Archives of Disease in Childhood, 1975, **50**, 610.

Concentrated milk feeds and their relation to hypernatraemic dehydration in infants

TIMOTHY L. CHAMBERS and A. E. STEEL

From the University Department of Paediatrics and Child Health, Leeds, and Seacroft Hospital, Leeds

Chambers, T. L., and Steel, A. E. (1975). *Archives of Disease in Childhood*, **50,** 610. **Concentrated milk feeds and their relation to hypernatraemic dehydration in infants.** The composition of milks usually fed to 25 infants admitted to hospital with a dehydrating illness was studied. 15 hypernatraemic babies had been given feeds of greater sodium concentration and osmolality than those fed to the 10 infants whose plasma sodium was below 150 mEq/l. Hypernatraemic dehydration may be followed by death or permanent brain damage. Most infants in the survey were receiving milk with a sodium content greater than that advised by the manufacturers. Suggestions are made for reducing the sources of error commonly made in the reconstitution of dried milk formulae.

Recent studies of infant feeding practices have drawn attention to the high concentration of solute that may be present in reconstituted dried cow's milk feeds (Taitz and Byers, 1972; Shukla *et al.*, 1972; Oates, 1973). One reason for this excess is that errors are made by mothers when making up their artificial feeds. Possible long-term consequences such as obesity and hypertension have been discussed (Davies, 1971; Shukla *et al.*, 1972). Of more immediate concern is the speculative association between giving concentrated feeds and the development of hypernatraemia during an intercurrent illness. Davies (1973) found that artificially-fed healthy infants had a significantly higher plasma osmolality than breast-fed infants. Colle, Ayoub, and Raile (1958) showed that giving high solute feeds to infants with diarrhoea during their illness predisposed to hypernatraemic dehydration. To date there is no evidence that the feeds usually given to babies who develop hypernatraemia are more concentrated than those given to ill babies with normal blood sodium levels. In the present survey we tried to find out if there was an association between the concentration of usual milks and the plasma sodium levels of dehydrated infants.

Patients and methods

From February to September 1974, dehydrated babies aged less than one year who were admitted to this hospital were eligible for study. Seacroft Hospital takes more than half the acute paediatric admissions for the city of Leeds and is the area infectious diseases unit. The criterion used for the definition of dehydration was that the infant should require intravenous fluid replacement during the first 24 hours. Initial assessment of hydration was left to the admitting physician, who arranged estimation of plasma sodium. Hypernatraemic dehydration was said to be present if the plasma sodium was 150 mEq/l or more. The management of this condition and its prognosis differs from dehydration accompanied by lower sodium values (Finberg and Harrison, 1955; Macaulay and Watson, 1967; Finberg, 1969).

Of the 25 babies studied, 18 were boys and 7 girls. Their ages ranged from 7 days to 9 months and the duration of their illness from one to 14 days (mean 4 days) before admission. The major symptom was diarrhoea in 8 babies, vomiting in 7, diarrhoea and vomiting in 5, feed refusal in 4, and a cough in one. 3 hypernatraemic infants had convulsions during rehydration. None of the babies died. The mother was interviewed while her baby was in the ward and details of the baby's previous health, the present illness, and feeding practice since birth were obtained. The usual brand of milk was recorded as well as the exact method used for measuring the amount of dried milk powder. Particular attention was paid to the way in which water was added to the powder, as errors easily occur at this stage; any additions to the milk were noted. The mother was asked how she altered the feeds during illness. We then asked her to bring to the hospital a sample of feed made up as she usually did for her healthy baby. 23 babies were receiving dried milk formulae, either half- or full-cream, fortified with iron

Received 16 January 1975.

and vitamins C and D. Two were fed pasteurized cow's milk. No babies were being given evaporated (unsweetened condensed) milk.

We analysed samples of milk obtained from the hospital milk kitchen, from bulk supplied prepacked milk, and also milks made up personally. Sodium concentrations in plasma and milk were measured by flame photometry with a Corning EEL model 450 photometer. Milk osmolality was determined using the depression of freezing point method with an 'Osmette A' automatic osmometer.

