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INFANT FEEDING, GROWTH AND MORTALITY: A 20-YEAR STUDY OF AN AUSTRALIAN ABORIGINAL COMMUNITY

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The data are presented on infant mortality, growth and feeding for an Australian Aboriginal Settlement over 20 years from 1953 to 1972. During this period the infant mortality rate fell from about 280/1000 to about 40/1000 although the growth, infant feeding and health facilities remained almost the same. It is proposed, as a hypothesis worthy of further exploration, that major factors leading to improvement in infant mortality have been a changed attitude to small infants and an ability to use health services appropriately. These factors may be important in all developing communities.

PUBLISHED reports comparing the welfare of breast-fed and bottle-fed infants give inconsistent results. There are reports that in developing countries, bottle-fed infants grow less rapidly and have higher death rates[1 2] than breast-fed infants, but there are two studies, one on a selected sample in Malaysia[3] and another from a national rural survey in Kenya[4] that show prolonged breast feeding increases the likelihood of growth retardation. In Western countries there are reports[5] that bottle-fed infants are more likely to be obese than breast-fed infants, but another[6] contradicts this finding. These inconsistencies probably arise from asking the wrong questions. In all cultures, except the most primitive, most infants grow and develop on many feeding regimes. Rather than condemn any particular regime, we should be asking why some mothers succeed and why others fail in raising their children.

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METHODS

In this paper the growth, mortality and feeding of infants living on an isolated settlement over a 20-year period have been analysed. The infant death rates have fallen dramatically during that time, but the factors conventionally thought to influence infant health have remained almost unchanged. Some other factor has obviously been operating, and it seems that the attitudes of mothers may well be a major determinant in the well-being of their infants.

The Population

Cherbourg Aboriginal Settlement is a community of about 1200 persons, situated 250 km north-west of Brisbane, in Queensland, Australia. The Settlement is administered by the Queensland State Government. The people live in wooden houses. All have electricity; some have a standpipe outside, but newer homes have water in the house. The Settlement is about 300 metres above sea level and inland, so summers are hot, but there are heavy frosts in winter. The children attend a Government school on the Settlement, and there are shops for purchase of food and basic commodities.

The health services comprise a 40-bed hospital staffed by trained nurses, who are almost invariably Caucasian. A general practitioner from a nearby country town visits the Settlement twice weekly and in emergencies to treat inpatients and outpatients at the hospital. The same general practitioner has served the community from 1956, and, although a new hospital was occupied during the period, the facilities and standard of service have changed little. Most patients are treated on the Settlement and most infants were born there, but patients with serious problems are sent by ambulance to a major hospital, usually in Brisbane. An Infant Welfare Clinic with a trained sister gives advice to mothers and weighs the infants regularly. The only large-scale public health measure undertaken during the study period was the institution of regular administration of piperazine to reduce the heavy load of ascaris. This measure is unlikely to have had any major effect on the welfare of infants under one year of age.

The Data

Records from the hospital, the Infant Welfare Clinic and the administrative office of the Settlement were made available for study and analysis. The records in the administrative office gave dates of birth and, where appropriate, death of all children living on the Settlement whether or not the birth/death occurred on the Settlement. From the records at the hospital and clinic were obtained the birth weights and the types of feeding and achieved weights throughout infancy.

The birth and death data for all years from 1953 to 1972 have been used to show the changing pattern of infant mortality. A more detailed analysis has been done on infants born in 1953, 1958, 1963, 1968 and 1972. For children born in these years, the weights at birth and 6, 12 and 24 months have been abstracted from the clinic cards, together with the duration of breast feeding. If the child died, the age of death was noted, but the data did not permit complete recording of the causes of death. Inevitably some of the records were incomplete and some were missing, but data

were available for over 90% of the children born in the five years selected for detailed study.

Most of the analysis has been done by simple tabulation, but for the analysis of the effect of breast/bottle feeding on the achieved weights, simple one-way analysis of variance has been used. The achieved weights were converted into percentages of the 50th percentile weight-for-age of the Boston standards,[7] so that data for boys and girls could be combined into the same tables.

RESULTS

Infant Mortality Rate

Over the 20 years studied, there was a dramatic fall in the infant mortality rates (Table 1 and Figure 1).

