diet or sun. The following groups of children will usually not require vitamin supplements (although if they are given they will not be toxic):

- the breast-fed baby born at term of a healthy mother who herself had an adequate vitamin D status in pregnancy (see above)
- a bottle-fed baby receiving a reasonable amount (not less than 500 ml/d) of infant formula or a follow-on milk

Particular care is necessary to ensure an adequate intake of vitamin D by the following groups of children and often vitamin supplements will be necessary to achieve it:

- children from Asia living in northern latitudes
- anyone whose exposure to sun is more limited (e.g. children in the more northern parts of the world, those living in areas with industrial air pollution, children who remain indoors a lot, children who are covered for cultural or religious reasons)
- those children receiving household milk as their main drink
- supplements of vitamin C are rarely necessary

Table 6. *Child mortality and vitamin A supplementation* (From Wharton & Morgan, 1992)

Place	Dose (g)	Dosing frequency	Reductions in deaths (%)
Tamil Nadu	2·5	Weekly	54
Hyderabad	60	Six monthly	–
Nepal	60	Four monthly	30
Sudan	60	Six monthly	–
Indonesia	60	Six monthly	34
Ghana	60	Four monthly	19

(Clark & Cockburn, 1988). At its most extreme this effect is seen with macrobiotic or other cult diets (Roberts *et al.* 1979).

Behavioural problems usually reflecting, but also causing, a disturbed mother and child relationship may present as growth faltering, or limited appetite. Often there is a refusal to try new tastes and textures (sometimes clinging to one favoured food, particularly from a bottle). One study recorded this problem in as many as 3 % of children, with a much higher prevalence in Asian children (Skuse *et al.* 1994).

Vitamin deficiencies

Again it is most people's impression that vitamin D-deficiency rickets is less common, but again actual values are not available. It is not clear why the prevalence has decreased. There is less use today of vitamin supplements, but the infants' longer-term consumption of an infant formula (all of which are fortified with vitamin D in Britain) may be responsible. In infants aged 6–9 months, infant formulas provided 82 % of the dietary vitamin D intake and commercial weaning foods 11 % of the dietary vitamin D intake (Mills & Tyler, 1992). The reduction in the industrial and domestic smoke pollution of the atmosphere may also have played a role in improving the vitamin D status of mothers and their babies.

In the developing world, vitamin A deficiency has long received considerable attention as a cause of xerophthalmia, keratomalacia and eventually blindness. More recently, however, there has been mounting evidence from several countries in the developing world

Table 7. *Incidence of iron deficiency in infants and children in the UK* (From Lawson, 1995)

Reference	Subjects	Criteria used	Incidence (%)
Grindulis *et al.* (1986)	22 months, Asian	Hb < 110 g/l	31
		Ferritin < 10 μg/l	57
Ehrhardt (1986)	6 months–4 years, Asian	Hb < 110 g/l	28
		Ferritin < 10 μg/l	45
	6 months–4 years, non-Asian	Hb < 110 g/l	12
		Ferritin < 10 μg/l	23
Aukett *et al.* (1986)	17–19 months, mixed inner city	Hb < 110 g/l	26
		Ferritin < 7 μg/l	47
Morton *et al.* (1988)	6 months, Asian	Hb < 110 g/l	12
		Ferritin < 10 μg/l	40
	6 months, non-Asian	Hb < 110 g/l	4
		Ferritin < 10 μg/l	36
	1 year, Asian	Hb < 110 g/l	26
		Ferritin < 10 μg/l	37
	1 year, non-Asian	Hb < 110 g/l	12
		Ferritin < 10 μg/l	21
James *et al.* (1988)	Mixed inner city	Hb < 105 g/l	
	All under 5 years		16
	All aged 1–2 years		25
	Afro-Caribbean		24
Marder *et al.* (1990)	All aged 15 months	Hb < 110 g/l	
	Mixed inner city		25
	Asian		39
	White		16
	Afro-Caribbean		20
Mills (1990)	8–24 months, inner city	Hb < 110 g/l	
	Asian		16
	White		9
	Others		6
Duggan *et al.* (1991)	4–40 months, Asian	Hb < 110 g/l	17
		Ferritin < 10 μg/l	35
		FEP > 80 μmol/mol Hb	41
Gregory *et al.* (1995)	Nationally representative		
	18–29 months	Hb < 110 g/l	12
		Ferritin < 10 μg/l	28
	30–41 months	Hb < 110 g/l	6
		Ferritin < 10 μg/l	18
A.M. Emond, N. Hawkins, C. Pennock and J. Golding (personal communication)	8 months, mixed	Hb < 110 g/l	27
		Ferritin < 12 μg/l	1·2

Hb, haemoglobin; FEP, free erythrocyte protoporphyrin.