Results

The infants were divided into two groups. Group A contained babies who on admission had a plasma sodium <150 mEq/l; there were 10 with a mean age of 1·8 months (range 7d – 6m). In group B were 15 infants with plasma sodium 150 mEq/l or higher (hypernatraemia) and a mean age of 2·2 months (range 7d – 9m). Fig. 1 shows the

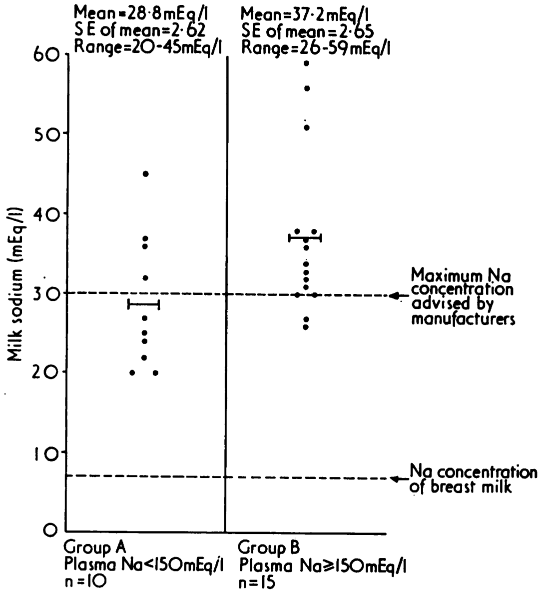

FIG. 1.—*Sodium concentrations of milks that were usually fed to dehydrated infants, with or without hypernatraemia. Significance of difference of means, P< 0·025.*

sodium levels in the milk samples for each group. The *maximum* milk sodium concentration recommended by the manufacturers (30 mEq/l) and the sodium content of breast milk are also indicated. In group A, 4 of 10 infants were being fed milk with sodium concentration >30m Eq/l, compared with 11 of 15 babies in group B (hypernatraemia). Fig. 2. shows the milk osmolalities. Also shown are

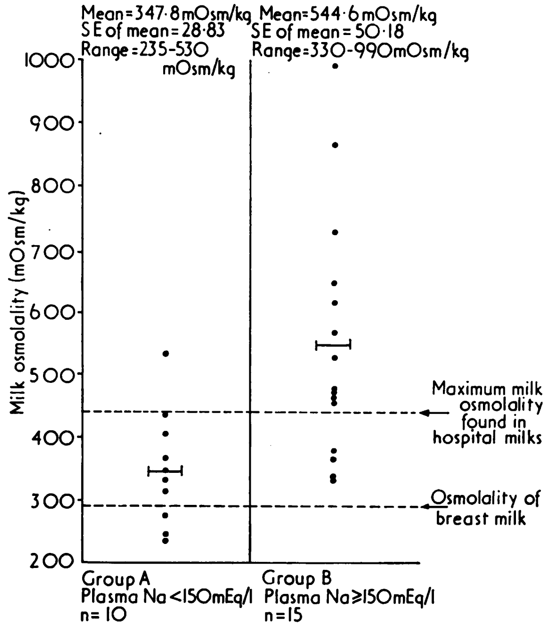

FIG. 2.—*Plasma sodium concentration and osmolality of milks that were usually fed to dehydrated infants, with or without hypernatraemia. Significance of difference of means, P< 0·0025.*

the maximum value obtained from analysis of prepacked and hospital milk kitchen samples (390 mOsm/kg) and the osmolality of breast milk (290 mOsm/kg, Kon and Cowie, 1961). Of the 10 group A babies, 3 were receiving milk of osmolality >390 mOsm/kg, compared to 11 of 15 in group B (hypernatraemia).