With small total numbers of births, the mortality rates per 1000 live births fluctuated widely, but in spite of this there was an obvious and rather rapid fall in the mortality rate about the middle of the study period. The mortality rate fell from about 280 per 1000 live births to about 40 per 1000 live births. This lower mortality rate was still about double the rate for the whole of the State of Queensland at that time.

TABLE 1
Total Births and Infant Deaths on the Settlement, 1953 to 1972

Year	Number of Infants		Mortality Rate (per 1000 Live Births)	Three-Year Sliding Average Mortality Rate (per 1000 Live Births)
	Born	Died		
1953 ..	75	16	213	—
1954 ..	70	20	285	255
1955 ..	59	19	322	288
1956 ..	62	16	258	272
1957 ..	77	19	246	225
1958 ..	70	12	171	196
1959 ..	62	10	161	148
1960 ..	71	8	113	170
1961 ..	49	13	265	165
1962 ..	60	9	150	149
1963 ..	20	3*		
1964 ..	99	9	91	139
1965 ..				
1966 ..	58	12	207	148
1967 ..	45	9	200	172
1968 ..	60	7	117	101
1969 ..	63	1	16	58
1970 ..	50	2	40	24
1971 ..	53	1	19	41
1972 ..	45	3	67	—

* Data incomplete for 1963.

Nutritional Status of Infants

The median weights for infants at birth and 6, 12 and 24 months were calculated for 1953, 1963 and 1972. The results are shown in Figure 2.

The weight gain follows the pattern commonly found in developing countries. Infants tend to be rather small at birth and gain weight very satisfactorily for the first few months, but thereafter lag behind the accepted Western standards of weight-for-age. Figure 2 shows that the patterns of growth have remained constant over the 20-year period and there has been no change in the weight-for-age to parallel the fall in the infant death rate. The means of the two-year weights are shown in Figure 1.

The Pattern of Infant Feeding and its Effect on Infant Weight Gains

The percentages of infants still breast fed at 1, 3, 6, 9 and 12 months are shown in Table 2.

There was a significant decline ($P<0.05$) in the duration of breast feeding from 1953 to 1963, but thereafter the pattern remained constant. There appeared to be a tendency to increased breast feeding in 1972, but with the small numbers involved this was not statistically significant.

To determine the effects of the duration of breast feeding on infant growth, infants born in each of the five index years were divided into four groups depending on the duration of breast feeding. The durations for each group

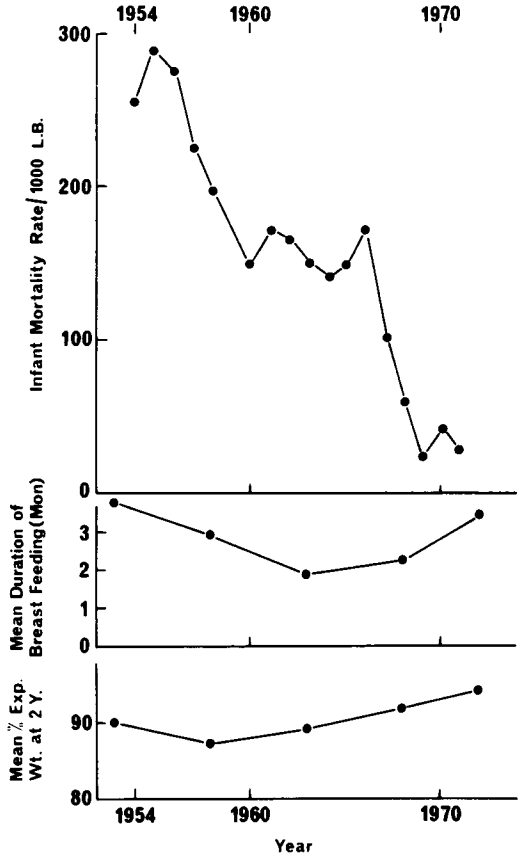

FIGURE 1: The upper graph shows a three-year sliding average of the infant mortality rate from 1953 to 1972. The lower graphs show the mean duration of breast feeding in the five selected years and the mean weights of infants at two years, expressed as a percentage of the Boston standards.

were: less than 1 month, 1 and 2 months; 3, 4 and 5 months; 6 months and over. The achieved weights (expressed as a percentage of the Boston standards) at birth and 6, 12 and 24 months were tested by analysis of variance to find whether the duration of breast feeding had any influence on subsequent weight. The results are shown in Table 3.

