MATERNAL MORTALITY AND LENGTH OF LIFE

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BEHIND the life table lies the story of the long and arduous struggle of man to prolong human life. The steady rise in the mean expectation of life which has occurred in the western world during the period of over a century for which we have adequate statistical data is eloquent proof of the very considerable successes which medical science has achieved. Progress has been uneven, however, both with respect to the separate causes of death and to the classes of the population upon which some of these causes bear most heavily, and concern has frequently been expressed over the fact that puerperal mortality, a cause of death which is largely amenable to control by medical treatment, has shown so little improvement. In the words of Mr. Pitt-Rivers, "Public health work has certainly reduced infant mortality, but it is in precisely those countries where the reduction in infant mortality has been effected, that the maternal death rate has remained high."[2] The toll of life taken by an individual cause of death can be decreased, either by improvements in preventive medicine which lessen the number of persons exposed to the risk of death from that particular cause, or by more successful treatment of those who do run that risk. Now it is obvious that, viewed from this standpoint, maternal mortality presents a problem of quite special interest. The most striking recent demographic phenomenon of the western world has been the steep and steady decline of fertility roughly since the last quarter of the nineteenth century. When fertility declines, maternal mortality will, other things being equal, account for fewer victims among all women since fewer women will be exposed to the risk of death

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[2] Pitt-Rivers, G. H. L. F.: The Problem of Maternal Mortality. *Eugenics Review*, January, 1935, p. 277. *Cf. also* Dublin, L. I. and Lotka, A. J.: TWENTY-FIVE YEARS OF HEALTH PROGRESS. New York, Metropolitan Life Insurance Company, 1937, p. 345.

from puerperal causes. It is the purpose of this paper to investigate the effect of the changing incidence of diseases and accidents of childbirth upon the mean expectation of life of females, and to attempt to show separately the effect on that life expectation of less frequent exposure to the risk of death from puerperal causes—in other words, of declining fertility. Because of the excellence of its demographic data, Sweden was chosen for the investigation. Deaths are registered by place of residence rather than by place of occurrence so that mortality rates are automatically corrected for effects of hospitalization. Since an important urban-rural fertility differential exists, the subdivision by urban and rural areas was preserved.[3]

The Effect of Maternal Mortality on Life Expectancy

The pioneer work by Bernouilli, d'Alembert, Farr, and more recently by Dublin and Lotka, has shown the method and significance of constructing life tables with individual causes of death eliminated.[4] By comparing such a life table with the life table con-

[3] Confinement figures by age groups were obtained from Sveriges Officiella Statistik. Befolkningsrörelsen, deaths from all causes and maternal mortality data from Dödsorsaker. Unfortunately no information on deaths by causes is available for the years before 1911 and in addition the subdivision by age groups is not as detailed as would have been desirable, being by ten-year groups for the years prior to 1923. Population figures were obtained from the censuses of 1910, 1920, 1930, and 1935.

[4] Interest in the effect of single diseases upon the mean expectation of life seems to have been aroused in the early eighteenth century. News had been brought to France from the eastern Mediterranean region and the Middle East of the possibility of avoiding the dreaded smallpox by inoculation. A violent controversy ensued over the merits and demerits of treatment and in the course of it the mathematician, Daniel Bernouilli evolved a method of constructing a life table with the single cause of death, smallpox, eliminated. Shortly afterwards the method was criticized and improved by d'Alembert, and Duvillard calculated the increase in life expectancy which the elimination of death from smallpox would bring about. For historical and methodological discussion of the problem, *see*

(a) Karn, M. Noel: An Enquiry into Various Death-Rates and the Comparative Influence of Certain Diseases on the Duration of Life. *Annals of Eugenics,* 1931, iv, pp. 279-326.

(b) ———: A Further Study of Methods of Constructing Life-Tables When Certain Causes of Death Are Eliminated. *Biometrika,* 1933, xxv, pp. 91-101.

(c) Farr, William: Effect of the Extinction of Any Single Disease on the Duration of Life. *Supplement to the Thirty-fifth Annual Report of the Registrar-General for England and Wales,* 1873.

(d) Dublin, L. I. and Lotka, A. J.: Length of Life. New York, The Ronald Press Company, 1936, p. 121 ff.