Table 8. *Iron and psychomotor development: longer-term intervention studies* (From Lansdown & Wharton, 1995)

Study	Design	Treatment	Results
Palti *et al.* (1983) (Israel)	464 infants aged 3 months were followed up over 5 years (184 anaemic, 280 normal)	Not known	Anaemic infants had lower scores on Brunet–Lézine or Wechsler Scales at 2, 3 and 5 years independent of treatment
Aukett *et al.* (1986) (UK)	Ninety-seven ID anaemic children, 17–19 months Identified via screening programme in community child health clinics. Random allocation to treatment or placebo groups. Hb < 80 g/l excluded	Treated group: $FeSO_4$ and vitamin C for 2 months Controls: vitamin C only for 2 months	Weak association between rise in Hb and number of new developmental skills achieved on Denver Screening Test Significantly more treated children achieved the expected six new skills over 2 months
Deinhard *et al.* (1986) (USA)	Children aged 18–60 months Treated A: ID anaemic (25) Control A: normal Treated B: ID non-anaemic (22) Control B: ID non-anaemic (23) Matching on gender and at least two of: age, race, mother's education. Exclusion criteria include: low birthweight; height and weight; no disease, mental or developmental retardation Treatment and placebo controls	Oral Fe 6 mg/kg daily for 6 months to both treated groups Placebo to controls	1. Mental development (Bayley Beales and Stanford–Binet Form L-M): Group A: Treated group showed no significant change. Control group showed significant increase at 3 and 6 months; significantly higher than treated group at 3 months. Group B: No significant change in either group 2. Behaviour rating: Group A: controls more responsive at 3 and 6 months than in treated group Group A: mean values for emotional tone (happiness); control group significantly higher at baseline and 3 months but not at 6 months Group B: no significant difference
Lozoff *et al.* (1987) (Costa Rica)	182 children, 12–23 months fifty ID anaemic, forty-two ID intermediate, nineteen ID non-anaemic, thirty-six Fe depleted non-anaemic, thirty-five Fe replete	1. 1 week treatment: anaemic and intermediate groups had oral Fe, intramuscular Fe or placebo	Hb increased in treated groups No treatment effect 7 d
	Double-blind random-allocated placebo controlled study for first week	Non-anaemic had oral Fe or placebo	At 3 months the originally observed lower baseline Bayley Mental and Motor scores were no longer evident in ID anaemic infants whose ID and anaemia were corrected
	Eight possibly confounding variables controlled (see Table 11.2)	Placebo injection for those not receiving parenteral Fe 2. After 1 week: The parenterally-treated infants and Fe replete infants given placebo drops for 3 months; all other infants treated with oral Fe	Significant lower scores persisted in those with only partial recovery of ID

Seshadri & Gopaldas (1989) (India)	Study 3: forty-eight boys, 8–15 years	Group A: Daily oral Fe 30 mg for 60 d	Hb of all treated children responded to treatment
	Randomly assigned to three groups, sixteen in each group	Group B: Daily oral Fe 40 mg for 60 d Group C: Placebo	Post-treatment tests of visual recall, clerical skills and two subtests of the Wechsler Scale showed significant differences in both treated groups and controls on all but one measure
	Study 4: sixty-five pairs of girls, 8–15 years	Oral Fe 60 mg for 60 d twice in the school year	Treated group had significant benefit on all measures of Fe status and on tests of clerical skills and mazes at 8 months, no significant difference at 4 months
	Matched for age, Hb and cognitive test scores Randomly assigned to treated or placebo groups		4 months after supplementation, Hb of treated group almost to baseline with concomitant drop in almost all scores
Walter *et al.* (1989) (Chile)	196 infants at 3 months	Four dietary groups: breast-fed children assigned to fortified cereal or not; bottle-fed children to fortified or unfortified infant formula	
	At 9–12 months	Thirty-nine anaemic, 127 ID non-anaemic, thirty controls identified from four dietary groups	Lower Hb concentration and longer duration of anaemia associated with lower Bayley Mental and Motor scores
	At 12 months, double-blind placebo controlled trial for 10 d	Oral Fe or placebo for 10 d	Slight non-significant increase in scores in treatment and placebo group
	At 12·5 months, all ID children	Oral Fe to all children for 3 months	Slight non-significant increase in scores
Idjradinata & Pollitt (1993) (Indonesia)	126 infants, 12–18 months	Oral Fe 3 mg/kg per d for treated children	ID anaemic group who received treatment had significantly higher Bayley Scale Scores than placebo group and the scores were similar to those in Fe-replete groups. The ID non-anaemic group who received treatment had similar scores to those of the placebo group at the end of the study
	Selection criteria as Lozoff *et al.* (1987) Three groups identified: fifty ID anaemic twenty-nine ID non-anaemic forty-seven Fe replete, non anaemic Each group randomly assigned to treatment or placebo	Placebo for others Tested 1 d before and immediately after 3 months' treatment	

