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Effects of the health service and environmental factors on infant mortality: the case of Sri Lanka

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SUMMARY One of the findings of this study is that regional variations in the infant mortality rates of Sri Lanka are large, ranging from 26 per 1000 live births in Jaffna to 91 per 1000 in Nuwara Eliya, a tea estate district. These differences are more strongly associated with regional variations in environmental determinants of mortality than with regional variations in public health expenditure. The most significant environmental factor associated with interregional infant mortality rates was found to be the nature of the water supply ($r = -0{\cdot}82$, significant at the 99% level). Regional government expenditure on health had only a weak association with infant mortality rates ($r = 0{\cdot}08$).

There is increasing and justifiable concern in developing countries about the social and environmental determinants of health. These conditions could be expected to improve as development proceeds and it might be argued that there is no need to consider such factors within a health policy framework. This is emphatically not the case. An understanding of areas in which a concentration of efforts will achieve the greatest improvement is an essential prerequisite for decisions on resource allocation.

In this study the associations between specific health service and environmental variables and the infant mortality rates of Sri Lanka are examined both across regions and through time. Thomas McKeown has argued that most of the improvement in the health of the population of developed countries occurred in conjunction with socioeconomic improvements and before the establishment of extensive curative medical care services.[1] It has also been noted that the necessary return of infants who have been helped by curative medical care services to a hostile environment decreases the ability of these services to have as significant an impact on the health of the population as they otherwise could.[2]

The major factors considered by demographers to have had a significant environmental effect on infant mortality are access to food, medical care, sanitation, and housing.[3] In this study the association between the last two and the infant mortality rates of different regions of Sri Lanka is quantitatively examined. The relationship between the primarily curative medical care services and the infant mortality rates is also examined. It is suggested that particular environmental improvements might significantly increase the impact of the medical care services of Sri Lanka on the health of the population and particularly on the infant mortality rates.

Methods

Four methods of analysis are used in determining the relative influences on infant mortality rates (IMRs) of different health service and environmental factors in Sri Lanka. The first two utilise time series data and the last two cross-sectional data. The initial mode of analysis is a simple graphical comparison of government health expenditure per caput over time and the national IMR over time. This has been done both in money terms (current rupees) and at constant (1955) prices (Figs. 1 and 2).

The IMR is the number of deaths of children in the first year of life per thousand live births in that year. The total period covered is 1946–74 (Figs. 1 and 2). Registration of births and deaths has been virtually complete over the whole of this period. Government health expenditure data relate to the period 1955 to 1973. Expenditure on maternal and child health can be considered as a constant proportion of the budget during the first phase of relatively constant per caput expenditure. In more recent years this programme has been expanded and an increasing proportion of the health budget has been devoted to maternal and child health.

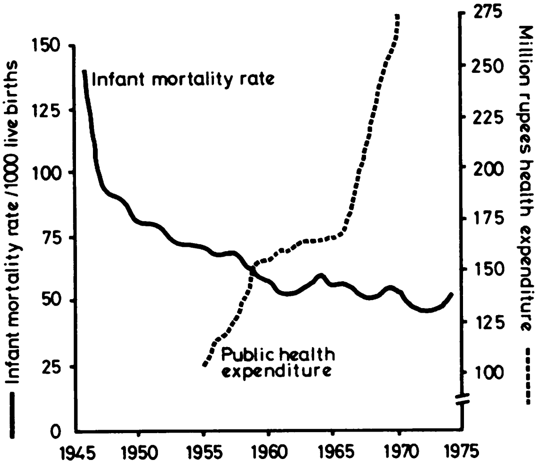

Fig. 1 *Infant mortality rates[4] and public health expenditure[5] in Sri Lanka.*

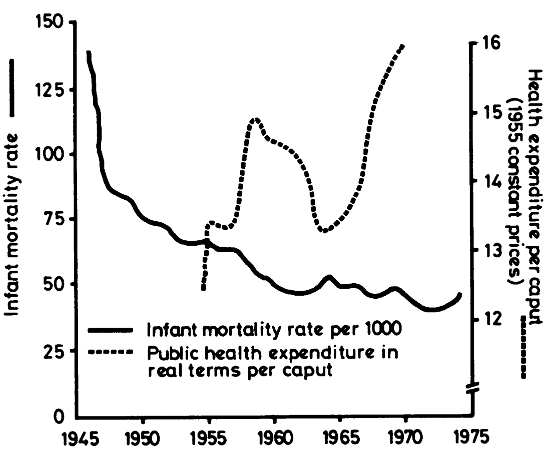

Fig. 2 *Infant mortality rates[4] and per caput real health expenditure[5] in Sri Lanka.*

