A COMPREHENSIVE INDEX FOR LONGITUDINAL MONITORING OF CHILD HEALTH STATUS

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ABSTRACT

The aim of this study was to develop a single comprehensive index of child mortality for longitudinal assessment of health status of children. The need for such a comprehensive index arose from conflicting trends in different child mortality indicators. The data for the study was taken from the Sample Registration System (SRS) reports of the Registrar General of India. SRS is known to provide reliable estimates of births and deaths at the State and the National level.

The study included five child mortality indicators, namely, under five mortality rate (U5MR), infant mortality rate, neonatal mortality rate, perinatal mortality rate and still birth rate. These were available for fifteen states of India over the years 1972-1988. To develop this index we modified an earlier method based on factor analysis so as to make the index suitable for longitudinal analysis.

Factor analysis of data on various indicators of child mortality revealed two factors which together explained 78% to 93% of the total variation in different years. The first factor was identified as representing mortality after birth and the second as before and during birth. The comprehensive index was obtained as a linear combination of these two factors. The resultant index thus fairly represented all five mortality indicators and provided a comprehensive and reasonably correct picture of child mortality. The lower the magnitude of this index, the better was the child health status. Trends in the index showed that the highest decline in the magnitude was in the state of Kerala followed by Punjab, Andhra Pradesh, Gujarat and Maharashtra in that order. This indicates steady improvement of the child health status over years in these states. In the State of Jammu and Kashmir, the index remained more or less constant over the years though the magnitude was low in the cross-sectional comparison with other states. Thus the comprehensive index developed by using factor analysis of the various mortality indicators can be used for the longitudinal monitoring of child health status in the states of India.

Keywords: *Child health status. Child mortality index, Trends, Factor analysis.*

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Some attempts(1 -6) have been made earlier to develop composite indices for health measurement for different target groups in the developing countries as well as for the global use. These are mainly based on combination of socio-demographic indicators like crude birth rate, crude death rate, infant mortality, life expectancy and literacy rate. The indices developed so far are mostly cross-sectional in nature and are not applicable for longitudinal assessment. There is thus a need for development of a comprehensive index for longitudinal monitoring of health(6).

Currently child health is attracting considerable attention particularly in the context of developing countries. Since morbidity is difficult to observe on national basis, the effect of health policies and programmes on child health are usually monitored by several mortality indicators. These include still birth rate (SBR), perinatal mortality rate (PEMR), neonatal mortality rate (NMR), infant mortality rate (IMR) and under five mortality rate (U5MR)(7). These rates are focussed on specific segments of life beginning from late pregnancy to 5 years of age. This focus is of tremendous help to planners in developing strategies to control age specific mortality. Nevertheless, a single but comprehensive measure is many times considered desirable in order to study trends in overall health status because of the simplicity entailed in its use. Such a comprehensive index could' be of tremendous help in studying trends over a period and in comparing various areas. Individual indicators can provide a conflicting picture on their trends which can pose problems to decision makers who may not have rigorous background in statistical and epidemiological methods. For example, a fairly high NMR value may be masked by a moderate value of U5MR if mortality in post neonatal segment is low. Similarly a substantial decline in infant mortality rate without a concomitant change in 1-4 years mortality rate may not be adequately reflected in U5MR. Further, on preview of the mortality rates in one State of the present data, neonatal mortality revealed an increasing trend while perinatal mortality was not changing over time and U5MR showed some decline. In some other states, PEMR and NMR remained static while IMR and U5MR declined. This may suggest a false sense of security of decline in child mortality, which could be taken as a plea for passive action, while in fact the situation in the younger age group, requiring more intensive intervention, may not be correspondingly improving. When one, wants to look at a collective picture of trends in overall child mortality status in correct perspective, a need of a comprehensive index is felt. The present study attempts to develop such an index, using various child mortality rates, for longitudinal assessment of child health status for various states of India through factor analytic approach.

