Lankinen KS, Bergström S, Mäkelä PH and Peltomaa M, eds.
Health and disease in developing countries. London:The Macmillan Press Limited, 1994:37-48.

5 INFANT MORTALITY AND BIRTH RATES

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INTRODUCTION

It has been suggested that decreasing infant mortality is a prerequisite for decreasing birth rates and the experience in several countries shows that decreasing infant mortality rates are indeed followed by declining birth rates. Actually, industrialised countries with their low infant mortality have low birth rates. In contrast, the highest birth rates are found in countries with the highest infant mortality (Tables 5.1a and b).[1] A few developing countries, such as Sri Lanka, China and Costa Rica, have managed to decrease the child death rates substantially.[2] This has been followed (or preceded) by a decline in birth rates to some of the lowest levels among developing countries. – But is this a true connection?

HISTORICAL AND RECENT EVIDENCE

Data from Sweden show that the striking decrease in infant mortality during the 19th century was soon followed by decreasing birth rates (Figure 5.1). A study of similar figures from 15 European countries showed a somewhat complex pattern. However, the conclusion after a detailed demographic analysis was that the data agree with the hypothesis that declining birth rates were preceded by decreasing infant mortality.[3] In only two instances the reverse was found. By the same token, a recent extensive investigation on the fertility in Europe mostly in the 19th century showed that decreases in fertility followed upon declines in infant mortality in the great majority of areas.[4] However, in several provinces, especially in France, a tendency of fertility decline could be noted already before a decline in infant mortality.

Analysis of regional variations in fertility and child mortality during the late 19th and

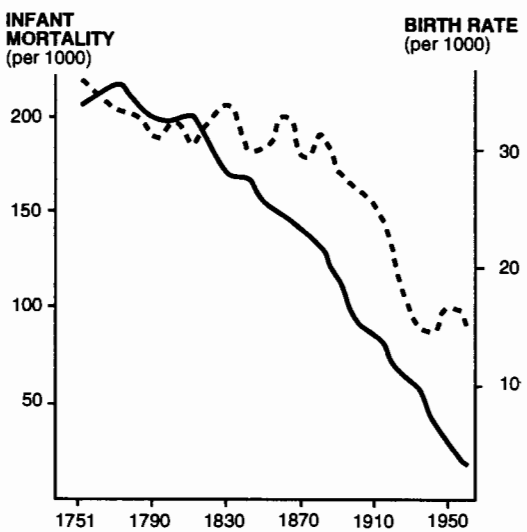

Figure 5.1. Infant mortality (——) and birth rates (- - -) in promille in Sweden during the 19th and 20th centuries.[3,4]

Table 5.1a. Infant and child mortality in the world population in relation to frequency of low birth weight, birth rate and literacy rate.[2]

1985 Mortality < 5 years of age (promille)	1985 Infant mortality (promille)	1982–83 Low birth weight (per cent)	1985 Birth rate (promille)	1985 Adult literacy rate male/female (per cent)
>175	136	14	47	42/21
95–174	83	13	42	68/50
30–94	44	9	30	89/84
< 30	11	6	15	97/93

early 20th century in England and Wales disclosed a positive correlation between the two variables.[5] On the basis of this study the authors suggested that the factors determining mortality also influence fertility and both variables are affected within a relatively short interval.

A positive correlation has been found between infant mortality and fertility in Finland and Sweden in the 19th century.[6] Similarly, the remarkable decrease in infant mortality during the 1970s in Costa Rica showed a significant relation to decreasing fertility rates.[7]

We have analysed the contemporary relationship between infant mortality and birth rates across nearly 100 developing countries making use of data published by UNICEF.[2] These data show a positive association between the two rates, especially in most recent times (Figure 5.2). The correlation coefficient between infant mortality and birth rates is 0.58 in 1960 and 0.79 in 1985. No country (except India in 1985) exhibits simultaneously an infant mortality rate above 100 per 1000 and a birth rate below 35 per 1000. Thus, it seems that a moderate infant mortality is a necessary condition for fertility transition or, in other words, *a combination of high infant mortality and low fertility seems incompatible.*

The contrary is not true, however. There are many countries with a moderate infant mortality and a very high birth rate, with Jordan and Syria in 1985 as outstanding examples. By 1960 many countries had reduced their infant mortality to moderate levels but in very few of them fertility had started to decline. Singapore, with an infant mortality of 36 and a crude birth rate of 38, exemplifies this situation in Figure 5.2. The six countries with a moderate birth rate of less than 35 in 1960 (Yugoslavia, Argentina, etc.) essentially lay in

Table 5.1b. Infant mortality and birth rates in selected countries 1985.[2]

Country	Infant mortality (promille)	Crude birth rate (promille)
Africa		
Somalia	152	48
Sudan	112	45
Egypt	93	35
South Africa	78	38
Asia		
Bangladesh	124	43
India	105	30
Thailand	44	26
Japan	6	13
Latin America		
Bolivia	117	43
Brazil	67	30
Chile	22	22
Cuba	15	17
North America		
USA	11	16
Canada	9	15
Europe		
USSR	24	19
Greece	14	15
UK	10	13
Sweden	6	11

