Plasma osmolality, sodium, and urea in healthy breast-fed and bottle-fed infants in Newcastle upon Tyne

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Dale, G., Goldfinch, M. E., Sibert, J. R., and Webb, J. K. G. (1975). *Archives of Disease in Childhood*, 50, 731. **Plasma osmolality, sodium, and urea in healthy breast-fed and bottle-fed infants in Newcastle upon Tyne.** Plasma osmolality, sodium, and urea were measured on samples from 50 healthy infants, aged between 18 and 125 days, attending child health clinics in Newcastle upon Tyne. 3 infants had osmolalities greater than 300 mOsm/kg, a lower incidence of hyperosmolality than that previously reported. There was a difference ($P < 0.001$) between the plasma urea levels of breast-fed and bottle-fed infants, but not between the osmolalities of these groups. The mean plasma urea of bottle-fed babies was 53 mg/100 ml (SD 12.47), 50.1 mg/100 ml (SD 10.9) if additional solids were being given, and 18.4 mg/100 ml (SD 7.81) for breast-fed babies. There was little difference between the plasma sodium levels of each group. The mean plasma sodium for all groups combined was 135.2 mmol/l (SD 2.3); no plasma sodium exceeded 140 mmol/l.

Concern has been increasingly expressed over present infant feeding practices (*British Medical Journal*, 1973) associated with the decline in breast-feeding, the early introduction of solids, and the use of improperly prepared feeds. Taitz and Byers (1972) found that a worrying proportion of feeds made up at home were too concentrated, and Wilkinson and co-workers (1973) reported that even trained personnel could make serious errors in reconstituting milk powder. There is a clear relation between overfeeding in early infancy and obesity in childhood (Eid, 1970; Shukla *et al.*, 1972), and suggestive evidence of a relation between high solute feeding and an increasing prevalence of hypernatraemia (Simpson and O'Duffy, 1967).

Davies (1973) found raised plasma osmolality in a significant number of healthy infants in Cardiff. Because of the obvious importance of determining whether these Cardiff findings are applicable elsewhere, we undertook a survey of healthy babies attending child health clinics in Newcastle upon Tyne. In addition to determining the distribution of osmolalities in this sample, we

considered it important to relate these to sodium and urea levels and to patterns of feeding.

Patients and methods

The babies studied were a consecutive series aged between 18 and 125 days attending 4 child health clinics in Newcastle upon Tyne in January and February, 1974. The clinics (Arthur's Hill, Cruddas Park, Fenham, and Jesmond) were selected to give a reasonable cross-section of housing and social conditions in the city. Of the 53 mothers to whom the purpose of the survey was explained, first by one of the health visitors and then by one of us (J.R.S.), 50 agreed to participate. After a short history and an examination to establish normal health, 1 ml of blood was taken by heelprick, without undue squeezing, into a tube containing lithium-heparin anticoagulant. Plasma osmolality was determined using a Knauer semimicro osmometer, sodium and potassium using an IL 143 flame photometer, and plasma urea by a diacetyl monoxime method using an IL 368 Clinicard analyser. Babies found to have a plasma osmolality in excess of 300 mOsm/kg were re-examined and the mother advised on feeding.

Results

For purposes of analysis the 50 babies were divided into four groups on the basis of their feeds (Table I). The weights of the 50 babies are

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TABLE I
Number of babies in each of the feeding groups

Group A (breast-fed)	Group B (bottle-fed on SMA)	Group C (bottle-fed alone on formulae other than SMA)	Group D (bottle-fed with additional solids)	Total
7	3	14	26	50

FIG.—Weight chart of infants studied. The 3 babies found to have a plasma osmolality of 300 mOsm/kg or over are arrowed. ●, group A, breast-fed infants; ○, group B, bottle-fed on SMA (Scientific Milk Adaptation); ▽, group C, bottle-fed alone on milk formulae other than SMA; □, group D, bottle-fed (on formulae other than SMA) with additional solids. Centiles for this age group are means of male and female weights from data of Tanner et al. (1966).

shown in the Fig. The sample, including 23 boys and 27 girls, is significantly heavier ($P < 0.05$) than the mean of norms for British boys and girls obtained by Tanner, Whitehouse and Takaishi (1966). 14 infants were below the 50th centile for weight, against 36 above: and only one was below the 10th centile against 11 on or above the 90th. There were differences among the four groups. 3 out of 7 breast-fed infants (43%) had a weight on or above the 90th centile compared with 6 out of 26 (23%) on artificial feeds with added solids. The slope of the regression line for the weights of group D as a whole was found to be steeper ($P < 0.05$) than that of group A (breast-fed). The slopes of the regression lines for groups B and C were intermediate between A and D, but these differences were not significant. These regression lines suggest that breast-fed babies, though initially heavier, later gain weight less rapidly than infants

who are bottle-fed with added solids. The numbers examined are small for firm conclusions, however.

Mean osmolality and standard deviation for each group are shown in Table II. The differences between these four groups were not significant. 3 babies had a plasma osmolality of 300 mOsm/kg or over (Fig.). A further blood sample taken from one of these babies showed that plasma osmolality had fallen from 309 mOsm/kg to 288 mOsm without a change in feeding pattern.

Plasma urea levels are shown in Table III. There was a highly significant difference ($P < 0.001$) between breast-fed babies (A) and both bottle-fed groups (C and D). The mean plasma urea of groups C and D was not significantly different but there was a difference ($P < 0.001$) between groups B and C and between groups B and D. There was no significant difference in plasma sodium concentration in the four groups (Table IV). Mean plasma sodium concentration of all groups combined was 135.2 mmol/l (SD 2.33). The lowest value obtained was 130 mmol/l and the highest 140 mmol/l.