Data and Methods

The data for this study were taken from the Sample Registration System (SRS) reports(8-18). The office of the Registrar General of India initiated this System in India with the objective to provide reliable estimates of birth and death rates at the State and National levels. The field investigation under SRS consists of continuous enumeration of births and deaths in a statistically valid sample of villages and urban blocks by resident part-time enumerator, generally a local teacher, and an independent six monthly retrospective survey by a full time supervisor. The unmatched and partially matched events are reverified in the field to get an unduplicated count of correct events. Since the SRS is by far the most reliable source, it was utilized for the present analysis.

The mortality indicators utilized for the development of a comprehensive child mortality index are SBR, PEMR, NMR, IMR and U5MR. Under five mortality rate (U5MR) was not directly available for the SRS reports. It was derived from under five death rate by using the formula: U5MR = Under 5 death rate *percent population under five/ crude birth rate *10.

The pertinent SRS data are available for the years 1970 to 1988 for 15 to 17 major States of India. Data for the States of Andhra Pradesh, Assam, Gujarat, Haryana, Himachal Pradesh, Maharashtra, Orissa, Tamil Nadu and Uttar Pradesh are available for 1970-1988 (19 years); for Karnataka, Kerala and Punjab from 1971 to 1988 (18 years); and for Jammu and Kashmir and Rajasthan from 1972 to 1988 (17 years). Data for the Bihar and West Bengal are available only for 1981 to 1988 (8 years). Complete data on the above five mdicators are thus available only for fifteen States for the years from 1972 to 1988 (17 years). These only are included in the present analysis. These fifteen states comprised 73.8% of the total population of the country.

Statistical Methods

The method of computing an index of health developed by Chandra Sekhar *et al.(6)* was modified to get a comprehensive index of child mortality. This method utilizes factor analytic appraoch(19-21) to explain the observed relations among indicators in terms of simple factors. This technique also determines the number of factors required to represent the major portion of the picture provided jointly by all the indicators. A brief description of the method in our context is as follows.

Denote the five mortality indicators used for the development of the index by X_i (i = 1,2,3,4,5). The factor model is adequate when $X_i s$ are correlated because that is a prerequisite for presence of common factors shared by the indicators. Additional evidence of sharing common factors is that the partial correlations among $X_i s$ would be low. Various tests like Bartlett's and Kaiser-Meyer(20) are available to check the validity of this assumption. Suppose the number of common factors explaning major part of variation is M. The factor model assumes

$$X_i = a_{i1}F_1 + a_{i2}F_2 + ... + a_{iM}F_M + e_i,$$

where F_m (m=1,2,...,M) are the common factors. A .well known procedure of principal components is used to extract factors which also determines the number of appropriate factors. In our case, this turned out to be M = 2. The factor extraction also determines the values of a_{im} which are called loadings. Sometimes these are rotated to get high loadings for some factors and low for the others. We use varimax method of rotation. The next step is to obtain factor score coefficients by

$$W_{mi}\Sigma_u a_{mu}r^{ui}(m=1,2;u,i=1,2,3,4,5)$$

where r^{ui} is the (μ,i)th element of inverse of correlation matrix of $X_i s$. In the third step, factor scrores K_m for State j are obtained by

$$K_m = \Sigma_i w_{mi} x_i \ (m=1,2).$$

The details of all this procedure are

available in Cattle(19). We obtained these factors scores separately for each of the 15 states and for each of the 17 years using values of X; for that particular state in a year. If the factor score for jth state is K_m for any particular year, our index of child mortality (ICM) for that state and year is given by

$$ICM = H_J = \Sigma_m V_m \Sigma_i W_{mi} X_{ij}$$
$$(j = 1,2,\ldots\ldots,15),$$