The second method is an examination of the relationship between the national percentage of unsupervised births and the national IMR during the years 1961–68. The number of live births that were not supervised either by a public health midwife or in an institution amounted to roughly 100 000 a year, or slightly less than a third of the 350 000 births that took place each year in Sri Lanka during this period (Table 1).

The third method is a cross-sectional analysis for the year 1968 of the association between regional government health expenditure per caput and the regional IMRs based on the administrative divisions

Table 1 *Relationship of unsupervised births to infant mortality rates, 1961-68*

Year	*Total births (thousands)* *Supervised*	*Unsupervised*	*Unsupervised %*	*IMR per 1000 live births*
1961	364	95	26·2	52
1962	371	100	27·0	53
1963	366	105	28·5	56
1964	362	111	30·6	57
1965	369	103	27·9	53
1966	369	116	31·4	54
1967	370	114	30·7	48
1968	384	123	31·9	50
				r = −0·15

Source: Simeonov LA.[6]

Table 2 *Per caput government regional health expenditure[7] and regional IMR[8]: 1968*

Region	*IMR*	*Per caput expenditure (rupees)*
Kandy	70	52
Ratnapura	62	44
Batticaloa	60	44
Kalutara	56	58
Badulla	55	42
Galle	54	57
Vavuniya	52	73
Kegalle	48	42
Matale	47	41
Kurunegala	45	54
Anuradhapura	44	59
Puttalam	44	43
Colombo	43	38
Matara	39	38
Jaffna	33	71

Product moment correlation coefficient = 0·08

of the country. A correlation coefficient is obtained as a measure of the degree of association of these variables (Table 2).

The fourth method is an analysis of the relationship of geographically based regional IMRs to selected influential regional indicators of environmental status for the year of the national census, 1971. These consist of the percentages of households in each region with tap water (T), well water (W), river water (R), latrines (L), cement floors (C), tiled or asbestos roofs (R), brick or cabook walls (B), or electricity (E) (Table 3). The analysis of the influence of the various indicators upon the IMR has been carried out by showing the correlation between variations in the levels of the indicators and variations in the infant mortality rate in Sri Lanka. Data on material indicators usually refer to the existence rather than the utilisation of these. The three indicators on the type of water supply normally used relate to the percentage of households in each district obtaining drinking water from taps, or wells, or other sources, usually rivers. Some of the tapped supplies are

Table 3 *Some environmental determinants of infant mortality: 1971*[9,10]

Region	IMR per 1000 live births	Tap water	Well water	River water	Latrine	Cement floor	Tiled/asbestos roof	Brick/cabook walls	Electricity
		Correlation coefficient (r)							
		0·33	−0·82	0·80	0·49	−0·52	−0·37	−0·25	−0·11
		Percentage of households with:							
Numara Eliya	91	12	20	68	42	13	14	27	4
Kandy	61	16	47	37	31	26	29	34	7
Ratnapura	59	20	50	30	15	28	34	22	2
Badulla	56	27	29	44	23	18	29	40	5
Batticaloa	53	4	79	17	4	41	23	33	8
Matale	49	11	60	29	9	23	26	26	4
Kegalle	45	12	71	17	19	31	29	31	2
Colombo	41	30	67	3	37	72	57	49	22
Amparai	41	10	68	21	9	49	31	42	8
Galle	40	4	85	11	19	54	57	37	6
Kurunegala	39	2	86	12	8	29	15	19	2
Anuradhapura	39	4	73	23	5	27	26	25	3
Moneregala	39	8	46	46	5	15	26	17	4
Mannar	39	28	66	6	5	37	33	31	6
Hambantota	37	8	68	23	4	29	34	22	2
Trincomalee	36	9	79	11	3	51	31	43	9
Matara	34	7	80	13	14	44	55	42	4
Polonnaruwa	34	3	82	15	9	41	29	37	4
Kalutara	34	4	81	15	30	56	59	45	9
Puttalam	33	7	80	12	18	47	22	29	5
Vavuniya	28	4	85	11	7	30	20	26	4
Jaffna	26	7	87	6	23	55	47	53	12