TABLE 2
Percentage of Infants Still Breast Fed at Different Ages in the Five Index Years

Year	Percentage of Infants					Number in Sample
	Aged 1 Month	Aged 3 Months	Aged 6 Months	Aged 9 Months	Aged 12 Months	
1953 ..	77	40	8	3	0	65
1958 ..	65	23	5	0	0	57
1963 ..	51	13	6	0	0	47
1968 ..	56	13	4	2	0	52
1972 ..	66	30	13	0	0	47

Overall, there has been a slight increase in the mean weights at the age of 2 years, the mean values being 89.8%, 87.1%, 88.1%, 91.9% and 94.4% of the standard Boston value in the years tested. These differences are

TABLE 3

The Mean Value for the Percentage of the Boston Standard Weight-for-Age Achieved by Aboriginal Children at Birth and 6, 12 and 24 Months with Differing Lengths of Breast Feeding

Year	Duration of Breast Feeding (Months)	Mean Percentage of Expected Weight-for-age							
		At Birth		At 6 Months		At 12 Months		At 24 Months	
1953 ..	<1	88	Sig.	105	Not Sig.	102	Not Sig.	105	Not Sig.
	1 to 2	105		98		93		98	
	3 to 5	102		93		88		93	
	6+	105		90		88		92	
1958 ..	<1	110	Not Sig.	92	Sig.	83	Sig.	82	Not Sig.
	1 to 2	97		94		87		86	
	3 to 5	108		110		96		90	
	6+	106		111		95		92	
1963 ..	<1	100	Not Sig.	93	Not Sig.	87	Not Sig.	88	Not Sig.
	1 to 2	105		97		93		89	
	3 to 5	99		96		93		91	
	6+	94		94		77		82	
1968 ..	<1	89	Not Sig.	94	Not Sig.	94	Not Sig.	91	Not Sig.
	1 to 2	91		93		90		93	
	3 to 5	95		100		88		83	
	6+	94		112		95		95	
1972 ..	<1	94	Not Sig.	90	Sig.	90	Not Sig.	92	Not Sig.
	1 to 2	93		94		94		96	
	3 to 5	95		103		95		95	
	6+	97		105		91		93	

statistically significant overall ($P<0.05$), but there was no significant difference between 1953 and 1972. For infants born in 1953, the birth weights of those who were breast fed for less than one month were significantly less than the birth weights of infants who had longer breast feeding. However, by the age of 6 months these small infants had caught up in weight with the others. For the 1958 group, those infants who received breast milk for more than three months were significantly heavier at 6 and 12 months, but by the age of 24 months there were no significant differences in the infants. A single isolated significant result was found for the 6-month weights of infants born in 1973. However, the overall result of this analysis showed that there were no systematic differences in weights associated with different durations of breast feeding. It was particularly noticeable that there were no significant differences at the age of two years.

The Pattern of Infant Feeding and Infant Mortality

The data on infant feeding at the time of death were examined to find whether there were differences in mortality rates between breast-fed and bottle-fed infants. For a number of infants who died, the type of feeding at the time of death was not recorded. The small number of infants dying made statistical analysis difficult, so the data from the five index years have been combined and the ages have also been grouped. The data have been assembled into infant-months of breast and bottle feeding in Table 4.

TABLE 4

*The Number of Infants Dying at Different Ages and the Type of Milk Feeding at the time of Death**

Ages of Infants (Months)	Breast Feeding		Bottle Feeding	
	Number of Infant-Months	Number of Deaths	Number of Infant-Months	Number of Deaths
1, 2, 3	547	3	525	4
4, 5, 6	99	0	705	11
7+	20	0	1588	9

* To enable comparisons to be made, the feeding is expressed as infant-months.

There were 24 deaths among the infants known to bottle feed at the time of their death and only three among those who were breast fed. The data gave the impression that a number of the deaths among the bottle-fed infants occurred within the first month after weaning.