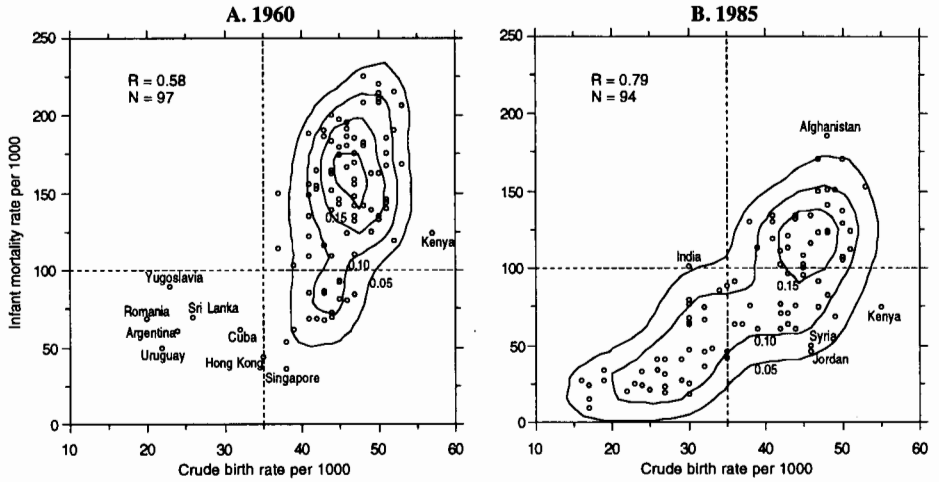

Figure 5.2. Scatterplot and smoothed density contours for the relationship between infant mortality and birth rate. Less developed countries, 1960 and 1985.[2]

a different category and their inclusion in the universe of less developed countries is questionable. It seems that a falling infant mortality rate has not been sufficient condition for fertility transition, at least by 1960. However, by 1985 the link between the two rates becomes much clearer (Figure 5.2, part B). Almost all countries with a birth rate below 30 per 1000 have also low infant mortality (below 50 per 1000). The emergence of this stronger association is compatible with claims that fertility declines boost infant mortality falls.

Statistical correlation alone, however, is not sufficient proof of a causal link. There is a distinct possibility that the correlation between infant mortality and birth rates is a spurious byproduct of underlying common determinants, such as women's education, social organisation, health infrastructure, or cultural practices. A first approach to get rid of some of these potential confounding variables (those that are constant over time) is by looking at the association between *changes* – rather than *levels* – in the two rates. In this regard, Figure 5.3 shows that the correlation between the decline in infant mortality and in birth rates stays high (0.74) during 1960–1985.

In countries like Hong Kong, Singapore, Costa Rica, and Cuba, spectacular fertility declines of about 50 per cent accompanied also spectacular infant mortality falls of about 80 per cent. In the other extreme, in backward countries, such as Kampuchea, Afghanistan, Ethiopia and Somalia, neither fertility nor infant mortality have changed in a meaningful way. In turn, no country but Peru and India presents a meaningful fertility decline of at least 20 per cent without presenting simultaneously a significant infant mortality reduction of at least 40 per cent. The absence of this conjunction suggests that either an infant mortality decline is a necessary precondition for a birth rate decline or that a fertility decline always causes infant mortality falls. In contrast, Figure 5.3 shows many countries

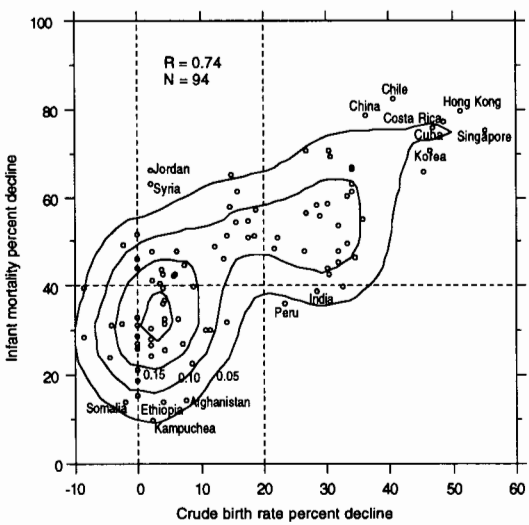

Figure 5.3. Scattergram and smoothed density contours for the relationship between the percentual decline in infant mortality and birth rates from 1960 to 1985. Less developed countries.[2]

Table 5.2. Multiple regression analysis of female illiteracy (FI), crude birth rate (CBR) and the ratio of population by physician (P/P) as explanatory variables for infant mortality rate (IMR). N = number of countries, R^2 = coefficient of determination, standard errors in parentheses. Discussion in text.