ID, Fe-deficiency; Hb, haemoglobin.

that vitamin A supplements, even in the absence of clinical overt deficiency, reduce child mortality. The results of six trials are summarized in Table 6 (Wharton & Morgan, 1992) and a discussion of the logistics is given by Filteau & Tomkins (1995).

Does this also have some message for developed countries? Are there pockets of vitamin A deficiency in underprivileged groups in this country? The British toddler survey (1·5–4·5 year olds) showed that 12 % of the children studied had plasma retinol levels below 0·75 μmol/l suggesting long-term dietary restrictions (Gregory *et al.* 1995). In the survey summarized in Table 2, infants aged 6–12 months who were receiving infant formula had mean intakes (801 μg) which were much higher than those of infants receiving breast milk (519 μg) or cows' milk (462 μg). The mean intake in lower social groups was a little more than that of those in the higher social groups, but all these values are above the reference nutrient intake (RNI) of 350 μg.

Zinc

There is no overt evidence of Zn deficiency in this country, but there are some concerns in both the developed and the developing worlds. There should perhaps be a more concentrated effort to assess nutritional status with respect to Zn in British children. The problem is twofold, in that 'tests' of Zn nutrition are difficult to interpret and the 'gold standard' for demonstrating deficiency is still the effects of Zn supplementation. Two supplementation studies have shown a positive effect of Zn supplementation in young children in 'temperate countries'. In Denver, USA, toddlers of immigrant Mexican families whose growth was faltering experienced some catch-up growth following supplementation (Walravens *et al.* 1989). In France, the breast-fed children of immigrants from North Africa who received Zn supplements grew bigger than unsupplemented children (Walravens *et al.* 1992). It is not clear whether this reflects an exhaustion of Zn 'supplies' in the lactating mother or whether some mothers have a defect in the mammary transport of Zn into the breast milk.

In Britain the average daily intake of Zn in older infants is 4·5 mg which is a little below the RNI (5 mg). Milk and milk products, commercial weaning foods and infant formula each supplied about one-quarter of the intake. Social-class differences were small (see Table 2).

Iron

The high prevalence of Fe-deficiency anaemia in British toddlers is well known; as is its association with psychomotor delay for which there is good evidence of cause and effect. I shall not, therefore, repeat all the evidence of cause and effect. Substantial reviews are available in the Task Force Report of the British Nutrition Foundation (Lansdown & Wharton, 1995; Lawson, 1995; Tables 7 and 8).

There are at least three outstanding questions concerning the problem. First, is the high prevalence of Fe-deficiency anaemia due entirely to dietary Fe deficiency or are there other factors operating? Certainly older infants in Britain have a greater intake of Fe if they are receiving an infant formula (total intake 11·3 mg, 1·4 mg from formula) compared with those receiving cows' milk (total intake 6·7 mg, 0·2 mg from cows' milk) but it is noteworthy that this difference does not seem to be wholly explained by the differences in the Fe content of the formula. Furthermore, controlled intervention studies in Britain using Fe-fortified formulas have given apparently conflicting results (see Table 9). In the Gloucester trial (Stevens & Nelson, 1995) the fortification with Fe of a follow-on formula

Table 9. *Comparison of two British trials of iron-fortified (IF) and non-fortified follow-on formula given from age 6 months to 18 months*