Inspection of Table 4 shows the similarity in the death rates of breast-fed and bottle-fed infants aged 1, 2 and 3 months. Although there were no deaths among the older breast-fed infants, the total number of infant-months of breast feeding was small. Fisher's exact probability test[8] showed that the probabilities *(P)* of these figures occurring by chance were 0.27 for infants aged 4, 5 and 6 months, and 0.98 for older infants. Although there may be a trend to higher infant mortality rate associated with bottle feeding, it falls well short of statistical significance.

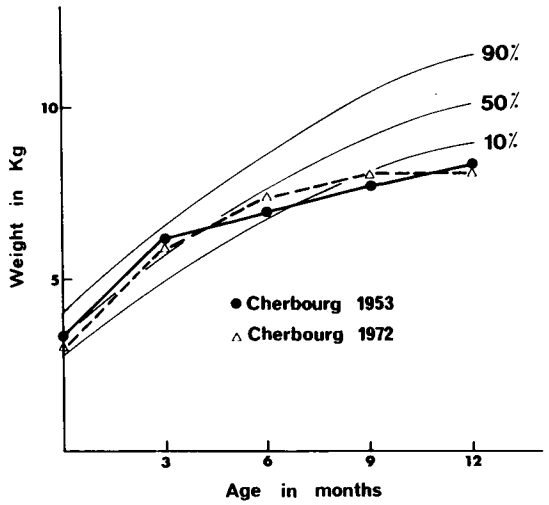

FIGURE 2: The growth curves of Aboriginal children in 1953 and 1972. There is no significant difference in the two curves. The percentile lines show the Boston standards.

DISCUSSION

This study has shown that infant mortality rate in a population can fall from 280 per 1000 live births to 40 per 1000 live births without major change in the type of feeding or in the level of nutrition. Neither did more detailed examination of infant growth and deaths show any consistent and systematic differences between infants on the two types of feeding. It appears that, in this community over the period studied, the type of milk given to the infant did not influence the growth rate and that neither the type of feeding nor the level of nutrition was responsible for the initial high death rate or its improvement. It can be argued that this community is not typical or representative of villages in developing countries. All communities have their peculiarities, and this argument can be supported or rebutted only when similar long-term studies have been done elsewhere. There must be data available around the world, but such studies are rare.

There are reports[1,2,9,10] suggesting that, in unsophisticated communities (in terms of present Western techniques and facilities), breast feeding is associated with better survival and growth of infants than is bottle feeding. There are, however, two studies whose results show quite fortuitously that, even in developing countries, bottle-fed infants may grow better than breast-fed infants.[3,4] If we

put forward the general proposition that, in developing countries, breast feeding produces better growth and lower mortality than bottle feeding, we must accept that the general proposition can never be proved, no matter how many confirmatory examples are cited, but a single contradictory finding destroys the proposition as a general statement. Such a situation has been reached with the universal "breast is best" proposition and yet we cannot ignore the large amount of evidence that seems to support it. We must therefore seek another Kuhnian paradigm[11] which encompasses existing data, removes apparent contradictions and itself leads to testable hypotheses. I propose such a paradigm, not as a hypothesis supported by strong evidence, but as a viewpoint which could lead to further research.

In truly "primitive" communities, the lack of breast milk to feed an infant is a death sentence, but in all but the most depressed and "primitive" communities, the majority of infants thrive and develop reasonably, if not ideally, no matter what type of feeding regime they are given. Other infants languish and die on the same regimes. Given a certain minimum of basic amenities, a mother can raise healthy children provided she has the intelligence, knowledge, incentive and desire to do so. We assume that the distribution of intelligence is about the same in all societies. The knowledge needed for rearing a child successfully is usually present locally, given the incentive and desire to seek it out. We therefore are left with incentive, desire and the opportunities available to the mother as variables in the success of child rearing. Unfortunately, incentive and desire cannot be measured objectively, and opportunity depends to some extent on the priorities of the mother. These cultural pressures are deeply felt and modify behaviour.[14] In Cherbourg Aboriginal Settlement, which I have been visiting for 15 years, there has been no major change in physical facilities, but the attitudes and expectations of the community have changed markedly. In the absence of conventional objective factors, these changes in attitudes and expectations should be considered as possible factors influencing the health of children, although they must be acting through a physiological mechanism.

