A Study on the International Comparison of Infant Mortality Rate

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I Introduction

Infant mortality rate is a very often used parameter to measure health status and socio-economic progress of a community or population. The progress of the health and environmental condition can be measured spatially or temporally. The bias introduced by using the infant mortality rate without considering the differences in data collection of the health administrations in various countries can be corrected partially with a simple method. Especially when using the infant mortality rate for international studies, this bias should be corrected. Whenever the health condition of a country is to be analyzed, several parameters are basically used. Among them, the crude death rate was the first to be criticized for its lack of definition when used without adjusting to sex and age at least, if specific age rates cannot be obtained.

Life expectancy also used widely, seems to be an incomplete parameter, if not accompanied by other attributes, like sex and age. That is to say, the wonder that the statistical analysis of health parameters offer to us, appear when the differences blossom, and classifications can be made.

But the differences, especially if they are too glamorous, must be analyzed for the reasons at every step of the elaboration of the

final data. This is especially important when comparing parameters from different countries, because what is meant at official level, is hard to be kept in normal practice. Much more difficult for the health administrations is to point out the origin of the difference of criteria in order to correct it, mainly due to the routine that generally is associated with data collection work.

Considering the domestic comparison of data of a country through different periods as an isolated fact, the analysis of the differences is not strongly affected by external errors, because the existing bias, if any, is always constant, and of identic origin.

When comparing cross-sectional data from an international point of view, these bias constitute the biggest handicap, and unless we are able to identify the origin, and perform a correction method, erroneous conclusions can be suspected.

It has already been reported by several authors (Fedrick & Butler, 1972, and Anderson, 1981) the underregistration and miss-classification of mortality statistics derived from the "first day", "first week", "first month", and "first year" period considerations, that is, bias introduced in the origin of elaboration, which can be called primary step bias. A secondary step bias remains

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in the handling of already published information, derived from errors in textbooks or software packages (Bland & Altman, 1988, and Clarke & Whitfield, 1978) or from the different quality control established in health administrations (for example, in the WHO Statistics Annual 1987, still countries present data of 1980, while nearly 50% report from 1984).

Still a tertiary step bias is introduced by the consideration of the published data without correction for further analysis. This fact also has been recently reported (Murray, 1988).

II Material and Methods

Using the 1987 WHO Statistic Annual as the only source of data for this study, the bias possibly introduced by the different authors consideration is relatively well controlled, and as well, WHO responds through its publication, for reliability and veracity of data.

In spite of this, the practically 5 years difference of data between countries remains uncontrolled, even if it is internationally recognized the speed of change of politics and socioeconomic development, and therefore, the importance of updating systems of information and reporting.

We considered all countries or areas included in this Annual, under two conditions: (a) $n > 50$, being n = number of deaths from the 28 week of pregnancy to the birthday, or from the birthday to the 6th day of life, to assure a minimum volume of data with which to operate; and (b) having published the number of late fetal deaths and the number of early neonatal deaths for the same year. From the 81 countries of areas included in the Annual, 47 were considered for our study ($N=47$).

From the infant mortality rate, the total live births for each country or area has been calculated, and then, the fetal death rate and early neonatal death rate (Table 1). The expectations from these data were that countries with low mortality rates should also have low early neonatal mortality rates and low late fetal mortality rates and viceversa. The ratio of the late fetal death rate to early neonatal death rate (LFEN) was calculated in order to prove strength to the asseveration that low levels of early neonatal death rates are also accompanied by similar values of late fetal death rates.

III Results and Discussion

The values of LFEN ranged between 0.51 and 2.14, being the mean 1.14, and the standard error 0.05 (Table 2).

A schematic graph can be built with several zones in which results can be expected (Fig. 1):

ZONE A would include countries with low range of infant mortality rates, and also low late fetal (Y), and early neonatal (X) mortality rates. The zone determined by the lines OO' and PP' means the hypothetical data to be expected considering the standard error ($p < 0.001$) of the ratio LFEN. So, all points representing countries or areas included in the inner part of AOP, would not have a statistically significant different condition, and could be qualified as "good sanitary condition for infants under one year". The countries or areas in AP, with statistically significant predominance of early neonatal death rate over late fetal death rate towards the value of the ratio 1.14 would include countries with not so good sanitary attention for the newborn compared with the prenatal