Discussion

The purpose of the study was to determine the prevalence of significant hyperosmolality in healthy infants. Because any blood examination in a normal baby imposes an emotional burden on the mother (and the operator) and may, unless carefully explained, generate unnecessary anxiety, we limited the sample to the essential minimum. The numbers are therefore small, but nevertheless suggest strongly that hyperosmolality on the scale found in Cardiff is not present in Newcastle upon Tyne. Whereas Davies (1973) found 16 out of 60 infants with a plasma osmolality of 300 mOsm/kg or above, only 3 of the Newcastle infants had values in this range and one of these had returned to normal when a second blood sample was obtained. The mean osmolality of Davies's babies who were bottle-fed with additional solids was 297 mOsm/kg, higher than the mean (289 mOsm/kg) for the similar group in Newcastle. The cause of this disparity is

TABLE II
Plasma osmolality

	Group A	Group B	Group C	Group D
Mean value (mOsm/kg)	283.7	283.7	288.9	288.9
SD	4.03	6.66	7.30	6.35

Groups A-D same as in Table I.

TABLE III
Plasma urea

	Group A	Group B	Group C	Group D
Mean urea (mg/100 ml)	18.4	23.7	53.0	50.1
SD	7.81	4.93	12.47	10.87

Groups A-D same as in Table I.

TABLE IV
Plasma sodium

	Group A	Group B	Group C	Group D	Combined
Mean plasma sodium concentration (mmol/l)	135.9	135.3	134.6	135.4	135.2
SD	2.79	3.79	1.87	2.33	2.33

Groups A-D same as in Table I.

not immediately apparent. It may be that there are differences in feeding practices between the regions. Alternatively, there may have been a change in practice during the interval between the two studies. The difference between Tanner *et al*'s weights and ours suggest that changes can occur, presumably because of nutrition. Awareness has been growing among doctors and health visitors of the dangers of overfeeding, and perhaps this has been emphasized to mothers during the interval between the Cardiff and Newcastle studies and this contributed to such a change in practice.

The figures obtained for plasma urea and sodium are perhaps more instructive than those for plasma osmolality. We have confirmed the work of Davies and Saunders (1973) on the relation of feeding to plasma urea concentration. There was a highly significant difference between babies fed on unmodified cow's milk formulae (with relatively high protein content) and those fed on breast milk. Though the figures are small, it seems likely that those babies receiving SMA have a lower plasma urea than the other bottle-fed infants. Indeed, these values appear to be similar to those of breast-fed babies. Our data suggest that healthy infants fed on some formulae may have plasma urea values

greater than 70 mg/100 ml, and these are certainly above the usually accepted upper limits of normal. There is no evidence that these plasma urea levels are harmful. The findings of such levels in clinical practice, especially in infants where impairment of renal function is suspected, must clearly be interpreted with caution.

The mean plasma sodium concentration did not appear to be influenced by the method of feeding. The value for the group as a whole was 135.2 mmol/l with a range (mean $\pm$ 2 SD) of 130.5–139.9 mmol/l. These figures are similar to the mean of 135.5 mmol/l with a range of 130.8–140.2 mmol/l, from a hospital population of infants aged between 1 month and 1 year (G. Dale, unpublished observation). These values suggest that the 'normal range' for plasma sodium in infants is about 5 mmol/l lower than the generally accepted value, which appears to be based upon adult data. Though plasma sodium is normally maintained within a narrow physiological range, a difference of this magnitude can have considerable effect on the management of sick infants. On the one hand a state of hyponatraemia may erroneously be considered to exist in cases when plasma sodium is in the region of 130 mmol/l. On the other hand,

marked hypernatraemia may be viewed with complacency, or recourse taken to the estimation of plasma osmolality, which is technically more difficult.

A small study like this can do no more than hint at the broad picture of infant nutrition in Britain today, and it would be wrong to derive generalizations from it. However, the indication that significant hyperosmolality is not prevalent is reassuring, while the occurrence of raised plasma urea levels in infants who are heavier than the norms of 9 years ago emphasize the need for sharper definitions of optimal nutrition and inappropriate overfeeding.

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REFERENCES

- British Medical Journal* (1973). (Leading article.) Fashions in infant feeding, 2, 727.
- 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, D. P., and Saunders, R. (1973). Blood urea: normal values in early infancy related to feeding practices. *Archives of Disease in Childhood*, 48, 563.
- Eid, E. E. (1970). Follow-up study of physical growth of children who had excessive weight gain in the first six months of life. *British Medical Journal*, 2, 74.
- 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.
- Simpson, H., and O'Duffy, J. (1967). Need for clarity in infant feeding instructions. *British Medical Journal*, 3, 536.
- Taitz, L. S., and Byers, H. D. (1972). High calorie/osmolar feeding and hypertonic dehydration. *Archives of Disease in Childhood*, 47, 257.
- Tanner, J. M., Whitehouse, R. H., and Takaishi, M. (1966). Standards from birth to maturity for height, weight, height velocity, and weight velocity: British children, 1965. Part II. *Archives of Disease in Childhood*, 41, 613.
- Wilkinson, P. W., Noble, T. C., Gray, G., and Spence, O. (1973). Inaccuracies in measurement of dried milk powders. *British Medical Journal*, 2, 15.

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