Teenage promiscuity is a widely accepted way of life on Aboriginal settlements. Fifteen years ago, pregnancy was common, the infants were usually unwanted, and they were frequently passed on to the grandmother to rear. This version of the extended family produced overcrowding, with many infants cared for by few adults. When infants became sick and died, grief was tempered by resignation and even relief. There were (and are) many good families in which mothers work hard with limited resources to rear their children. Inspection of the records on the Settlement, as well as personal knowledge, showed that some families had healthy living children; in others disease was frequent and death common. Throughout the community there was the feeling that disease and death of infants were inevitable. For example, chronic purulent otitis media was so common that, when asked whether her one-year-old child had had running ears, a mother replied: "No, not yet, doctor".

Today, teenage promiscuity with its attendant venereal disease is still common, but the widespread use of contraceptives has reduced the number of unwanted pregnancies. Overcrowding is less and mothers and grandmothers do not have so many small children to rear. There are still the good and not-so-good families, but the not-so-good are fewer and are subject to open criticism by others on the Settlement. This, together with the general rise in expectations, has made mothers more aware of the needs of infants, both in routine day-to-day care when they are well and in the appropriate use of health services when they are sick. It is now assumed implicitly that an infant will survive, and the demand for treatment of illness is both vocal and increasingly sophisticated. The highest levels of facilities, hygiene and care that are found in upper middle-class homes in all countries of the world are still uncommon, and this probably accounts for the fact that the infant mortality rate is still higher than the general level for the State of Queensland. However, such aggregated State statistics hide major variations. Even within the city of Brisbane (population 1 million), there are threefold differences in infant mortality and some of the highest rates are found in the area immediately around the main teaching hospitals.[15] Such differences in the attitudes to infant care and the priority given to it are found in all countries, but particularly in developing countries where the society ranges from urban *élite* to rural traditions. There may well be a general paradigm which would link existing data on infant mortality and growth with the distance that communities and individuals within those communities have progressed from the "primitive" traditional practice and beliefs. The type of care given to infants can be graded into four broad levels.

Level 1 is the "primitive" level, at which there has been no effective contact with international technology and values. In these communities birth and death rates are high and breast feeding is universal and essential for survival. Health care is in the hands of traditional healers and is ineffective against major disease. Hygiene is based on practices which are empirical and traditional, but often surprisingly effective. The water supply is a river or pool; cooking is by wood fire and housing depends on the community resources.

Level 2 is found where a community has come into contact with, and is learning to use, technology, but is still struggling to adapt its intellectual and social framework to cope with the change. This is a large level which could well be subdivided. Health services are usually introduced at an early stage of the development process, but are used by the community only as a last resort after traditional healers have failed. Patients are brought to hospital late and usually die, so that the local hospital becomes the "house of death". The fatalistic attitude to infant disease and death remains, but mothers experiment with bottle feeding and other "civilized" practices, often disastrously at first, but then with increasing sophistication. At this stage birth rates remain high, death rates may fall a little and there may be a difference between breast-fed and bottle-fed infants. Traditional beliefs about health and hygiene tend to remain, but piped water and other sanitary services are accepted.

A community at Level 3 has come to terms with the immediate technological changes and has an elementary understanding of the philosophies behind them. They can use major services, such as the curative health services, appropriately and can generally cope with common consumer technology. However, their grasp of the full potential and danger of these advances is still superficial and major errors can occur. At this level contraception has reduced the birth rate and the combination of hospitals

and hygiene has reduced the infant death rate. Artificial feeding becomes more common as mothers seek employment outside the home to raise their material standard of living. The initial disparity in death rates between breast-fed and bottle-fed infants declines until the difference is no longer perceived as a risk. Electric light, piped water, sewerage and kerosene or gas cooking are the normal expectations.