The mean sodium content and osmolality of the individual milk brands prepared by mothers of both groups of infants is shown in Table I. Two brands of full-cream milk were made up personally and analysed for sodium content and osmolality. The effect of variations in technique such as described by mothers in the survey was also assessed. The results are shown in Table II.)

Discussion

Three disturbing conclusions may be drawn from this study. Firstly we confirm previous speculation that the feeding of excessively concentrated milk to healthy infants predisposes to the development of hypernatraemic dehydration during illness. Babies' kidneys have a limited capacity to deal with high solute feeds. They can excrete concentrated urine (Edelmann and Barnett, 1960) and indeed do

TABLE I

Sodium concentration and osmolality of various brands of milks prepared by mothers

	Group A (plasma Na <150 mEq/l)			Group B (plasma Na ≥150 mEq/l)		
	No. in group	Milk Na (mEq/l) (mean and range)	Milk osmolality (mOsm/kg) (mean and range)	No. in group	Milk Na (mEq/l) (mean and range)	Milk osmolality (mOsm/kg) (mean and range)
Half-Cream Cow and Gate (Babymilk 1)	1	20	303	6	31 (26–36)	548 (380–730)
Full-Cream Cow and Gate (Babymilk 2)	4	36 (25–45)	425 (330–530)	5	43 (30–56)	542 (330–990)
Ostermilk 2	3	27 (22–32)	321 (247–367)	4	39 (27–59)	551 (331–867)
Cow's milk	2	22 (20–24)	255 (235–276)	-	-	-

TABLE II

Concentrations of feeds reconstituted by investigators

	Sodium (mEq/l)	Osmolality (mOsm/kg)
Full-Cream Cow and Gate (Babymilk 2)		
7 scoops powder + 7 oz (200 ml) water + 1 level teaspoon sugar	20	205
*7 scoops powder + water made up to 7 oz (200 ml) milk + 1 level teaspoon sugar	30*	323*
7 scoops powder (levelled along packet) + water made up to 7 oz (200 ml) milk + 1 teaspoon sugar	47	597
Ostermilk 2		
*6 scoops powder + 6 oz (170 ml) water + ½ level teaspoon sugar	32*	338*
6 scoops powder + water made up to 6 oz (170 ml) milk + ½ level teaspoon sugar	33	385
6 scoops powder (levelled along packet) + water made up to 6 oz (170 ml) milk + ½ level teaspoon sugar	36	416

*Reconstituted following manufacturer's instruction on the packet.

so when continually given artificial feeds (Zeigler and Fomon, 1971; Taitz and Byers, 1972). However, they do this at the expense of their water reserves. If these are further depleted by illness and not replenished because of anorexia, hyperosmolar dehydration must result. This is borne out by the fact that the sodium concentration and osmolalities of the feeds given to the infants in the present study before they become ill were greater in the hypernatraemic group than in babies with normal plasma sodium values.

We also discovered that many mothers were making up artificial milk formulae to an unacceptably high solute concentration. Taitz and Byers (1972) found 30 of 32 milk samples from a Sheffield baby clinic to contain sodium levels greater than their control value of 25 mEq/l. Using the same figure we found 20 of 25 milks to contain excess sodium. It is possible that the milks the mothers gave us might not have a similar composition to the milk fed to the baby. We assumed that mothers who were more careful about the preparation of milk brought to hospital would tend to adhere closely to the manufacturers instructions. Thus a mother who ordinarily prepared a concentrated feed would be more likely to give us a milk more dilute than usual. Since the Leeds figures are similar to those from Sheffield, it is probable that the test milks with which we were being supplied were made up by mothers in their usual way.

Shaw, Jones, and Gunther (1973) determined the ideal sodium content of commercial brands of artificial milks. Compared with their figures, all infants in the present survey were being given feeds too rich in sodium. There is a wide range in the reported normal values of sodium in milk; data on milk osmolality are scarce. Table III shows known values of each. If the figures in Table I for dried milks are reviewed, it will be seen that only the 3 babies in the nonhypernatraemic group who received Ostermilk 2 were receiving milk containing, on average, less sodium than the manufacturer's recommended maximum and of osmolality less than 390 mOsm/kg. The single infant in the nonhypernatraemic group who was fed half-cream Cow & Gate was the only other baby to receive reconstituted dried milk of acceptable osmolality.