(e) Irwin, J. O.: Recent Advances in Mathematical Statistics. *Journal of the Royal Statistical Society,* 1935, 98, p. 105 ff.

structed from the actual age-specific death rates, *i.e.*, with all causes operative, we can calculate the gain in life expectation which the elimination of the specific cause would bring, or in other words, the years or fractions of a year forfeited to that cause by a person in the life table population. If we carry through this calculation at different periods we can then observe the variation in years lost to the specific cause under observation, in this case maternal mortality.

In the present investigation a short method of computing the life tables is used, which does not involve the calculation of the probability of dying.[5] The age-specific death rates used in constructing the life table with deaths from diseases and accidents of childbirth eliminated are obtained as follows: If P is the observed population in a given age group, M^i the observed deaths from the cause i to be eliminated, and M^{-i} the observed deaths from all other causes, then the observed age-specific mortality rate from cause i, m^i may be expressed as $\frac{M^i}{P}$ and the observed age-specific mortality rate from all other causes m^{-i} may be expressed as $\frac{M^{-i}}{P}$. It follows that the hypothetical number of deaths which would occur in the age group, were the single cause i eliminated, would be

$$\overline{M}^{-i} = P.m^{-i} + \tfrac{1}{2} P.m^i.\, m^{-i},$$

since to those who actually die from all other causes $(P.m^{-i})$ must be added a number of deaths among those "saved" by the elimination of the cause i. Assuming that deaths from cause i are distributed evenly throughout the period, those "saved" from it $(P.m^i)$ will on the average be subject to the death rate from all other diseases (m^{-i}) for half the period. Thus the hypothetical death rate from all other causes with cause i eliminated, is

$$\overline{m}^{-i} = \frac{\overline{M}^i}{P} = m^{-i}\,(1 + \tfrac{1}{2}\, m^i).$$

Certain assumptions are implicit in this calculation and these

[5] For the method of computation *see* Doering, Carl R. and Forbes, Alice L.. A Skeleton Life-Table. *Proceedings of the National Academy of Sciences*, 1938, 24, pp. 400-405.

must be taken into account when the results are evaluated. It is assumed that the risk of death from the cause *i*, maternal mortality, is independent of all other risks of death; in other words the whole problem of joint causes of death is assumed away.[6] It is further assumed that death from cause *i* strikes at random among the individual members of the cohort of females and does not weed out the weaklings. If it did operate selectively in this way those "victims" of cause *i* who "survive" when it is eliminated would not be subject to the average death rate from all other causes.[7] The limitations of the data also introduce the possibility of inaccuracy. In constructing the life tables based on age-specific death rates for ten-year age groups we must assume that deaths are evenly distributed throughout the age interval. Obviously this is not true in the case of maternal deaths, especially in the older age groups. The accuracy of the more recent figures (1930-1931 and 1935-1936), however, was to some extent controlled by recomputing the life tables for five-year age groups. Little distortion seems to have been introduced by the ten-year age groupings[8] since the results based on the five-year age

[6] For rules governing classification in the United States when both puerperal and non-puerperal causes appear on the death certificate, *cf.*: Maternal Mortality in Fifteen States. Children's Bureau Publication No. 223, 1934, p. 6. Washington, D. C., United States Department of Labor.

[7] Indeed this is part of the eugenist explanation of the high maternal mortality rates in western countries, *e.g.*, "Survival of the strains of pregnancy and parturition depends far more on constitutional fitness and stamina than on medical preparation and obstetrical assistance. The child's chances of survival, however, are increasingly dependent, not upon its constitutional and hereditary robustness, but upon its protection from bacterial attack and the artificial and medical assistance it receives. In short, we save the weak or defective potential mothers at birth and during childhood, who become increasingly unfitted themselves to survive the test of giving birth." Pitt-Rivers: Weeds in the Garden of Marriage. Cited in Pitt-Rivers, *loc. cit.*, pp. 278-279. Mr. Pitt-Rivers' statement, even if correct, does, however, admit of a more optimistic interpretation. His argument, rephrased, is simply that some of the more delicate females who in an earlier period died in infancy or in childhood now live ten or even twenty years longer.

[8] Years forfeited at birth to maternal mortality.

	Based on Ten-Year Age Groups	Based on Five-Year Age Groups
Sweden, urban (1930-1931)	0.215	0.205
Sweden, urban (1935-1936)	0.172	0.170
Sweden, rural (1930-1931)	0.261	0.262
Sweden, rural (1935-1936)	0.208	0.209

groups did not differ significantly from those based on mortality rates for ten-year age groups.