shared, and wells are often collectively owned. When there is a shortage of water, the whole community will share whatever supply is available. The tea estate sector has particular problems with the quality of tap water supply; these problems are described below. The latrine indicator is the percentage of houses possessing, or having access to, latrines. The three indicators of the quality of housing refer to the types of building materials used. The data base is the percentage of houses in each district with particular types of roofs, walls, and floors. The roofing indicator is the percentage of houses in each region with either tiled or asbestos roofs. The wall materials indicator is the percentage with walls made either of brick or of cabook, a large sun-dried unfired brick. The flooring indicator refers to the percentage of houses with concrete floors. The alternative building materials would be coconut palm or reed thatching for roofs and walls, wattle and daub or mud for walls and floors, and wood for the main support structures. The electricity utility indicator is the percentage of households in each region supplied with electricity.

Results

TIME SERIES DATA

(1) There were three distinct phases in the decline of the infant mortality rate in Sri Lanka. The first phase was marked by the rapid decline in the rate from the estimated interwar level of over 200 per 1000 live births in the first year of life to 100 in 1946. The second phase marked a slow but steady decrease in the IMR from the 1946 level of 100 to about 50 in 1961. During the third phase, from 1961 to 1974, the IMR showed fluctuations without indicating a consistent downward trend (Figs. 1 and 2). The IMR had stopped its consistent decline in 1961. It was after this, in 1966, that expenditure on health started to increase rapidly. This swift increase in expenditure continued throughout the late 1960s and early 1970s. During the latter period, the proportion of government expenditure on maternal and child health was itself increasing.

(2) During the period 1961–67 no relationship could be discerned between the supervision of births by the health system and the infant mortality rates. The product moment correlation coefficient for these was $r = -0·15$. This is statistically insignificant (Table 1).

CROSS-SECTIONAL DATA

(3) Interregional data on infant mortality and per caput government health expenditure also showed no discernible or statistical ($r = 0·08$) relationship to regional IMRs (Table 2). Interregional variation in

both these factors was quite large. The IMR varied from 33 in Jaffna to 70 in Kandy, one of the tea estate regions. Per caput government health expenditure varied from 39 rupees in Matara to 73 rupees in Vavuniya.

(4) *(a)* There was a poor and statistically insignificant relationship between district IMRs and district usage of tap water (r = 0·33); *(b)* there was a strong negative relationship (r = −0·82) between use of well water and regional IMRs. High use of well water is associated with low incidence of infant mortality. Well water is the main source of drinking water for 69% of households in Sri Lanka. Multivariate regression analysis yielded a highly significant (T-ratio 3·1 with 13 df) coefficient of −0·81 (see Appendix); *(c)* there was a strong positive association (r = 0·80) between the extensive usage of river water and the high infant mortality rates of different districts. River water is used directly by 25% of the population of Sri Lanka; *(d)* there was a weak positive association (r = 0·49) between regional provision of latrines and regional IMRs. This assumed the correct sign and became significant (r = −0·79) once the estate sector was eliminated from the estimation process; *(e)* there was a weak negative association (r = −0·52) between the percentage of houses with cement floors and the regional IMR. Low IMRs are associated with high percentages of houses with cement floors; *(f)* there was a weaker negative association (r = −0·37) between the percentage of houses with tiled or asbestos roofs and the regional IMR; *(g)* there was no significant relationship (r = −0·25) between the type of material used for walls and the district IMR; and *(h)* there was no significant relationship (r = −0·11) between the percentage of houses supplied with electricity and the district IMR.

Infant mortality rates were particularly high in the poor regions of the tea estate sector such as Nuwara Eliya. The IMR in this region of 91 in 1971 was almost as high as the national rate of 100 in 1947.