Table 1 Childhood mortality-related parameters in 47 selected countries

WHO Region (0)	Code (1)	Country/area (2)	Year (3)	Number of late fetal deaths(4)	Number of early neonatal deaths(5)	Infant mortality rate(6)	Late fetal death rate(7)	Early neo- natal death rate(8)	Late fetal- e.n. natal ratio(9)	Total live births (10)
AF	1	Mauritius	'84	404	249	24.8	19.8	12.2	1.62	20,362
AM	2	Argentina	'81	8,395	10,593	33.6	12.3	15.6	0.79	680,982
AM	3	Bahamas	'83	69	51	21.4	13.1	9.7	1.35	5,280
AM	4	Barbados	'80	60	66	22.3	14.2	15.7	0.90	4,215
AM	5	Canada	'83	1,828	1,740	8.5	4.8	4.6	1.04	374,352
AM	6	Chile	'83	1,542	2,091	21.9	5.9	8.0	0.74	260,502
AM	7	Costa Rica	'82	809	651	19.3	11.3	9.1	1.24	71,399
AM	8	Cuba	'83	1,913	1,477	16.8	11.5	8.9	1.29	165,357
AM	9	Guatemala	'81	6,733	3,758	63.9	21.9	12.2	1.80	307,887
AM	10	Puerto Rico	'81	775	907	18.6	10.9	12.7	0.86	71,236
AM	11	Trinidad-Tobago	'81	393	223	15.9	12.2	6.9	1.77	32,264
AM	12	United States	'81	24,744	24,384	11.9	6.8	6.7	1.01	3,639,076
AM	13	Uruguay	'82	575	828	29.4	10.5	15.2	0.69	54,524
S-EAS	14	Sri Lanka	'81	3,175	5,803	29.5	7.5	13.7	0.55	423,966
EUR	15	Austria	'84	381	502	11.4	4.2	5.6	0.75	89,298
EUR	16	Belgium	'84	780	531	9.8	6.7	4.6	1.46	116,224
EUR	17	Bulgaria	'84	840	779	16.1	6.9	6.4	1.08	122,236
EUR	18	Czechoslovakia	'84	1,148	1,934	15.3	5.0	8.5	0.59	228,105
EUR	19	Denmark	'84	228	207	7.7	4.4	4.0	1.10	51,818
EUR	20	Finland	'84	260	235	6.5	4.0	3.6	1.11	65,077
EUR	21	France	'84	5,820	2,721	8.3	7.7	3.6	2.14	758,675
EUR	22	Germany (East)	'84	1,236	1,182	10.2	5.4	5.2	1.04	229,200
EUR	23	Germany (West)	'84	2,567	2,474	9.6	4.4	4.2	1.05	586,770
EUR	24	Greece	'83	963	1,040	14.6	7.3	7.9	0.97	132,329
EUR	25	Hungary	'84	799	1,570	20.4	6.4	12.5	0.51	125,392
EUR	26	Ireland	'83	581	345	10.1	8.6	5.1	1.69	67,700
EUR	27	Israel	'84	549	641	12.8	5.6	6.5	0.86	98,516
EUR	28	Italy	'80	5,453	6,044	14.6	8.5	9.5	0.89	638,356
EUR	29	Netherland	'84	1,036	725	8.3	5.9	4.1	1.44	174,939
EUR	30	Norway	'84	261	189	8.3	5.2	3.8	1.37	50,120
EUR	31	Poland	'84	4,201	7,386	19.2	6.0	10.5	0.57	700,208
EUR	32	Portugal	'83	1,517	1,554	19.3	10.5	10.7	0.98	144,404
EUR	33	Rumania	'84	2,988	1,876	23.4	8.5	5.3	1.60	350,897
EUR	34	Sweden	'84	381	309	6.4	4.1	3.3	1.24	93,906
EUR	35	Switzerland	'85	345	274	6.9	4.6	3.7	1.24	74,638
EUR	36	Eng. & Wales	'84	3,634	2,821	9.5	5.7	4.4	1.30	635,474
EUR	37	N. Ireland	'83	204	155	12.1	7.5	5.7	1.32	27,190
EUR	38	Scotland	'84	379	339	10.3	5.8	5.2	1.12	65,243
EUR	39	Yugoslavia	'82	2,594	4,814	30.3	6.8	12.7	0.54	378,779
E-MED	40	Kuwait	'83	667	557	19.0	12.0	10.0	1.20	55,737
W-PAC	41	Australia	'84	1,193	1,059	9.2	5.1	4.5	1.13	235,109
W-PAC	42	Fiji Islands	'84	74	129	16.4	3.8	6.6	0.58	19,512
W-PAC	43	Hong Kong	'83	386	473	9.9	4.6	5.7	0.81	83,030
W-PAC	44	Japan	'84	8,753	4,274	6.0	5.9	2.9	2.03	1,486,667
W-PAC	45	Malaysia	'82	5,089	4,006	20.5	13.9	10.9	1.28	367,317
W-PAC	46	New Zealand	'84	261	170	11.6	5.1	3.3	1.67	51,466
W-PAC	47	Singapore	'84	243	192	8.8	4.4	3.5	1.26	55,303

Note: Countries with less than 50 cases of deaths have been omitted.

These countries are : French Guiana, British Virgin Is., Caiman Is., Greenland, St. Marino, Luxembourg, Isle of Man, St. Christopher, and Iceland.