where V_m is the proportion variance explained by the mth factor. This proportion of variance is also obtained at the stage of obtaining principal components mentioned earlier. SYSTAT package(22) was used for computations. A 15 x 17 matrix of TCM values was obtained corresponding to 15 states and 17 years. Such an index gives due weightage to various components of child mortality measured by different indicators. As we shall see, this enables us to have cross-sectional as well as longitudinal assessment of child mortality in different states. It is also clear from the factor model that with a change in the magnitude of the mortality indicators, there is corresponding change in the factor scores and so in the index. A time trend in the mortality indicators will be reflected in the index when unstandardized indicators are used in computing factor scores. The use of standardized indicators in the computation as done by Chandra Sekhar *et al.(6)* and further standardization on (0-100) scale have the following drawbacks for our stated objectives: (i) it is cross-sectional in nature; (ii) it has a severe limitation that it always varies from 0-100 and measures the relative position only. The straight use of their procedure is, therefore, not appropriate for evaluating the longitudinal trends in ICM. Our modification is in terms of using unstandardized mortality indicators to compute the factor scores. Further, standardization is usually adopted in situations where different indicators have separate units of measurement. Luckily, in the present series the mortality indicators are expressed in terms of either 1000 births as in SBR and PEMR and 1000 live births as in NMR, IMR and U5MR. This results in a marginal difference of the base which for our study can be ignored.

Trend analysis of the comprehensive index would enable us to study secular changes in the child mortality status as a whole in different states of the country. It is not always possible to detect the trend visually. For different states, the trends in ICM and U5MR were computed by using ordinary least squares linear regression method after logarithmic (natural) transformation. Such transformation was necessary because of the varying magnitudes in the absolute changes could mislead the comparisons. For example, a fall in the index by 10 points from 100 to 90 represents a reduction of 10% whereas the same 10 point fall from 20 to 10 represents a reduction of 50%.

Results

The factor loadings obtained after varimax rotation show that, generally across the years, the first factor is mostly shared by U5MR, IMR, and NMR and to some extent by PEMR also. The second factor is mostly shared by PEMR and SDR. Thus, PEMR is equivocal and happens to figure in both the factors. The loadings are shown *Table I.* The first

TABLE I– *Factor Loading and Per cent Variance Explained for First Factor and Second Factor in Different Years*

Year	Factor loadings						% variance explained	
	Factor I				Factor II			
	NMR	IMR	U5MR	PEMR	PEMR	SBR	Factor I	Factor II
1972	0.95	0.98	0.98	0.64	−0.61	−0.84	65.4	21.8
1973	0.98	0.98	0.95	0.80	0.61	0.90	69.8	23.8
1974	0.97	0.95	0.96	0.89	−0.47	−0.84	71.3	19.3
1975	0.94	0.97	0.96	0.90	0.63	0.24	70.9	11.3
1976	0.93	0.98	0.95	0.82	0.65	0.65	68.4	17.6
1977	0.87	0.98	0.93	0.57	0.90	0.67	58.4	29.0
1978	0.89	0.96	1.00	0.63	0.85	0.52	62.6	22.4
1979	0.54	0.93	0.95	1.00	0.92	0.43	45.7	32.2
1980	0.94	0.96	0.99	0.67	0.71	0.89	64.7	28.5
1981	0.92	0.99	0.96	0.75	0.69	0.66	66.5	20.9
1982	0.90	0.97	0.95	0.81	0.49	0.86	67.6	25.1
1983	0.98	0.96	0.95	0.91	0.34	0.85	72.5	17.4
1984	0.83	0.99	1.00	0.88	0.20	0.61	69.3	9.70
1985	0.90	0.89	1.00	0.69	0.73	0.59	62.9	21.0
1986	0.92	0.83	0.78	1.00	0.62	−0.41	63.8	20.2
1987	0.97	0.96	0.97	0.79	0.66	0.65	68.1	17.9
1988	0.97	0.92	0.96	0.66	0.73	0.78	69.6	23.4

factor can be identified as representing mortality after birth and the second as before and during birth. The first factor explains 45.7% to 72.5% of the total variation in different years while the second 9.7% to 32.2%, The two factors together explain 77.9% to 93.2% of total variation in different years. This is a large proportion. Such high percentage of explained variation validates the use of factor analysis for these data.