Level 4 is the level currently attained by privileged members of all advanced societies. They can use the technology appropriately and with some insight. In the event of a breakdown of equipment or a service they can rapidly mobilize the resources available. Their concepts and philosophy are basically those of received scientific knowledge, although at a more superficial level they may well be influenced by fads and fashions. At this level birth rate is low and there is the expectation that every infant will be healthy and survive to adulthood. No matter how the infant is fed, the standard of care and hygiene is such that disability or disease arising from errors in management are rare. The physical health of children is taken for granted and anxiety is centred on mental and emotional welfare.

The levels of beliefs and practices in child rearing described here are necessarily artificial divisions in a continuous process, but they do serve to categorize communities. No nation has all its families in a single level. In most Western countries, the *élite* are at Level 4, but the larger part of the population is at Level 3. In developing countries, the range is often much wider. At the top there is a small group at Level 4, and a slightly larger group at Level 3, while the majority rural traditional populations are at Level 2. Level 1 is now a rarity anywhere in the world. The Cherbourg Aboriginal Settlement appears to have crossed the border from Level 2 to Level 3 over the last 20 years.

This hypothesis can explain the apparent contradictions in the effects of breast and bottle feeding in infants in different studies. It seems probable that mothers at the lower end of Level 2 do not initially have the skills or facilities to use bottle feeding effectively; the results are therefore bad in terms of infant health and survival. However, as these mothers and the community around them learn, they manage artificial feeding adequately. By this time they are reaching the upper limits of Level 2 and the results of various regimes of infant feeding are all similar. The high level of malnutrition among breast-fed infants in Kenya, as compared with bottle fed infants, may reflect either maternal malnutrition which could not support adequate breast milk over long periods, as has been found in Gambia,[12] and/or the traditional delay in starting solid foods among these children, as is often found in communities at the lower end of Level 2.

What a mother does is one thing; why she does it is another. Every mother has her priorities and, although we may not agree with her course of action, it seems likely that she has weighed the pros and cons as well as she can when she makes a decision about infant feeding, so that the resulting action is the one that is most likely to fulfil her priorities. Although it is conventional among nutrition scientists to see the biological mother-child axis in isolation, in fact, a mother has to view a much wider field and make decisions in the presence of considerable uncertainty. Figure 3 and Figure 4 illustrate these two points of view.

A computer model which takes account of 40 of the factors which must enter the mother's consideration has been designed and run,[13] and this model suggests that, at least in urban slum conditions, the decisions of the mother may effectively optimize the family well-being.

The paradigm of levels of development cuts across national boundaries, as all countries have communities at different levels, and the action needed differs with the level of the family or the community, rather than the country in which it lives. By the time a family has reached Level 3 or 4, the short-term gains and losses of different types of infant feeding have fallen below the level of perceived risk and decisions are made on other grounds. It seems a world-wide phenomenon that people are trying to acquire at least some of the "Western" customs and

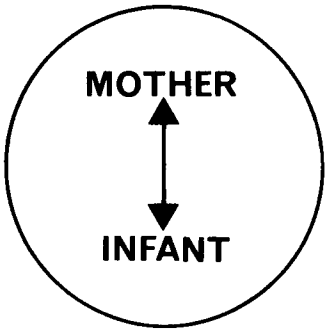

FIGURE 3: The conventional view of the relationship between a mother and her infant. This is unrealistic.

possessions. Attempts to frustrate these aims will probably be ineffective and are likely to provoke resentment. Protection, which in this context implies paternalistic limitation of choice, as well as the more conventional regulation of inferior and dangerous goods, must be incompatible with free choice and risk taking. It seems inevitable that communities should be given the opportunity to sample "Western living" and then have the choice of accepting or

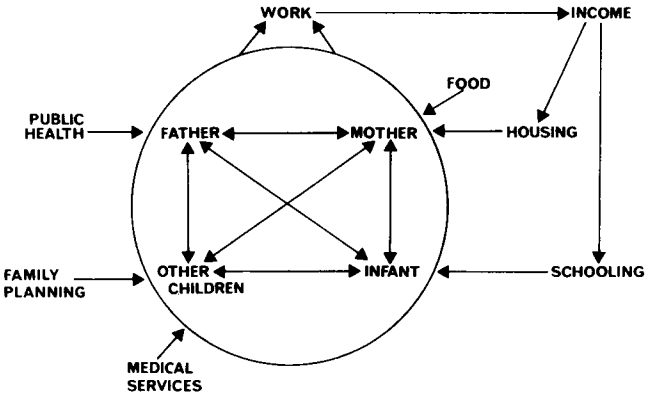

FIGURE 4: This gives a better view of the factors which a mother must consider when making decisions about her infant.