1960								
IMR = 5.78	•	$FI^{0.40}$ (0.08)	•	$CBR^{0.35}$ (0.23)	•	$P/P^{0.07}$ (0.02)	$N = 88$ $R^2 = 0.69$
1985								
IMR = 1.39	•	$FI^{0.36}$ (0.06)	•	$CBR^{0.70}$ (0.18)	•	$P/P^{0.09}$ (0.03)	$N = 81$ $R^2 = 0.80$
% Decline 1960-85								
IMR = 24.7	+	0.23•FI + (0.06)		0.61•CBR + (0.08)		0.05•P/P (0.03)	$N = 77$ $R^2 = 0.63$

in the quadrant where there is a conjunction of big infant mortality reductions and modest or nil birth rate declines, which means that either an infant mortality reduction is not a sufficient condition for a birth rate decline or that a fertility decline is not a precondition for an infant mortality reduction. Jordan and Syria are clear examples of this combination.

Multiple regression analysis gives a more precise indication of the magnitude of the relationship between infant mortality and fertility, and tests whether this relation is merely a residual byproduct of third variables. With data from about 80 developing countries, we have created multiple regression models on the country-level infant mortality with three explanatory variables: female illiteracy (FI) as indicator of (the lack of) socioeconomic development, the crude birth rate (CBR) as indicator of both fertility and the burden of children for a society, and the ratio of population by physician (P/P) as indicator of (the lack of) health care resources available to the population.[2]

Three regression equations were estimated: two multiplicative equations for both 1960 and 1985, and an additive equation for the percent 1960–1985 change. Partial derivatives demonstrate that a multiplicative relationship in the absolute values of the variables levels results in an additive relationship in their rates of change. The regression coefficients for the CBR estimate the per cent change in IMR resulting from one per cent change in the CBR, net of changes in the other two variables (Table 5.2).

Although the data do not support an independent association between IMR and CBR in 1960*, a clear and significant association between these two variables emerges in 1985. A reduction of 1 per cent in the CBR would generate 0.70 per cent reduction in the IMR according to the 1985 equation. A similar figure (0.61 per cent) occurs in the more demanding equation for longitudinal changes. These effects of CBR on IMR, which are net of the influence of the other two variables in the regression, are higher than those of illiteracy and substantially higher than those of the population/physician ratio.

Thus, cross-country covariation in infant mortality and birth rates by 1985 and in their decline from 1960 to 1985 give strong support to the hypothesis of a connection – and probably one of a causal nature – between these two rates. Studies of many countries during the last few decades have repeatedly found similar results.[8,9] Analysis of 53 African, Latin American and Asian countries showed that when infant mortality decreased after World War II, birth rates declined at the same pace. A remarkably high correlation coefficient of –0.82 between the percentage of wives practising family planning and the infant mortality rate has been reported in 99 developing countries *circa* 1982, an association that is even higher than that corresponding to the variable education measured in several ways.[10] A study with data from 88 developing countries proposes that the combined effect of education

*The regression coefficient of 0.35 is lower than 1.96 x 0.23 = 0.45, where 1.96 is the 97.5 percentage point of the standard normal distribution and 0.23 the standard deviation.

and infant mortality explains about 70 per cent of the variation in birth rates.[11] This study also found that the effect of education on fertility increased considerably when infant mortality declined.

POSSIBLE MECHANISMS LINKING CHILD MORTALITY AND BIRTH RATE

Clearly the relation between the two variables is multifactorial and there is no single explanation. Moreover, causation probably is bidirectional – infant mortality effects fertility and the latter influences the former – or there can be even other variables, biological or socioeconomic.

Breast-feeding decreases both infant mortality and fertility

Since breast-feeding decreases both infant mortality and fertility, this clearly is an intervening variable linking infant deaths and subsequent fertility. Studies conducted since the late nineteenth century have shown that infant mortality is inversely linked to breast-feeding practices.[12] It is well known that breast-feeding decreases morbidity and mortality in diarrhea.[13] The risk of non-breast-fed babies in a developing country to die from diarrhea during the first months of life may be 25-fold compared with exclusively breast-fed babies.[13] A recent study showed that even partial breast-feeding could protect against 70–80 per cent of diarrhea attacks in young infants of poor population groups in Pakistan.[14] In the same population, partial breast-feeding decreased the risk of attracting neonatal septicemia 18 times compared with non-breast-fed controls.[15]

Such protection against the two most common causes of the high early infant mortality in poor areas, can strikingly decrease infant morbidity and mortality in developing countries where it is usually high.[16] Although previous evidence that breast-feeding also protects against respiratory infection has been less convincing, a well performed epidemiological study in Brazil has shown that breast-feeding significantly decreases mortality in respiratory infections as well.[17] This finding is of great importance since respiratory tract infections are a major cause of death in childhood in developing areas.