			Haemoglobin (Hb) concentration (g/l) and percentage of children with Hb below 110 g/l at following ages (months):									
			9		12		15		18		24	
	Fe content (mg/l)	No. in groups	g/l	%	g/l	%	g/l	%	g/l	%	b/l	%
Stevens & Nelson (1995), Gloucester												
Follow-on formula: IF	12	44–24	116	20	116	21	119	15	122	0		
Non-IF	0·5	48–26	117	23	121	17	121	9	120	15		
Daley *et al.* (1996), Birmingham												
Follow-on formula, IF	12	45			124	3			123	2	124	0
Cows' milk	0·5	44			116	31			115	33	118	26

Table 10. *Effects of iron-fortified milk* (From Wharton 1992*b*)

Centre	Intervention	Factor	Children with anaemia	
			Before intervention	After intervention
Minneapolis	WIC programme	PCV < 33:	(1973)	(1977)
(Miller *et al.* 1985)		12–17 months	14	3
		18–23 months	6	2
Yale	WIC programme	9–16 months:	(1971)	(1984)
(Vasquez-Seone *et al.* 1985)		Mean Hb (g/l)	111	118
		Mean Hb below 98 g/l	23	1
Bristol	Health education	13–24 months:	(1986)	(1990)
(James *et al.* 1989; James, 1991)		MCV below 75 fl	25	16
		Mean Hb (g/l)	117	119
Santiago (Olivares *et al.* 1989)	Fe fortification of milk at 3–12 months		Unfortified	Fortified
		15 months: Hb < 110 g/l	35	0
		Fe/TIBC < 10%	60	22
		Ferritin < 10 μg/l	60	15
Syracuse (Tunessen & Oski, 1987)	Continued use of Fe-fortified infant formula after 6 months		Whole cows' milk	Infant formula
		12 months: Hb < 110 g/l	25	11
		MCV below 72 fl	35	13
		Ferritin < 12 μ g/l	17	1

WIC, women, infants and children; PCV, packed cell volume; Hb, haemoglobin; MCV, mean corpuscular volume; Fe/TIBC, saturation of total Fe-binding capacity with Fe (%).

(compared with an unfortified formula) did not result in higher haemoglobin values, whereas in Birmingham (Daly *et al.* 1996) the use of an Fe-fortified formula (compared with pasteurized cows' milk) resulted in higher haemoglobin values and much less anaemia. These results are consistent, however, with the argument that the haemoglobin-promoting effects of an Fe-fortified formula may be due to other qualities of the formula in addition to the extra intake of Fe. These 'other qualities' of the formula may be less inhibition of Fe absorption because of the lower concentrations of protein, Ca and P, greater absorption of Fe because of the higher vitamin C content, reduced incidence of immunologically-induced milk enteropathy, or less leakage of blood from the gut.

There is conflicting evidence concerning blood loss. In the USA, in Iowa one-third of older infants receiving whole cows' milk had significant losses of blood from the intestine, equivalent to about one-third of the Fe absorbed (Ziegler *et al.* 1990). On the other hand, a study in New Orleans did not observe this blood loss, although many more of the infants receiving whole cows' milk had evidence of low plasma concentration of ferritin (Fuchs *et al.* 1993*a,b*).

It seems then that while the epidemiological association of Fe-deficiency anaemia and the early introduction of whole cows' milk seems well founded, the exact pathological mechanisms behind the epidemiology are not clear.

A second outstanding question is the mechanism by which Fe-deficiency anaemia results in psychomotor delay. Again, the possibilities are well documented in the literature, involving changes in the composition of neural lipids, or altered neurotransmitter metabolism (Wharton, 1992*a*; Evans, 1995).

The third question is what is the best method of prevention? A pragmatic method is the continued use of an Fe-fortified formula until at least the age of 1 year, and there are arguments for extending its use into the toddler years.

Such policies are associated with a very low prevalence (1 %) of Fe deficiency in Hong Kong toddlers aged 18 months (Leung *et al.* 1988) and a distinct shift upwards in the haemoglobin distribution in populations of children receiving these foods in various countries (Table 10, Wharton, 1992*b*).

Nevertheless, a full understanding of the pathological mechanisms involved might refine this pragmatic policy. For example, would it be possible to achieve the same effect with less Fe fortification if other qualities of an infant formula substantially increased Fe absorption or reduced blood loss?

CONCLUSION

The health of the British weanling is improving. In the late 1970s the prevalence of coeliac disease and rapid weight gain (vastly in excess of that seen in breast-fed babies) fell substantially (not reviewed here). Since then, rickets and weight faltering seem to be less common. Fe-deficiency anaemia remains a problem and there are unanswered questions concerning its pathophysiology and methods of prevention.

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