Discussion

TIME SERIES DATA

(1) The sharp decrease of the IMR in the first phase, from 1940 to 1946, is not easy to explain in terms of sharply defined quantitative indicators because the necessary data are not available for this period; even the IMR is a broad estimation. Yet clearly it was during this period that action was taken to eliminate many of the traditional practices which increased infant mortality. Two of the factors which contributed to high mortality rates were risk of infection and nutritional problems. One practice was the use of dung as a healing agent. In 1906 the Registrar of Ceylon Medical College commented on the high incidence of tetanus neonatorum in Colombo:

> 'This tetanus is due to infection of the navel after separation of the umbilical cord after birth. The infection is due to dirt and should therefore be preventable'.[6]

Another was the custom noted by a Colombo medical officer of giving an infant only castor oil and sugar for the first three days after its birth. This resulted in severe disturbances of the digestive system. These disturbances were compounded by the disruption caused to the lactation cycle of the mother.

The sustained decrease in the second phase, between 1946 and 1961, from an IMR of 100 to 50 took place during the period in which the bulk of the current health services and nutritional programmes were established. Government expenditure on health reached about 150 million rupees, or about 15 rupees per caput, by 1961.

During the third phase fluctuations in infant mortality, which hovered around 50, were of more significance than a sustained decrease. Government expenditure on health rose sharply, particularly after 1966, to about 300 million rupees in 1973, or double the 1961 figure in money terms. I will examine this third phase in greater detail in an effort to define the characteristics peculiar to this period and to identify possible courses of action that are necessary to bring about a further decrease in the IMR.

Increasing government health expenditure could, until 1962, be closely associated with a decline in the IMR. In the period after 1961, however, there is little, if any, direct inverse relationship between variations in the IMR and the rise in public health expenditure, as can be seen in Fig. 1. This relationship emerges as a particularly dramatic and perverse one if the effect of the rapid rise in health expenditure after 1965 is considered. There is little decline in the IMR associated with this very steep increase in health expenditure from 170 million rupees to over 270 million rupees. It might fairly be concluded that increasing government expenditure in its present form will no longer have a significant effect upon reducing infant mortality, and that either national expenditure or the structure of the health system might need to be revised accordingly.

Because the current IMR of 52 in Sri Lanka, even after a rapid fall, remains considerably higher than that in developed countries, there is obviously a need for a much closer examination of the factors that govern it. Only then will it be possible to outline a package of policies to bring about a further steady decline in the rate. Some of the lessons of the Sri Lanka experience may also be relevant to policies in other developing countries. In many of these countries nutritional status would be an important determinant of the IMR. In Sri Lanka extensive nutrition programmes are in progress, and the diseases of anaemia and malnutrition are only the fifth leading cause of death of infants. This study has therefore focused on other determinants of the IMR.

(2) Supervision of births, either by a public health midwife or in an institution, might have been assumed to be a major determinant of the IMR. The data base for this is narrow in terms of numbers of years for which data exist. Roughly one-third of the 2·5m births during this period were covered by the health services. The product moment correlation coefficient between lack of supervision and the IMR is insignificant (r = 0·15). It might, therefore, be concluded that there is no longer any significant relationship in Sri Lanka between coverage of births by the health system and the IMR. This might be due to the capability of the system as it now stands to cope with any birth with some risk attached to it.

CROSS-SECTIONAL DATA

(3) There was, similarly, no association between per caput regional government health expenditure and regional IMRs, although interregional variation in both of these was quite large. It should be noted, in examining Table 2, that the government allocation for the Colombo district arbitrarily excludes the allocation for the Colombo group of specialist hospitals which includes a paediatric hospital. Although their main users are Colombo residents, these are intended to serve the entire country, and their finances are not included in the regional allocations. Thus Colombo appears to have, paradoxically, both the second lowest government per caput allocation and the third lowest infant mortality rate in the nation. On a national level any relationship is negligible and the correlation coefficient is trivial and of the wrong sign.

(4) The IMR has been used as an indicator which could be expected to be rapidly responsive and relatively sensitive to changes in the primary environmental determinants of death. Yet certain limitations have to be kept in mind. Some part of the IMR can be due to health problems of the mother and congenital abnormalities. These and other infant deaths that may occur without the infant having ever left the hospital cannot be directly associated with external environmental determinants. Both these factors weaken the correlation between expectation of life at birth (e_o^1) and the IMR. There might be a tendency to assign to the IMR the function of a health indicator for the entire population. This would not be correct. However, it can be hoped that it might serve as one of the useful indicators of progress in health care development.