rejecting it in part or in whole. It may be possible to avoid difficulties and dangers of development with a measure of protection, but this must be relaxed as sophistication increases. There is no ideal balance between protection and opportunity; the mix must vary with time and place, and the community is likely to decide for itself what it wants. Under these circumstances, paediatricians and nutrition scientists must recognize, along with other

development planners, that, while education and regulation may well influence the outcome, communities will eventually set their own priorities for welfare and development.

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DISTRIBUTION AND INHERITANCE OF LOW SERUM THYROXINE-BINDING GLOBULIN LEVELS IN AUSTRALIAN ABORIGINES

A NEW GENETIC VARIATION

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Evidence is presented that low serum thyroxine-binding globulin (TBG) levels in Aborigines are widely distributed throughout Australia, and that these are inherited rather than acquired. Levels of TBG in children, and lack of any correlation of low TBG levels with alcohol consumption or liver dysfunction, suggest that the low levels are not acquired in adult life. Genetic studies in eight families indicate (with one exception) an autosomal dominant pattern of inheritance with direct male-to-male transmission. These findings are in marked contrast to the much rarer X-linked pattern of inheritance of low TBG levels in Caucasians. This type of prevalent and inherited low level of TBG in serum appears so far to be unique to the Aboriginal race. The synthesis (or degradation) of TBG may be controlled by an autosomal gene in Aborigines.

A prevalent low serum TBG level and its effects on thyroid function tests has been described by us in Western Australian Aborigines.[1] This major racial variation in TBG appears so far to be unique and raises questions as to its distribution in Australia and its cause. Clearly it would be disturbing from a health point of view if such low TBG levels were acquired rather than inherited, as many of the known causes of low TBG are due to factors such as severe illness, malnutrition, liver dysfunction and, possibly, alcohol intake in "healthy" drinkers.[2]

In order to examine the distribution of low TBG levels in Aborigines we have studied such levels throughout Western Australia, in parts of Northern Territory and Queensland and have noted the report of presumed low TBG levels in Aborigines in South Australia.[3]

To determine whether low levels of TBG in Aborigines were due to malnutrition, liver dysfunction or alcohol addiction we studied protein and albumin levels, liver function tests (LFTs) and levels of the enzyme γ-glutamyl-transferase (GGT) in 69 Aborigines from the Northern Territory. To determine whether the low levels were inherited rather than acquired we studied such levels in children, in part-Aborigines and in eight pure blood Aboriginal families.

MATERIALS AND METHODS

The assay of TBG was performed by the Corning-Immophase method. Measurements of protein, albumin, and the enzyme GGT levels, and LFTs, were performed by standard automated methods.

Serum samples were freshly obtained except for those from Warburton and Queensland which had been stored at −20°C for some time. Experiments with freezing and thawing serum samples up to 10 times in succession indicate that this treatment had no effect on the TBG assay; TBG in serum is a very stable protein, at least as far as its immunoreactivity is concerned.

Subjects of study were mainly full-blood Aborigines although a few of the subjects from Queensland and Northern Territory may have been part-Aboriginal. A part-Aboriginal group was obtained by means of records supplied by the Community Health Services in Western Australia. All serum samples, with the exception of the material obtained for pedigree studies in families, had been obtained for community health reasons and were in surplus from the original investigations.

RESULTS

Low serum TBG values were found in all Aboriginal groups studied, including children from two to 10 years of age and part-Aborigines. The map in Figure 1 shows the locations of the groups studied and the histograms in Figure 2 indicate the results found. The lower histogram in Figure 2 (Kimberley) is reproduced from Dick and Watson[1] for comparative purposes.

The 69 subjects shown in the Arnhem Land, Northern Territory, histogram in Figure 2 also had LFTs (bilirubin, alkaline phosphatase and AST) and total protein and

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