Other countries were omitted for data deficiency, as for example Spain, Soviet Union, Venezuela, Peru, etc.

WHO Regions : AF=Africa, AM=Americas, S-EAS=South East Asia, EUR=Europa,

E-MED=East Mediterranean, W-PAC=Western Pacific

Table 4 Values of the first principal components when performing PCA with infant mortality rate (PCA Prin 1), and with corrected infant mortality rate (PCA Prin 1*). Values of the corrected infant mortality rates by areas.

Country/area	Year	PCA Prin 1	Infant mortality rate	PCA Prin 1*	Corrected infant mortality rate
Mauritius	'84	12.654	24.8	15.872	28.31
Argentina	'81	19.437	33.6	17.672	31.87
Bahamas	'83	6.883	21.4	8.240	22.93
Barbados	'80	9.681	22.3	8.700	21.42
Canada	'83	-8.770	8.5	-8.797	8.55
Chile	'83	4.754	21.9	3.617	20.26
Costa Rica	'82	4.266	19.3	5.077	20.26
Cuba	'83	1.982	16.8	2.986	17.96
Guatemala	'81	49.059	63.9	53.137	68.23
Puerto Rico	'81	4.498	18.6	3.371	17.55
Trinidad-Tobago	'81	0.814	15.9	3.078	18.38
United States	'81	-4.492	11.9	-4.616	11.86
Uruguay	'82	14.953	29.4	12.542	27.00
Sri Lanka	'81	13.749	29.5	10.655	26.36
Austria	'84	-6.017	11.4	-6.788	10.67
Belgium	'84	-7.021	9.8	-6.158	10.79
Bulgaria	'84	-0.701	16.1	-0.625	16.26
Czechoslovakia	'84	-1.414	15.3	-3.201	13.52
Denmark	'84	-9.785	7.7	-9.721	7.85
Finland	'84	-11.111	6.5	-11.051	6.64
France	'84	-8.375	8.3	-6.586	10.26
Germany (East)	'84	-6.872	10.2	-6.906	10.25
Germany (West)	'84	-7.991	9.6	-8.041	9.62
Greece	'83	-1.543	14.6	-2.001	14.22
Hungary	'84	4.766	20.4	1.676	17.27
Ireland	'83	-6.050	10.1	-4.573	11.74
Israel	'84	-4.076	12.8	-4.672	12.26
Italy	'80	-0.750	14.6	-1.398	14.03
Netherland	'84	-8.767	8.3	-8.071	9.11
Norway	'84	-9.055	8.3	-8.506	8.96
Poland	'84	3.000	19.2	0.686	16.87
Portugal	'83	4.471	19.3	4.119	19.05
Rumania	'84	6.149	23.4	7.475	24.85
Sweden	'84	-11.255	6.4	-11.009	6.73
Switzerland	'85	-10.541	6.9	-10.218	7.32
Eng. & Wales	'84	-7.645	9.5	-7.183	10.07
N. Ireland	'83	-4.378	12.1	-3.694	12.91
Scotland	'84	-6.663	10.3	-6.522	10.53
Yugoslavia	'82	14.000	30.3	11.094	27.35
Kuwait	'83	4.445	19.0	5.133	19.84
Australia	'84	-8.068	9.2	-7.934	9.42
Fiji Islands	'84	-1.283	16.4	-2.739	14.95
Hong Kong	'83	-7.245	9.9	-7.883	9.32
Japan	'84	-11.202	6.0	-9.900	7.45
Malaysia	'82	6.625	20.5	7.744	21.80
New Zealand	'84	-6.202	11.6	-5.483	12.42
Singapore	'84	-8.916	8.8	-8.598	9.21

PCA Prin 1 =Principal component values when performing PCA with late fetal death, early neonatal death, and infant mortality rates.

PCA Prin 1*=Principal component values when performing PCA with late fetal death, early neonatal death, and corrected infant mortality.

rates outside the estimates of the standard error of the mean, in one or another sense, have got to be suspected of bias.

The correction of the bias can be implemented considering:

P =ratio of late fetal deaths to perinatal deaths (each country)

P' =ratio of late fetal deaths to perinatal deaths (mean value)

N =number of live births

α =perinatal mortality rate

β =infant mortality rate

β' =corrected infant mortality rate (CIMR)

$$\beta \doteq \beta + (1 - \frac{\beta}{1000}) (P - P') \alpha$$

(the complete mathematical formula development is in Appendix)

With this consideration, all countries can be calculated for the "corrected mortality rate" (β'), and the bias introduced by the shifting from the early neonatal deaths to the late fetal deaths, is theoretically eliminated. This fact would allow international comparisons more accurately.