(a) Usage of tap water is weakly associated with high IMRs (r = 0·33). There may be several contributory factors to this poor relationship. In the estate sector, water classed as tap water is in fact often stream water piped directly to taps in houses. This has been proved in the past to be contaminated by sewage outflows. Tap water, even in many of the larger urban areas, is not chlorinated to any particular standard. Previous contamination of the reservoirs further upstream may make tap water a source of uncertain quality. Among the diseases that may result some are major causes of infant mortality, including diarrhoeal and infectious diseases; *(b)* the use of well water is strongly associated with low IMRs (r = −0·82). This source is less liable to pollution than tap water because the wells are normally surrounded by a protective wall to prevent any flow of water from the surface into the well; *(c)* conversely, the use of river water is strongly associated with high IMRs (r = 0·80). On this evidence, it would seem that changing the source of water supplies from rivers to wells could be a primary health measure and should therefore have considerable priority; *(d)* initial estimation of the national association between regional availability of latrines and regional IMRs revealed a weak positive association (r = 0·49). Latrine construction programmes have been encouraged by the government by the provision of a concrete base with a water seal and a subsidy of 30–50 rupees towards the cost of digging the pit and constructing a hut. These latrines are normally separate from, and often uphill from, the houses. Although conversion is also encouraged, and most of the latrines are of the type with an S bend containing a water seal, there are still many pit latrines in use, some of which empty into streams or irrigation canals. The presence of these, particularly in the estate sector in the central hill country at the source of many rivers, also places at risk communities in larger urban centres further downstream, because they too are likely to use this water. It might be that the provision of latrines has no direct influence on the IMR unless such provision is also associated with adequate water supplies. Both the function of the water seal and the practice of washing hands are dependent on the availability of water. The positive nature of the association may be further explained by the existence of a major central programme subsidising and aiding the construction of latrines, concentrating on areas seen to be at high risk. If this is the case, the allocation of resources in this manner may not have been great enough to overcome the

initial disparities that gave rise to such a concentration.

Elimination of the tea estate sector, where latrines are provided but normally shared by many households, are poorly maintained, and are frequently out of use, revealed the true and expected nature of the relationship between the IMR and latrine availability ($r = -0{\cdot}79$). This is a strong association. The provision of a private latrine for each household would be a primary health measure with significant effects on the IMR. The need for such provision could be seen as particularly urgent in the tea estate sector where the IMR is far above the national average and where the pollution of the water supply has repercussions on the health of communities downstream; *(e)* the weak inverse relationship between flooring material and the IMR can be explained by the fact that cement floors are easier to clean and may reduce the incidence of infectious diseases. They also provide better protection against ground water and damp than mud floors; *(f)* the main effects of different roof structures lie in the type of protection these afford against sun and rain. In a developed country an unprotected asbestos roof might be considered a health hazard in its own right. Asbestos is, however, one of the cheapest roofing materials available, an excellent insulator against the heat, waterproof, and weakly associated with low IMRs; *(g)* the extremely weak association between wall materials and the IMR indicates that modern walls are not appreciably better than traditional materials in terms of the effect on health; *(h)* there was no association between regional supplies of electricity and regional IMRs. Electricity supplies are expected to increase dramatically in the near future as a result of the implementation of the accelerated Mahawelli Development Plan but the effects of this plan on health may prove negative, as an increased utilisation of river water from the extensive associated canal works is likely. The same canals could pose problems as disease vectors for malaria.

Conclusion

The national IMR of Sri Lanka has been stable since 1961 at about 50, despite subsequent increases in the health budget. In order to effect further improvements, health policies should be directed at improving latrine facilities and transferring the sources of domestic water from rivers to wells. The mean IMR of the four worst districts, Nuwara Eliya, Kandy, Ratnapura, and Badulla, is 64, more than twice that of the four best districts, Jaffna, Vavuniya, Puttalam, and Kalutara, where it is 31. By effecting improvements in the water supplies and latrine facilities of the first group of districts it should be possible to decrease the IMR of those districts to somewhere near the level of the latter group. This would bring the national IMR to 37.