Table II shows original data on five indicators in different states along with factor scores and index of child mortality (ICM) for the year 1988 as an example. Factors scores (K_1 and K_2) for the first and second factor are computed as a linear combination of mortality indicators using factor score coefficients as follows:

K_1 = 0.309*U5MR + 0.292*IMR + 0.304*NMR -0.1788PEMR -0.105*SBR

K_2 = -0.176*U5MR -0.092*IMR + 0.017*NMR -0.597*PEMR -O.68*SBR

The factor score coefficents came from SYSTAT output of factor analysis for each year and each indicator. Indicator values for a particular year and state when substituted, in K_1 and K_2 give the

TABLE II—*Data on five Indicators Along with Factor Scores and ICM for the Year 1988*

State	Indicators					Factor scores		ICM
	U5MR	IMR	NMR	PEMR	SBR	K1	K2	
Andhra Pradesh	117.3	83	58.1	54.3	11.9	86.5	13.2	63.3
Assam	150.4	99	64.9	59.7	13.5	104.3	10.3	75.0
Gujarat	129.9	90	50.8	41.2	8.0	88.3	–0.2	61.4
Haryana	123.5	90	46.5	46.7	16.8	85.1	10.1	61.6
Himachal Pradesh	96.4	80	43.6	28.6	10.1	70.4	0.4	49.1
Jammu & Kashmir	97.4	71	44.7	58.8	29.7	71.8	32.4	57.5
Karnataka	108.0	74	62.8	58.7	20.8	82.3	24.4	63.0
Kerala	39.8	28	18.0	25.4	11.8	29.2	13.9	23.6
Maharashtra	94.8	58	46.4	46.4	16.1	66.9	17.4	50.6
Madhya Pradesh	191.6	121	72.8	56.5	12.6	125.4	–1.3	87.0
Orissa	150.4	122	70.8	60.3	22.3	112.0	14.7	81.4
Punjab	88.6	62	33.8	50.3	27.4	61.8	27.9	49.6
Rajasthan	203.8	103	68.3	54.3	7.6	122.7	–6.6	83.8
Tamil Nadu	101.8	74	52.4	56.2	15.6	77.4	20.3	58.6
Uttar Pradesh	181.3	124	69.0	50.3	10.5	121.0	–5.0	83.1

values of the factor scores. After obtaining K_1 and K_2, the ICM for the 1988 is obtained as

$$ICM = (69.68\ K_1 + 23.4^*\ K_2)/100$$

where 69.6 and 23.4 are the percentage variation explained by Ihe factor one and factor two, respectively for this year (*Table II*).

For the state of Andhra Pradesh in the year 1988 (*Table II)* the computations for factor scores and index are performed as shown below.

$K_1 = 0.309*117.3 + 0.292*83 + 0.304*58.1 - 0.178*54.3 - 0.105*11.9 = 86.5$

$K_2 = -0.176*117.3 - 0.092*83 + 0.017*58.1 = 0.597*54.3 - 0.68*11.9 = 13.2$

$ICM = (69.6*86.5 + 23.4*13.2)/100 = 63.3$

After substituting the values of the factor scores, the ICM is similarly computed for each state. For the remaining 16 years fl 972-1987) also the yearwise index is computed similarly. The values of the index thus computed reflect due weightage to each component of child mortality, yet provide a comprehensive picture obtained jointly by the five indicators. The changes in the index (ICM) are shown in *Fig. 1* for selected States alongwith the corresponding changes in each of the five mortality indicators for different States of India.

Now to study the trend, we ran regression of ICM and U5MR on years after logarithmic transformation. Regression coefficients obtained for different States are shown in *Table III* which we