Among the 47 considered countries, 12 of them (i.e. France, Japan, etc.), increase the IMR after the correction (CIMR), while 7, decreased this variable (i.e. Hungary, Poland, etc.). The differences appeared in the rest of the countries, can be attributed to statistical variability, and not to a real difference.

The corrected mortality rates of each country (CIMR) would not be enough to draw definite conclusions, because of the interconnection with the late fetal and early neonatal death rates. At the same time, the simple plotting of IMR and, LFDR or ENDR would not weight the importance of every factor in a final result.

The principal component analysis (Kendall,

1957) has been used in this study as an alternative method of evaluation, and performed through three variables: infant mortality rate, early neonatal, and late fetal death rates.

The results of the performance of principal component analysis obtained, are compared with the results of the principal component analysis when the IMR is substituted by the "corrected IMR", and in a parallel way, the classification of the countries by the IMR and the "corrected IMR" (CIMR) (Table 3, Table 4).

IV Conclusions

If no changes in the country order classification were induced, it could be concluded that this bias was not enough big to be worth of a correction, but the fact that changes appear, evidences the shifting from ENDR to LFDR in several countries. Especially in areas with supposed reliable health registration system, this is relevant; in the areas where health statistics is deficient or does not have a minimum standard of accuracy, until other factors are controlled, it is very difficult to measure the weight of this bias.

It is logic to think about a more rational concept of better health status for early childhood, considering the classification of countries by PCA-Prin1, and not only by the corrected infant mortality rate, because, although a bias is relatively well controlled, the PCA-Prin1 reflects more a global approach to health care.

It is not mandatory to think that when evaluating the trend of infant, late fetal, or early neonatal mortality rates of a country, this correction should be performed, but it is absolutely necessary to bear it in mind when

carrying out international comparisons, especially of countries belonging to different categories.

Appendix

Correction of IMR which includes the bias induced by the erroneous calculation of late fetal deaths.

α : PMR=Perinatal mortality rate (per 1.000 live births)

β : IMR=Infant mortality rate (per 1.000 live births)

$$P = \frac{\text{Number of late fetal deaths}}{\text{Number of late fetal deaths} + \text{Number of early neonatal deaths}} \\ = \frac{\text{late fetal death rate}}{\text{perinatal death rate}}$$

P' =average of P for the 47 countries of Table 1

N =Number of live births

β' =corrected IMR under the assumption $P=P'$

$$\beta' = \frac{\frac{N\beta}{1000} + (P-P')\frac{N\alpha}{1000}}{N + (P-P')\frac{N\alpha}{1000}} \cdot 1000 = \frac{\beta + (P-P')\alpha}{1 + \frac{(P-P')\alpha}{1000}}$$

$$\div [\alpha + (P-P')\alpha] \times [1 - \frac{(P-P')\alpha}{1000}]$$

$$(\because |\frac{(P-P')\alpha}{1000}| \ll 1.0)$$

$$\beta' \div \beta + (1 - \frac{\beta}{1000})(P-P')\alpha$$

$$(\because |(P-P')\alpha \frac{(P-P')\alpha}{1000}| \ll 1.0)$$

$$\frac{N\beta}{1000}: \text{Number of infant deaths}$$

$$\frac{N\alpha}{1000}: \text{Number of perinatal deaths}$$

$$P\frac{N\alpha}{1000}: \text{Number of late fetal deaths}$$

$$P'\frac{N\alpha}{1000}: \text{Number of "true" late fetal deaths}$$

$$P\frac{N\alpha}{1000} - P'\frac{N\alpha}{1000} = (P-P')\frac{N\alpha}{1000} \text{ bias which}$$

should have been included in early neonatal deaths group (infant deaths group)

$$\text{Number of true live births: } N + (P-P')\frac{N\alpha}{1000}$$

Number of true infant deaths:

$$\frac{N\beta}{1000} + (P-P')\frac{N\alpha}{1000}$$

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〔資 料〕

乳児死亡率の国際比較に関する研究

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日本の周産期死亡は諸外国に比べ、特に後期死産率が早期新生児死亡率よりもかなり高い。早期新生児死亡と数えるべき死亡を後期死産に数えると、乳児死亡率に影響を与える。そこで、1987年のWHO発行の統計年報（World Health Statistics Annual）に記載された47カ国の後期死産数、早期新生児死亡数、出生数、乳児死亡数を用い、後期死産数と早期新生児死亡数の比率を諸外国のデータの平均値と仮定したときに、日本のほか諸外国の乳児死亡率がどのように変化するか計算し

た。その結果、早期新生児死亡を後期死産に数えるようなバイアスのかかる国と、逆に後期死産を早期新生児死亡に数えるバイアスのかかる国が存在することがうかがわれた。乳児死亡率を健康指標として、国際比較をする場合には、本研究で示した方法で乳児死亡率を訂正後、主成分分析によって総合的な評価を行なったほうがよいと思われる。

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