Thirdly, attention must be drawn to the number of babies (6) with hypernatraemia who had been fed on half-cream milk. 12 infants were aged 2 weeks or less and most were born in a hospital which uses this milk. The manufacturer does not advise the addition of sugar when this feed is reconstituted, as occurred with 3 of the babies studied. The osmolalities of the resulting milks were 524, 617, and 730 mOsm/kg. Raised sodium levels in these milks show that excessive amounts of powder also contributed to these concentrations. Half-cream milks deserve to be superseded by 'humanized' milks. These are lower in phosphorus, protein, and sodium content than half- or full-cream milks, and they are fortified by iron and vitamins C and D, but they do not need to have sugar added. They may be used throughout the whole of the first year of life at the same dilution. Finberg (1958) pointed out that during illness growth may be halted, thus diminishing nutritional needs. He also noted that milk feeds may increase the bulk of stools in an episode of diarrhoea and thus enhance water loss. When their babies became ill, 18 mothers did not alter their feeds, except to withdraw solids if these were being given. 5 mothers (2 on advice of a midwife) diluted the feeds, mainly, by using one less scoop of powder than ounces of water. Even so, the osmolality of the resulting milk was greater than 350 mOsm/kg in all cases.

It is a matter of concern that the importance of diluting milk feeds—or removing milk from the diet altogether when babies are sick—is not being emphasized to mothers. Even more alarming was the practice of 2 mothers who substituted 'sugar water' (1 teaspoon glucose to 1 oz water, osmolality 1065 mOsm/kg) and rose hip syrup (1 teaspoon to 1 oz water, osmolality 490 mOsm/kg) in the belief that they were giving their babies diluted feeds. Hypernatraemia and metabolic acidosis both inhibit the utilization of glucose (Heggarty, Trindade, and Bryan, 1973; Nitzan, 1974) which can accumulate in the blood, increasing its osmolality. There is clearly an urgent need for publicizing rational medical advice on how to make up feed susbstitutes. Soluble electrolyte tablets may have a useful role in this situation; however, if they are reconstituted incorrectly, hypernatraemia might still occur.

How do babies' feeds become concentrated? In general, gross errors in making up feeds did not seem to have been committed. Small alterations in technique may cause large variations in osmolality and sodium content. The most notorious of these is the way in which the spoonful of dried milk

TABLE III

Reported sodium conccntration and osmolality of various milk formulae

Source	Sodium(mEq/l)		
	Half-cream Cow & Gate (Babymilk 1)	Full-Cream Cow & Gate (Babymilk 2)	Ostermilk II
Shaw *et al.* (1973)	17	21	19
Manufacturer	16·1*	23·9*	30†
		'Full-cream milk'	
		Sodium (mEq/l)	Osmolality (mOsm/kg)
Taitz and Byers (1972)		26	–
Stern, Jones, and Fraser (1972)		26	315

*A. Dew, personal communication, 1974.
†J. F. Griffin, personal communication, 1974.