A major reason for the strong protective effect of breast-feeding is the high content in the milk of the secretory IgA antibodies which are specially adapted to protection of mucous membranes, e.g. the mucosa in the gastrointestinal and respiratory tracts, against infectious agents.[18] The mother's milk contains secretory IgA antibodies against all the microbes the mother has been exposed to and which her infant is likely to meet as well after delivery. It has been shown that the protection provided by breast-feeding against *Vibrio cholerae, Campylobacter* and enterotoxigenic *Escherichia coli* relate to the content of the maternal milk of secretory IgA antibodies against these pathogens.[19–21] In addition to secretory IgA, human milk contains several other components that might support the defence against infections in the breast-fed infant.[18]

The fact that breast-feeding has a contraceptive effect was noted by Aristotle: 'while women are suckling children, menstruation does not occur according to nature, nor do they conceive'. It is the stimulation of the nipple that induces the hormonal changes, resulting in prevention of ovulation and conception.

The term 'lactational amenorrhoea method' or LAM has been used for this form of contraception. In a study from Australia it was recently demonstrated that in well nourished,

Refugee mother breast-feeding in Wollo Province, Ethiopia. Photo: UNICEF/Bill Campbell

partially breast-feeding mothers the contraceptive effect was 98.3 per cent at 6 months of lactation, 93 per cent at 12 months and 87 per cent at 24 months.[22] A contraceptive effect of 90 per cent was obtained by breast-feeding six times daily for 2 years. In Chile LAM was also applied successfully during the first 6 months of lactation.[23] In a traditional society like Pakistan, where partial breast-feeding is the rule[24], a significant contraceptive effect was verified for the first 6 months of lactation. After that breast-feeding obviously becomes too irregular or infrequent to provide a continuous hormonal stimulus sufficient for full contraception (Ashraf *et al.*, unpublished observations).

Still, it is being claimed that LAM may prevent more conceptions in the developing world than all family planning programmes together.[25] LAM may be the only family planning method available for those 300 million couples or so in the world, who do not want a new pregnancy but are unaware of contraceptive possibilities. For them it is crucial to know that to be effective LAM requires frequent and persistent breast-feeding, although it can be partial.[22,26] It may be that in many, if not most traditional societies, breast-feeding is partial with other foods and fluids given from birth onwards and the interval between breast meals may vary.[24,27]

Studies have shown that a decrease in infant mortality tends to increase the duration of lactational amenorrhoea and result in better birth spacing.[28–31] A surviving infant means that the mother will continue to breast feed, which results in both a prolonged contraceptive effect and an improved defence against potentially lethal infections in the infant, decreasing infant mortality.

Worldwide evidence. Although the nutritional status of the mother can influence fertility demographic studies have demonstrated that its effect is less than a 10 per cent.[32] According to studies in Papua New Guinea variability in natural fertility may be explained to 75 per cent by breast-feeding practices.[33]

The striking decrease in infant mortality during the 19th century, followed some 20 years later by a decrease in fertility in Sweden (Figure 5.1), may certainly have several explanations including education and socioeconomic development. There is, however, data to suggest that an important factor could have been an increase in breast-feeding, which perhaps resulted from a campaign for better nutrition and health care started in the 1830s.[5,34] Those studies also give the first good historical evidence of the fact that breast-feeding leads to a striking decrease in infant mortality caused by diarrhea.[5,35]

From Senegal it was reported that with no infant deaths in the family, the time interval between two deliveries increased by 9 months if weaning was postponed by 1 year beyond the first year of life.[36] The average interval between births was shortened from 3 to 2 years if an infant died during the first month of life so that breast-feeding was interrupted, according to a study from Kerala.[37]

In Nepal it was found that for a child born less than 18 months before or after a sibling the risk of dying was three times higher than for a child born with an interval of 24 months or more. This association was unrelated to the mother's age or the birth order.[38] In Senegal it was shown that one third of all children were weaned too early because of a new pregnancy. Too early weaning is followed by a much increased risk of infections that cause malnutrition and endanger growth, development and life. It was noted that for such a child the likelihood of dying within a year increased by 50 to 150 per cent.[39] Actually the African word 'kwashiorkor' means the deprivation of a child who is no longer breast-fed because the mother has become pregnant again.[40]

On the basis of a study of 25 developing countries it was determined that if the interval between births were at least 2 years, infant mortality would be reduced by 10 per cent and child mortality (one to four years) by 16 per cent.[37] Shorter spacing increases the risk not only by interrupting breast-feeding and impairing nutrition, but also by increasing the risk of low birth weight (LBW) deliveries.

Family size and infections

It has been stressed that demographic data are inadequate for really untangling the many factors involved in the relation between fertility and infant mortality, such as mother's age, parity, birth-spacing, nutrition, education, socioeconomic level and the likes.[41,42] However, birth spacing stands out as a dominant variable compared with maternal age and parity. Blacker suggested that, in addition to maternal depletion and sibling competition resulting from frequent deliveries, there may be another causal relationship between short birth interval and high infant

mortality.[42] This would be the effect of infections in relation to birth-crowding which might be more important than the factors listed above.

Infectious diseases are the major cause of high infant mortality in developing countries. Poverty is followed by poor housing, lack of sanitation and potable water, unhygienic conditions and a continuous heavy exposure to microbes.[27] Besides being a major cause of morbidity and mortality, frequent infections also lead to undernutrition. Certain infections have a higher fatality rate in this setting, especially measles at young age. The presence of several young children in a family therefore increases the risk of a poor outcome.