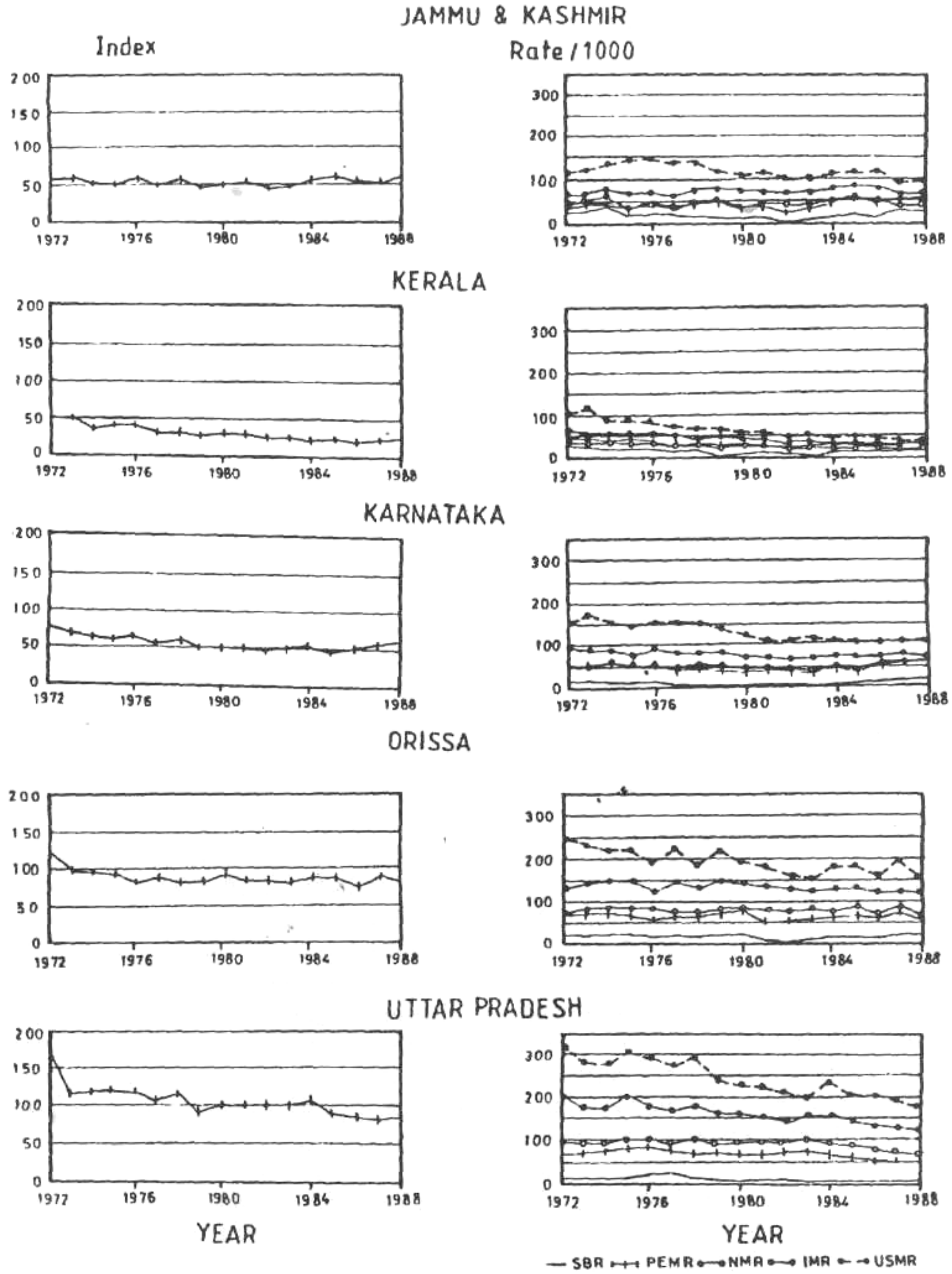

Fig. 1. ICM and child mortality rates from 1972-1988 in some selected States of India.

TABLE III–*Secular Trend Coefficients Comparison of ICM and U5MR*

State	ICM		U5MR	
	Trend Coeff.	Rank	Trend Coeff.	Rank
Andhra Pradesh	–0.037	3	–0.046	3
Assam	–0.021	11	–0.024	12
Gujarat	–0.036	4	–0.037	6
Haryana	–0.022	10	–0.028	10
Himachal Pradesh	–0.028	8	–0.036	7
Jammu & Kashmir	+0.000	15	–0.018	15
Karnataka	–0.018	13	–0.031	9
Kerala	–0.054	1	–0.070	1
Maharashtra	–0.033	5	–0.047	2
Madhya Pradesh	–0.019	12	–0.021	14
Orissa	–0.015	14	–0.024	11
Punjab	–0.040	2	–0.045	4
Rajasthan	–0.023	9	–0.023	13
Tamil Nadu	–0.029	7	–0.043	5
Uttar Pradesh	–0.031	6	–0.034	8

All coefficients both the ICM and U5MR are highly significant ($p < 0.01$) except of ICM for Jammu and Kashmir.