Table 1 (top section) shows the potential years of life lost to puerperal causes of death. At first sight the magnitudes involved do not seem large, the greatest loss charged to maternal mortality being 0.40 years in rural Sweden in 1910-1911. That is to say, if there were no deaths from puerperal causes, a girl aged 20—in the life table

Table 1. Trends in years of life lost to puerperal causes and percentage of remaining years of life lost to puerperal causes among Swedish females, by age and rural-urban residence.

Years	Age								
	0	1	5	10	15	20	30	40	50+
	Years of life lost to puerperal causes								
Rural									
1910–1911[1]	.35	.37	.38	.39	.40	.40	.26	.05	.00
1920–1921	.30	.32	.33	.33	.34	.33	.21	.05	.00
1930–1931	.26	.27	.28	.28	.28	.26	.16	.03	.00
1935–1936	.21	.22	.22	.22	.22	.21	.12	.03	.00
Urban									
1910–1911[1]	.16	.18	.19	.19	.19	.19	.11	.03	.00
1920–1921	.21	.23	.23	.24	.24	.23	.12	.03	.00
1930–1931	.21	.22	.23	.23	.23	.22	.12	.03	.00
1935–1936	.17	.18	.18	.18	.18	.18	.09	.02	.00
	Percentage of remaining years of life lost to puerperal causes								
Rural									
1910–1911[1]	.58	.59	.63	.69	.76	.82	.64	.16	.00
1920–1921	.49	.50	.54	.58	.64	.67	.51	.16	.00
1930–1931	.41	.42	.44	.48	.53	.53	.38	.09	.00
1935–1936	.32	.32	.34	.37	.41	.42	.27	.08	.00
Urban									
1910–1911[1]	.28	.29	.31	.33	.37	.39	.28	.11	.00
1920–1921	.35	.35	.38	.41	.45	.47	.29	.10	.00
1930–1931	.34	.34	.36	.39	.43	.44	.29	.09	.00
1935–1936	.26	.27	.28	.31	.33	.36	.22	.05	.00

[1] In calculating the 1910-1911 figures the deaths for 1911 were applied to the female population at the Census of December 31, 1910, since the 1910 mortality statistics are not subdivided by age and cause.

population of rural Sweden in 1910-1911—would live, on the average, 0.40 years longer than she would under existing mortality conditions. A clearer idea of the significance of the figures is obtained, however, if they are expressed as percentages of the remaining expected years of life. This is done in the lower section of Table 1.[9] Both the absolute and relative figures increase slightly up to age 20 years and then decline to zero at all ages over 50 years, when the cause is no longer operative. Throughout the period under consideration the toll of years taken by puerperal deaths is consistently greater in the rural than in the urban areas, but this differential has become steadily smaller.

In rural areas there was a steady improvement at all ages from 1910-1911 to 1935-1936. At age 20 years, when the percentage of the remaining potential years of life forfeited to puerperal causes reaches its maximum, the years of life lost fell from 0.40 years in 1910-1911 to 0.21 years in 1935-1936, equivalent to a decline in the percentage of the remaining years of life lost to puerperal causes from 0.82 per cent in 1910-1911 to 0.42 per cent in 1935-1936. These figures may at first glance look rather insignificant. It must be noted, however, that whereas the actual increase in expectation of life at birth from 1910-1911 to 1935-1936 was 5.57 years, at age 20 years it was only 2.22 years. Thus the years gained at the expense of puerperal causes of death between 1910-1911 and 1935-1936, 0.19 years, were equivalent to about 8.6 per cent of the actual gain in the expectation of life at that age.

In urban areas the evolution of the figures is very different. At age 20 the years lost to puerperal causes of death rose from 0.19 years in 1910-1911 to 0.23 years in 1920-1921 and then fell again gradually to 0.18 years in 1935-1936. At that age the percentage of the remaining years of life forfeited to maternal deaths rose from 0.39 per cent in 1910-1911 to 0.47 per cent in 1920-1921 and then declined to

[9] It must also be borne in mind that in comparisons over time the result is affected by changes in mortality from other causes as well as from changes in mortality from the single cause under observation.

0.36 per cent in 1935-1936. Thus maternal mortality was practically as important a cause of death among the total urban female population at the end of the period under observation as it was at the beginning.