It has recently been claimed that the declining fertility seen in England and Wales 1849–1950 accounted for at least a 24 per cent decrease in postneonatal mortality caused by pneumonia and bronchitis.[43] Suggestive evidence has been provided that the high measles mortality among children in developing countries is not related to undernutrition as often believed, but to crowding in families with many children. Crowding results in transmission of high infectious doses that may provoke severe disease (Chapter 17).[44]

The effect of child deaths on reproductive behaviour

The classic demographic transition theory sees high fertility as a response to high levels of infant and child mortality.[45,46] Parents have many children to replace those who have died or parents set excess fertility goals in anticipation of children deaths.[47] The demographic literature calls these phenomena 'replacement' and 'insurance' effects, respectively.[48] In addition, in some societies parents want to compensate for the loss of a child, especially if they have lost a son.[49–51] One reason is that they strongly wish to have at least one son alive to support them when they grow old.[52] This is the case in India, where no social security system exists for the aged. To be sure with 95 per cent probability to have at least one surviving son when they are old, the parents may aim at having about six live born babies.[53] An expression of this as well as of other factors has been found in studies from Pakistan and Bangladesh showing a relationship between the experience of child deaths in the family and the family size (Table 5.3).[54]

Mothers with three or more child deaths have three times as many children as mothers who have not lost a child, all ages combined. This connection becomes even more striking when comparing the birth intervals for the Bangladeshi mothers. It was 37.2 months in families without child deaths, but 24.1 months in the families with deaths. However, this was not found for the Pakistani mothers. In some studies it has not been possible to establish a significant relationship between child deaths and family size.[54]

Other factors

After observing that numerous or ill-spaced children are likely to be also unwanted, some

Table 5.3. Mean number of children born to women of different ages in relation to the number of experienced child deaths.[54]

Number of child deaths	Mother's age (years)					
	15–24	25–29	30–34	35–39	40–49	Total
Pakistan						
0	1.1	2.8	4.0	4.5	4.7	2.4
1	2.4	3.9	5.2	5.5	6.1	4.5
2	3.6	4.8	6.0	7.2	7.0	6.2
>2	4.4	6.0	6.8	8.4	8.9	7.9
Bangladesh						
0	1.8	3.6	4.9	5.7	5.6	2.6
1	3.3	5.0	5.9	6.6	7.2	4.7
2	4.6	5.9	7.1	7.6	8.6	6.2
>2	6.3	7.4	8.6	9.4	10.4	8.3

authors have postulated that unwanted births have higher risk of death as consequence of parental neglect, underinvestment in resources to save their lives, and even other more obvious forms of infanticide.[55,56] Direct or indirect infanticide can occur especially under severe resource constraints. The relatively high mortality of female infants in many poor places in South Asia strongly suggests the existence of some kind of infanticide.

Some authors have also pointed out *indirect* links between family planning and improved child survival.[57,58] One of these indirect effects is the improvement in maternal and child health programmes originating in savings from prevented pregnancies, i.e. from fewer prenatal consultations and deliveries. Another extrafamilial effect is that some family planning programmes (especially in Latin America) target the prevention of high risk pregnancies, for example in diabetic women. Changes in the affective relation between mother and her planned children have been mentioned among these indirect links.

It has also been argued that improved health education and other developments bring about both a decreasing infant mortality and a fall in birth rates.[37] The undernourished, illiterate, unhealthy and oppressed may have little sense of freedom or capacity to influence their situation, including planning the size of the family. With education, better health and economy, it is probable that the family would welcome measures to increase birth spacing that would result in physically and mentally healthier children. However, it has not been possible to fully evaluate the weight of different factors as to their effect on mortality and fertility. Education is clearly of importance.[11] It seems as if 'modernisation' of societies will lead to a decrease in infant mortality as well as birth rates, probably in a number of ways.

A certain level of economic security is obviously accompanied by the choice of fewer children.[59] Only in very poor communities do children contribute to the income of the family. As soon as the family is better off, children are not used for work but are sent to school, and therefore start to cost instead. Evidence of a wish for fewer and healthier children after improvement of child survival has been given in a recent review sponsored by the Population Division of the UN, which confirms the connection between child mortality and fertility.[47] However, local variations are also stressed, e.g. related to the actual level of mortality and attitudes. Emphasis is put on the importance of contraception, which when available reinforces the linkage between improvement in child survival and fertility decline. Furthermore, this connection between the two parameters is in agreement with the fact that the decrease in infant mortality during recent years, through a more frequent use of vaccines and ORS, has already been followed by a decrease in fertility rate in large parts of the developing world.[60]

Claims and controversies

Revisionists claim that the increasing world population is not an economic problem.[61] It is true that there is enough food available for a growing world population, although it is inadequately distributed.[62] It seems cynical to believe, however, that a yearly addition of 150 million children giving a 90 million world population increase, mainly in developing countries, can be managed, when already today there are severe deficiencies especially in the availability of health care. With the growth of family size the expenditure of food *per capita* decreases. There was a 500 kcal negative difference in food consumption between families with four compared with two children according to a study from Colombia.[39]