prefer to call trend coefficient in the present setup. These coefficients can be interpreted as average change in log mortality per year. The ranking of various states with respect to per cent change in log mortality varies depending on whether one uses U5MR or 1CM as the index of child mortality. For example, ICM revealed highest linear decline in Kerala followed by Punjab, Andhra Pradesh, Gujarat and Maharashtra, but U5MR showed that the order to be Kerala, Maharashtra, Andhra Pradesh, Punjab and Tamil Nadu. Also the trend coefficients for ICM were in general lower than that of U5MR. This is because ICM is giving proper weightage to relatively less decline in IMR, NMR, PEMR and SBR. U5MR seems to be unduly affected by high decline in 1-4 year mortality. This is further documented by the picture obtained in Jammu and Kashmir which shows a significant decline in U5MR. But, there was no significant secular change in ICM for this state during.the corresponding period. The decline in various components of child mortality is varying which can be appreciated from *Fig. 1.* This figure implies that in Jammu and Kashmir, the decline in U5MR is mainly due to decline in 1-4 year mortality whereas the 0-1 year component and SBR are virtually static.

Discussion

In the present study we combined different child mortality indicators to obtain a comprehensive index of child mortality which successfully provided a means of longitudinal monitoring of child mortality. The need for such a comprehensive index arose due to conflicting trends in different indicators of various states while studying the secular changes in child mortality.

In the State of Jammu and Kashmir for example, the neonatal mortality showed a significant ($p < 0.05$) increasing trend, perinatal mortality was static but U5MR showed a significant ($p < 0.01$) decline. The decline in U5MR clearly is the result of decline in mortality in the 1-4 year age group. Thus U5MR in this case is not representative of all of its components. On the other hand, TCM for this State shows a trend coefficient of nearly zero *(Table III)* which reflects the composite effect of the trend in each indicator. This very clearly illustrates how ICM is a better, index relative to U5MR. In Orissa and Karnataka also, FEMR and NMR remained stationary *(Fig. 1);* IMR showed a significant ($p < 0.01$) decline but U5MR revealed an appreciable decline ($p < 0.001$). The ICM had a trend coefficient of -0.015 and -0.018 for Orissa and Karnataka, respectively *(Table III)* which were much smaller in absolute value than -0.024 and -0.031 for U5MR. In view of stationary PEMR and NMR in these States, a lower coefficient in TCM is a better reflection of the comprehensive situation obtained by the simulatenous consideration of the 5 indicators. Thus, weightage given in TCM to each indicator has a desired sobering effect when required. The graphs of Kerala and Uttar Pradesh have been included in *Fig. 1* for comparison purposes. Kerala happens to be the state with lowest rates and Uttar Pradesh with highest rates of child mortality.

Can the summary information on child mortality changes over time achieved by tedious calculations for ICM be replaced by a simple summation of U5MR and SBR? This possibility could not be substantiated even for the State of Jammu and Kashmir in which discordance was maximum. A simple summation of two or more indicators can not be adequate replacement of the statistically computed ICM which gives differential weightage to its several components depending on their contribution to the overall picture.

In the context of developing countries with scarce resources, summary mortality indices are sometimes utilized to prioritize resource allocation for health interventions amongst different sub-units of the country. This prioritization would vary depending upon whether U5MR or TCM is utilized. If a comprehensive summary picture is required for mortality for studying secular trends giving weightage to all the age segments, obviously ICM seems preferable.

There are some difficulties precluding a widespread use of this comprehensive index of child mortality. Firstly, it requires tedious statistical computations. However, with the widespread availability of computers and statistical packages, this is not a major obstacle. Secondly, the ICM unlike the mortality indicators, does not have an actual meaning as far as mortality rates are concerned. This is probably also true for other such comprehensive indices(3,6). Thirdly, it can be used only in countries where computed mortality rates of various segments are available. These drawbacks are minor. We find that the factor analytic approach can be profitably employed to provide a comprehensive index of child mortality which gives due weightage to SBR, PEMR, NMR, TMR and U5MR. Thus, 1CM can be utilized for longitudinal monitoring of child health status and for comparison between different states.

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