powder is levelled—if it is levelled at all. 10 mothers did not use the recommended method of dipping the scoop in the powder, taking it out, and levelling the powder with the back of a table knife: 7 of their babies were hypernatraemic. The most common variation was to drag the scoop up the side of the packet, thus compressing the powder. Wilkinson *et al.* (1973) showed that the amount of powder in the scoop can be increased by using this method. Table III shows by how much the sodium content and osmolality of the milk can thus be raised. Pressing the back of a teaspoon down on the powder in the scoop and shaking surplus powder off the scoop were two other faulty methods used. 2 mothers who said they used knives to level the scoops were subsequently observed to use the packet sides: it may be that some of the other 12 were not as careful as they claimed. The instructions for SMA milk (not used in the survey) stipulate that the powder should be packed in the scoop before levelling. Another source of confusion is that one popular brand (Ostermilk) advises that a fixed amount of water be added to a certain number of scoopsful of powder, while another (Cow & Gate) states that enough water should be added to the powder to make up a given volume. 20 mothers, regardless of the brand of milk used, said they added a fixed amount of water. When asked to describe the method step by step, 7 described making the mixture up to the number of ounces required, using a jug for mixing. The amount of sugar added was variable. 14 mothers put in amounts varying from ¼ to 1 teaspoon. Again, when questioned in detail, none levelled the spoons and ½ teapsoon would be more accurately described as 1 teaspoon levelled down. The errors that can be made by variations in technique are shown in Table II.

Hypernatraemic dehydration does not only imply electrolyte imbalance. Morris-Jones, Houston, and Evans (1967) showed that 36% of hypernatraemic infants have neurological symptoms during their illness. On follow-up 9% retained clinical neurological disability ranging from cerebral palsy to mental subnormality. Macaulay and Watson (1967) calculated that 1000 schoolchildren in England and Wales may have a physical handicap which could be a result of hypernatraemia. They also suggested that hypernatraemia caused 100 deaths per annum. This figure may be an underestimate, since Emery, Swift, and Worthy (1974) have implicated hypernatraemia in the pathogenesis of the sudden unexpected death in infancy syndrome (cot death) which is responsible for about 1000 deaths a year.

Contemporary feeding practices are alarming. Since the habits of a generation are unlikely to alter quickly, it would be logical to change the constituents of dried milks to reduce the possibility of error. To this end, and as a second best to the more widespread promotion of breast feeding, we welcome the advent of modern 'humanized' milks low in solute content and needing no additional sugar. Cow & Gate 'V' Formula, Ostermilk Complete Formula, and SMA are examples of such milks. Greater use of these may be stipulated by adopting one as National Dried Milk—and advertising it as being 'new formula'. To be completely acceptable to mothers the price of a new milk must be competitive with established brands. Table IV shows the prices of milks obtainable in Leeds; it does not allow for the fact that some powders reconstitute to a greater volume of milk than others. It must be recalled that large families or those with a low income are entitled to receive National Dried Milk free of charge. Deferring the introduction of cereals until the age of 3 months or later would also help, but this has been pointed out many times before with seemingly little effect.

TABLE IV

Retail prices of dried milk formulae (October 1974)

Brand	Amount of powder in oz (g)	Price (pence)
SMA	15·9 (605)	60
Ostermilk Complete Formula	17·5 (662)	50
Cow & Gate 'V' Formula	16 (610)	49
Half-Cream and Full-Cream Cow & Gate (Babymilk 1 and 2)	16 (610)	47
Ostermilk 1 and 2	16 (610)	46
National Dried	20 (761)	20

It would be a sound move to implement the recent recommendations of a working party of the DHSS (1974) and standardize instructions for making up milk feeds, without sugar being added. The suggestion of Shaw *et al.* (1973) that electrolyte composition be added to the list of ingredients on the packet side, should be implemented. Other manufacturers might copy the advice given on the Ostermilk packet: 'If baby is perspiring, he may be overheated and a drink of cooler, boiled water, not milk food, may be given between feeds to quench his thirst. If in doubt about your baby's needs, or if baby is unwell, consult your doctor or nurse.' The advice given in such a situation must be clear and simple. There is a strong case for discarding such feeds as 'sugar water' for the *first aid* treatment of infants with gastrointestinal upset, and substituting plain water. Medical and nursing professions must agree upon reliable and standardized methods to be used in the preparation of milk feeds for infants. The importance of taking a detailed feeding history should be impressed upon those who care for sick infants. They should take any opportunity for the education of mothers in the correct methods of reconstituting feeds, the hazards of overfeeding and the safe ways in which feeds may be prepared for ill babies.