The effect on population growth of a 50 per cent reduction in infant and child mortality is illustrated in Figure 5.4. This is not an unrealistic task since about three million child deaths can be prevented yearly with the vaccines already available. Measles and poliomyelitis could actually be eradicated. Many of the about four million deaths of children in acute diarrhea every year could be prevented by availability of clean water, latrines, and health education and ORS. India would have about 4.4 million fewer child deaths and 7.5 million fewer births each year if the whole nation could have the same low mortality and birth rate as the State of Kerala.[26] That world population total will be reduced as a consequence if infant mortality rate is reduced by 50 per cent is important information, since it totally contradicts the opinion that measures aiming at reducing infant mortality might worsen the problem of rapid population growth.

In this connection it is of interest that it has been claimed in a recent publication that decreased public health efforts for children, such as ORS and vaccination programmes, might have to be accepted to reduce the

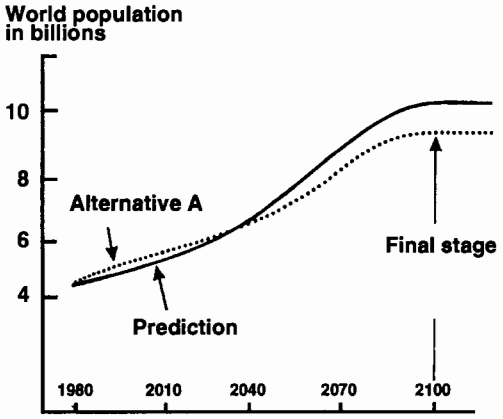

Figure 5.4. The impact on population growth of a 50 per cent reduction in child deaths (Alternative A).[37] Discussion in text.

population increase. This was actually done because of deep concern about the ecological destruction following the dramatic population increase in some parts of the developing world, endangering the possibilities for future populations in these areas to support themselves. The statement is erroneous because an *increased infant mortality has very little demographic effect*. The population increase will continue due to the large fertile populations already born. This fact can be illustrated by the indications that all the cases of AIDS dying in Africa during the 1990s may still only correspond to one month of population increase on this continent – according to currently known incidence figures. There is, however, evidence of prevalence figures of HIV seropositivity among antenatal care attenders approaching 50 per cent in Zimbabwe (MOH, Zimbabwe, unpublished).

The link between infant mortality and birth rates gives us the basis for public health policies that continue to try to decrease infant mortality, thereby also gaining decreasing fertility as reviewed above. This is strengthened further by a recent authoritative analysis of the involved factors by the Department of International Economy and Social Affairs at the United Nations.

CONCLUSIONS

When child mortality rates decrease, birth rates also decline. The relation between these two rates is quite complex but the weight of the evidence is in favour of the interpretation that decreasing infant mortality may lead to decreasing birth rates and vice versa. However, it is very difficult to evaluate the significance of the various components due to the multifactorial, bidirectional relationship.

Education, especially of women, is clearly important, but more diffuse factors, such as modernisation and improved socioeconomic conditions, are also involved. Breast-feeding leads to decreased infant mortality, increased birth spacing and decreased fertility. The important interrelation between education, breast-feeding, infant mortality and fertility is illustrated in Figure 5.5. Historical as well as recent data suggest that breast-feeding is an important factor in this connection. It is also the cheapest and most easily available nutrition and support of host defence for children. Up to 75 per cent of the variability in natural fertility has been related to breast-feeding practices, whereas maternal nutrition has been reported to have less than a 10 per cent effect. Large families run a higher risk of more frequent and more dangerous infections since the children are presumably subjected to them at a younger age with higher doses of the infectious agent. This risk is smaller when fertility is low. Some studies, but not all, show that the experience of child deaths in the family is followed by an increased number of births. These factors alone cannot explain the relation between decreasing infant mortality and birth rate. However, it can be stated generally that the measures that lead to a decreased infant mortality also lead to a decreasing birth rate, usually within a short time span. Availability of contraceptives enhances this linkage.

It is possible to further decrease the present infant mortality by preventing several million deaths per year, especially those caused by

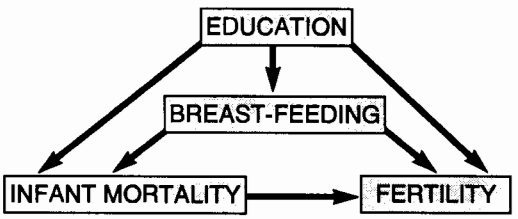

Figure 5.5. Education of mothers results in decreased infant mortality, decreased fertility and an increase in breast-feeding, which in itself decreases infant mortality and fertility. The interrelationship is illustrated.

diarrhea and infectious diseases preventable by vaccination. Such a decreased infant mortality would most likely be followed by decreased birth rates, resulting in many million fewer births per year in developing countries.