In order to design an effective package of health policies, it would also be necessary to carry out an epidemiological investigation in depth of the effects of environmental determinants of morbidity for all age groups. Given the high risk associated with infectious diseases, the use of combined immunisation programmes would seem to be indicated. Above all, it would be necessary to work out in detail the estimated cost of the policies recommended here. The fact that serious consideration ought to be given to water supplies and latrines was substantiated at the United Nations Water Conference in 1977 at Mar Del Plata where 1981–1990 was declared International Drinking Water Supply and Sanitation Decade. It is possible that these factors are also of major significance in other developing countries.

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References

[1] McKeown T, Record RG, Truner RD. An interpretation of the decline in mortality in England and Wales during the twentieth century. *Popul Stud* 1974; **29:** 391–422.
[2] Sadre M, Donosa G, Hedayat H. The fate of the hospitalised malnourished child in Iran. *J Pediatr* 1973; **19:** 28–31.
[3] Sagan LA, Afifi AA. *Health and Economic Development I: Infant Mortality*. Laxenburg, Austria: International Institute for Applied Systems Analysis, 1978.
[4] Department of Census and Statistics. *The Population of Sri Lanka*. Colombo: Department of Census and Statistics, 1974.
[5] Economic and Social Commission for Asia and the Pacific. *Population of Sri Lanka*. Bangkok: Economic and Social Commission for Asia and the Pacific, 1976.
[6] Simeonov LA. *Better Health for Sri Lanka*. New Delhi: World Health Organisation, 1975.
[7] Ministry of Finance. *Estimates of the Revenue and Expenditure of the Government of Ceylon*. Colombo: Ministry of Finance, 1968.
[8] Department of Census and Statistics. *Bulletin of Vital Statistics, Sri Lanka*. Colombo: Department of Census and Statistics, 1974.
[9] Registrar General of Colombo. *Vital rates of Sri Lanka*. Colombo: Department of Census and Statistics, 1976.
[10] Department of Census and Statistics. *National Census: Census of Housing*. Colombo: Department of Census and Statistics, 1971.

Appendix

Product moment correlation coefficients give some insight into the association between these factors. A more detailed analysis has been carried out using the Regress Mk II linear regression package at Manchester University.

Extra variables included at this stage were the infant mortality rate of the following year, 1972, and population density.

The column of data for river water was suppressed to solve for interdependency of the water supply variables. This yielded a data set of 22 observations on 11 variables.

The regression on the infant mortality rate for 1971 produced the following equation, with T-ratios in brackets:

$$I_1 = \underset{(6\cdot0)}{-98} \quad \underset{(1\cdot1)}{-0\cdot38T} \quad \underset{(3\cdot1)}{-0\cdot81W} \quad \underset{(0\cdot26)}{+0\cdot09L} \quad \underset{(1\cdot2)}{+0\cdot07P} \quad \underset{(1\cdot3)}{+0\cdot52F} \quad \underset{(2\cdot0)}{-0\cdot47R} \quad \underset{(0\cdot21)}{+0\cdot07B} \quad \underset{(0\cdot4)}{-1\cdot4E}$$

where

I_1 is the infant mortality rate for 1971 per 1000 live births.
T is the percentage points of houses using tap water.
W is the percentage points of houses using well water.
L is the percentage points of houses using latrines.
P is the population density per hundred square miles.
F is the percentage points of houses with concrete floors.
R is the percentage points of houses with tiled or asbestos roofs.
B is the percentage points of houses with brick or cabook walls.
E is the percentage points of houses with electricity.

The regression on the infant mortality rate for 1972 produced the following equation, with T-ratios in brackets.

$$I_2 = \underset{(4\cdot8)}{-91} \quad \underset{(0\cdot39)}{-0\cdot15T} \quad \underset{(2\cdot5)}{-0\cdot76W} \quad \underset{(0\cdot09)}{+0\cdot04L} \quad \underset{(1\cdot3)}{+0\cdot09P} \quad \underset{(1\cdot2)}{+0\cdot56F} \quad \underset{(1\cdot9)}{-0\cdot54R} \quad \underset{(0\cdot51)}{+0\cdot22B} \quad \underset{(1\cdot6)}{-1\cdot9E}$$