Most of the infants studied were admitted in the care of Drs. J. Stevenson and H. Pullen. We are grateful for their encouragement and for the enthusiastic co-operation of their ward staff. Dr. S. R. Meadow gave helpful advice and criticism.

References

Colle, E., Ayoub, E., and Raile, R. (1958). Hypertonic dehydration (hypernatraemia): the role of feedings high in solutes. *Pediatrics*, **22**, 5.

Davies, D. P. (1973). Plasma osmolality and feeding practices of healthy infants in the first three months of life. *British Medical Journal*, **2**, 340.

Davies, P. A. (1971). Feeding. *British Medical Journal*, **4**, 351.

Department of Health and Social Security Working Party (1974). *Present-Day Practice in Infant Feeding*, H.M.S.O. London.

Edelmann, C. M., Jr., and Barnett, H. L. (1960). Role of the kidney in water metabolism in young infants. *Journal of Pediatrics*, **56**, 154.

Emery, J. L., Swift, P. G. F., and Worthy, E. (1974). Hypernatraemia and uraemia in unexpected death in infancy. *Archives of Disease in Childhood*, **49**, 686.

Finberg, L. (1958). The possible role of the physician in causing hypernatraemia in infants dehydrated from diarrhea. *Pediatrics*, **22**, 2.

Finberg, L. (1969). Hypernatraemia in infants as a cause of brain damage. *Yearbook of Pediatrics*, p. 49. Ed. by S. S. Gellis. Year Book Medical Publishers, Chicago.

Finberg, L., and Harrison, H. E. (1955). Hypernatraemia in infants. An evaluation of the clinical and biochemical findings accompanying this state. *Pediatrics*, **16**, 1.

Heggarty, H., Trindade, P., and Bryan, E. M. (1973). Hyperglycaemia in hyperosmolar dehydration. *Archives of Disease in Childhood*, **48**, 740.

Kon, S. K., and Cowie, A. T. (1961). *Milk: The Mammary Gland and its Secretion*, Vol. 2. Academic Press, New York.

Macaulay, D., and Watson, M. (1967). Hypernatraemia in infants as a cause of brain damage. *Archives of Disease in Childhood*, **42**, 485.

Morris-Jones, P. H., Houston, I. B., and Evans, R. C. (1967). Prognosis of the neurological complications of acute hypernatraemia. *Lancet*, **2**, 1385.

Nitzan, M. (1974). Hyperglycaemia and uraemia in hyperosmolar dehydration. *Archives of Disease in Childhood*, **49**, 500.

Oates, R. K. (1973). Infant-feeding practices. *British Medical Journal*, **2**, 762.

Shaw, J. C. L., Jones, A., and Gunther, M. (1973). Mineral content of brands of milk for infant feeding. *British Medical Journal*, **2**, 12.

Shukla, A., Forsyth, H. A., Anderson, C. M., and Marwah, S. M. (1972). Infantile overnutrition in the first year of life: a field study in Dudley, Worcestershire. *British Medical Journal*, **4**, 507.

Stern, G. M., Jones, R. B., and Fraser, A. C. L. (1972). Hyperosmolar dehydration in infancy due to faulty feeding. *Archives of Disease in Childhood*, **47**, 468.

Taitz, L. S., and Byers, H. D. (1972). High calorie/osmolar feeding and hypertonic dehydration. *Archives of Disease in Childhood*, **47**, 257.

Wilkinson, P. W., Noble, T. C., Gray, G., and Spence, O. (1973). Inaccuracies in measurement of dried milk powders. *British Medical Journal*, **2**, 15.

Ziegler, E. E., and Foman, S. J. (1971). Fluid intake, renal solute load and water balance in infancy. *Journal of Pediatrics*, **78**, 561.

Correspondence to Dr. T. L. Chambers, University of Leeds, Department of Paediatrics and Child Health, Medical Education Centre, Seacroft Hospital, York Road, Leeds, LS14 6UH, Yorks.