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References

1. Visaria P, Visaria M. Indian population scene after 1981 census: a perspective. Economical Political Weekly, Nov. 1981:1727–80.
2. UNICEF. The state of the world's children. Oxford: Oxford University Press, 1987.
3. Matthiessen PC, McCann JC. The role of mortality in the European fertility transition: aggregate level relations. In: Preston SH, ed. The effects of infant and child mortality on fertility. New York: Academic Press, 1978: 47–68.
4. Coale AJ, Watkins SC. The revised proceedings of a conference on the Princeton European Fertility Project. Princeton: Princeton University Press, 1986.
5. Brass W, Kabir M. Regional variations in fertility and child mortality during the demographic transition in England and Wales. In: Hobcraft J, Rees P, eds. Regional demographic development. London: Croom Helm, 1977: 71–88.
6. Lithell UB. Breast-feeding and reproduction. Studies in marital fertility and infant mortality in 19th century Finland and Sweden. Acta Universitatis Upsaliensis. Studia Historica Upsaliensis 1981; 120: 1–87.
7. Rosero-Bixby L. Infant mortality in Costa Rica: explaining the recent decline. Stud Fam Plann 1986;17: 57–65.
8. Beaver SE. Demographic transition theory reinterpreted: an application to recent natality trends in Latin America. Lexington: Lexington Books, 1975.
9. WHO report. Health trends and prospects in relation to population and development. In: United Nations, Department of Economic and Social Affairs. The population debate: discussions and perspectives. Vol. I. Geneva: WHO, 1978.
10. Caldwell J. Routes to low mortality in poor countries. Pop Dev Rev 1986; 12(2):171–220.
11. Glassman MB, Ross JA. Two determinants of fertility decline: a test of competing models. Stud Fam Plann 1978; 9: 193–7.
12. Knodel J, van de Walle E. Breast feeding, fertility and infant mortality: and analysis of some early German data. Pop Stud 1967;21(2):109–31.
13. Feachem RG, Koblinsky MA. Interventions for the control of diarrhoeal diseases among young children: promotion of breast feeding. Bull WHO 1984; 62: 271–91.
14. Jalil F, Mahmud A, Ashraf RN, *et al.* Epidemiology of breast feeding and diarrhoea in a developing country. Acta Paediatrica (submitted).
15. Ashraf RN, Jalil F, Zaman S, *et al.* Breast feeding protects against neonatal sepsis in a high risk population. Arch Dis Child 1990;66: 488–490.
16. Zaman S, Jalil F, Karlberg J, Hanson LÅ. Early child health in Lahore II Morbidity. Acta Paediatr 1993;(Suppl 390):63-78.
17. Victora CG, Smith PG, Vaughan JP, *et al* . Evidence for protection by breast feeding against infant deaths from infectious diseases in Brazil. Lancet 1987; ii: 319–322.
18. Hanson LÅ, Brandtzaeg P. The mucosal defence system. In: Stiehm RT, ed. Immunologic disorders in infants and children. Philadelphia: Saunders, 3rd ed, 1989: 116–155.
19. Glass RE, Svennerholm A-M, Stoll BJ, *et al.* Protection against cholera in breast-fed children by antibodies in breast-milk. N Engl J Med 1983;308: 1389–1392.
20. Cruz JR, Gil L, Cano P, *et al.* Breastmilk anti-*Escherichia coli* heat-labile toxin IgA antibodies protect against toxin-induced infantile diarrhoea. Acta Paediatr Scand 1988;77: 658–662.
21. Ruiz-Palacios GM, Calva JJ, Pickering LK. Protection of breastfed infants against *Campylobacter* diarrhoea by antibodies in human milk. J Pediatr 1990;116:707–713.
22. Short RV, Lewis PR, Renfree MB, Shaw G. Contraceptive effects of extended lactational amenorrhoea: beyond the Bellagio Concensus. Lancet 1991;337: 715–717.
23. Perez A, Labbok MH, Queenan JT. Clinical study of the lactational amenorrhoea method for family planning. Lancet 1992;339: 968–970.
24. Ashraf RN, Jalil F, Khan SR, *et al.* Early child health in Lahore, Pakistan. IX. Feeding patterns. Acta Paediatr 1993 (Suppl 390):47-61.
25. Rosa FW. Breast feeding in family planning. PAG Bull 1975;5: 5–10.
26. Thapa S, Short RV, Potts M. Breast feeding, birth spacing and their effects on child survival. Nature 1988;335: 679–82.

27. Hanson LÅ, Adlerberth I, Carlsson B *et al.* Breast feeding in reality. In: Hamosh M, Goldman A, eds. Human lactation 2. Maternal-environ-mental factors. New York: Plenum Press, 1986: 1–12.
28. Ryder NB, Influence of declining mortality on Swedish reproductivity. In: Current research in human fertility. New York: Milbank Memorial Fund, 1955.
29. Coale AJ, Hoover EM. Population growth and economic development in low income countries. New Jersey: Princeton University Press, 1958.
30. Hyrenius H. Fertility and reproduction in a Swedish population group without family limitation. Popul Stud 1958;12: 121–30.
31. Potter RG, New ML, Wyon JB, Gordon JE. Application of field studies to research on the physiology of human reproduction. In: Sheps MC, Ridley JC, eds. Public health and population change. Current research issues. Pittsburgh: University of Pittsburgh Press, 1965; 143–73.
32. Habicht JP. Newsletter. Mammary gland biology and lactation 1987;6:2.
33. Wood JW. Newsletter. Mammary gland biology and lactation 1987;6:2.
34. Brändström A, Stenflo G. Dependence between birth intervals and infant mortality. The case of Nedertorneå 1818–1896. European Population Conference, Finland, 1987.
35. Brändström A. The loveless mothers. Acta Universitaris Umensis. Umeå studies in the Humanities 62, 1984. (In Swedish with English summary).
36. Cantrelle P, Leridon H. Breast feeding mortality in childhood and fertility in a rural zone in Senegal. Popul Stud 1971;25: 505–553.
37. UNICEF. The state of the world's children. Oxford: Oxford University Press, 1984;49–63, 92–99.
38. Charlaw RW, Waidya K. Birth interval and the survival of children to age five: some data from Nepal. J Trop Pediatr 1983;29: 31–34.
39. Huffman SL. Child spacing for maternal and child health. Mothers and children 1984;4: 1–12.
40. Williams CD. Child health in the Gold Coast. Lancet 1938, i: 97–102.
41. Preston SH. Mortality in childhood: lessons from World Fertility Survey. In: Cleland J, Hobcraft J, eds. Reproductive change in developing countries. Oxford: Oxford University Press, 1985: 252–272.
42. Blacker JGC. Health impacts of family planning. Health Policy and Planning 1987;2: 193–203.
43. Reves R. Declining fertility in England and Wales as a major cause of the twentieth century decline in mortality. The role of changing family size and age structure in infectious disease mortality in infancy. Am J Epidemiol 1985;122: 112–126.
44. Aaby P, Bukh J, Lisse IM, *et al.* Overcrowding and intensive exposure as determinants of measles mortality. Am J Epidemiol 1984;120: 49–63.
45. Notestein F. Economic problems of population change. In: Proceedings of the eight international conference of agricultural economists. London: Oxford University Press; 1953:13–31.
46. Davis K. Institutional patterns favoring high fertility in underdeveloped areas. Eugenics Q 1955;2(1):33–39.
47. Lloyd CB, Ivanov S. The effects of improved child survival on family planning practice and fertility. Studies in Family Planning 1988; 19(3):141–161.
48. Preston S. Introduction. In: Preston S., ed. The effects of infant and child mortality on fertility. New York: Academic Press, 1978:1–18.
49. Rutstein S. The relation of child mortality to fertility in Taiwan. In: Social statistics section. Proceedings of the American Statistical Association. 1970: 348–353.
50. Wyon JB, Gordon J. The Khanna study: population problems in rural Punjab. Cambridge: Harvard University Press, 1971.
51. Harrington J. The effect of high infant and childhood mortality on fertility: a simulation model study. In:Preston SH, ed. The effects of infant and child mortality on fertility. New York: Academic Press, 1978: 235–257.
52. Venkatacharya K. Influence of variation in child mortality on fertility: a simulation model study. In: Preston SH, ed. The effects of infant and child mortality on fertility. New York: Academic Press, 1978: 235–257.
53. Pottenberg T. Fertility and family life in an Indian village. Michigan papers on South and Southeast Asia. Ann Arbor: University of Michigan, 1975.
54. Chowdhury AKMA, Khan AR, Chan LC. Experience in Pakistan and Bangladesh. In: Preston SH, ed. The effects of infant and child mortality on fertility. New York: Academic Press, 1978: 113–33.
55. Scrimshaw S. Infant mortality and behaviour in the regulation of family size. Pop Dev Rev 1978; 4(3):383–403.
56. Scrimshaw S. Infanticide as deliberate fertility regulation. In: Bulatao RA, Lee RD, eds. Determinants of fertility in developing countries 2. New York: Academic Press; 1983:245–266.
57. Bongaarts J. Will family planning reduce infant mortality rates? Pop Dev Rev 1987;13(2):323–34.

58. Potter J. Does family planning reduce infant mortality? Comment. Pop Dev Rev 1988; 14(1):179–87.
59. Werner D. Health care in Cuba: a model service or a means of social control – or both? In: Morley D, Rohde J, Williams G, eds. Practicing health for all. Oxford: Oxford University Press, 1987:17–37.
60. UNICEF. The state of the world's children. Oxford: Oxford University Press, 1989.
61. Bauer PT. Are world population trends a problem? In: Wattenberg B, Zinsmeister K, eds. Washington DC: American Enterprise Institute for Public Policy Research, 1985: 19–24.
62. Editorial. Poverty, malnutrition and world food supplies. Lancet 1987; ii:487–490.

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