The Trend in Puerperal Risk Rates

The puerperal risk rate in Sweden is obtainable from the formula $\frac{M^i}{C}$, where M^i is the number of maternal deaths definitely ascribed to the puerperal state, and C the number of confinements.[10] Deaths from puerperal causes represent deaths where diseases and accidents of pregnancy are considered the sole or the principal cause. The accuracy of the figure thus depends upon the accuracy of diagnosis and this may vary both as between doctors and over time. In the case of maternal mortality this might not be expected to present much cause for uneasiness. But from the point of view both of diagnosis and of classification the problem of abortion introduces an element of uncertainty,[11] since the numerator M^i includes some, but not all post-abortive deaths,[12] a great part of which probably take place in the earlier months of pregnancy. It includes only those cases of death where the primary cause is connected with childbirth and excludes deaths of child-bearing women where other causes are said to be of primary importance. Thus changes in death certificate procedure or in death rates from other nonpuerperal causes which occur in conjunction with and take precedence over puerperal causes might cause spurious variations in the number of deaths

[10] For a good discussion of the reliability of maternal mortality rates with special reference to the United States, *see* Woodbury, Robert M.: Maternal Mortality. Children's Bureau Publication No. 158, 1926, pp. 3-21. Washington, D. C., United States Department of Labor.

[11] For instance, at the 1938 meeting of the International Commission for the Decennial Revision of the International Nomenclature of Diseases it was unanimously agreed that after 1940 criminal abortions would be classified as due to puerperal causes. Previously they had been classified under homicide. However, no such changes appear to have been made in the period under observation.

[12] Although criminal abortions were classified throughout the period under homicide, many criminal abortions are probably entered under puerperal causes.

assigned to puerperal causes.[13] The denominator *C* obviously excludes the successful abortions and also the foetuses born in the earlier months of pregnancy. Since it automatically eliminates possible distortion which might be caused by plural births or by unregistered stillbirths it is, however, preferable to a rate based on total births and may therefore be regarded, subject to the above qualifications, as a reasonably accurate measure of the risk of death run by women in those cases of pregnancy which develop to or near to the normal term of viability.

The evolution of this rate showed some interesting features. (*See* Table 2.) In rural areas it fluctuated irregularly around a level of about 2.5 deaths per 1,000 confinements throughout the period 1911 to 1936, a slight rise being apparent after 1925. In urban areas, the rate in 1911 was 1.89 per 1,000 but quickly rose above the rural level and reached 3.59 in 1919. After some improvement another peak was reached in 1929 when the rate was 4.71, followed by an irregular downward movement to 4.02 in 1936.[14]

When age-specific maternal death rates are computed it becomes evident that the risk of death is relatively high for very young mothers and for those in the upper age groups. Direct standardization (by ten-year age groups) showed that changing age-composition of mothers caused no significant distortion (*see* Table 2). Again, the risk of death is much greater for plural than for single births. Since, however, the percentage of multiple pregnancies is a small and probably more or less constant fraction of the total, it will not affect the accuracy of the rate appreciably. Medical statisticians have shown that the mortality risk is greater for first than

[13] *e.g.* In cases where two causes, one puerperal and the other not, are listed, and the non-puerperal cause takes precedence, a decline in the latter will, *cet. par.*, cause a rise in the maternal death rate.

[14] The divergence between the two rates makes it clear that if any significant change in death certificate procedure occurred it did not affect rural and urban areas equally. Part of the spread between rural and urban puerperal risk rates may be spurious since abortions are not included as confinements and thus appear in the numerator but not in the denominator of the fraction. *Cf.* pp. 298-299 supra and pp. 301-302 infra.

Year	Rural		Urban	
	Crude Rate[1]	Standardized Rate[2]	Crude Rate[1]	Standardized Rate[2]
1911	2.89	2.89	1.89	1.89
1912	2.43	2.42	1.93	2.25
1913	2.34	2.34	1.98	1.98
1914	2.61	2.62	2.48	2.47
1915	2.98	2.97	2.57	2.57
1916	2.73	2.73	2.36	2.36
1917	2.28	2.28	2.88	2.87
1918	2.30	2.30	3.31	3.31
1919	3.03	3.06	3.59	3.61
1920	2.48	2.51	3.05	3.05
1921	2.69	2.74	2.59	2.60
1922	2.35	2.38	2.88	2.86
1923	2.24	2.23	2.46	2.10
1924	2.10	2.10	3.08	3.07
1925	2.47	2.53	3.00	3.00
1926	2.81	2.84	3.20	3.22
1927	2.61	2.68	3.14	3.09
1928	3.03	3.11	3.92	3.90
1929	3.41	3.46	4.71	4.71
1930	3.04	3.08	4.53	4.73
1931	3.33	3.44	4.41	4.53
1932	3.07	3.24	4.23	4.35
1933	2.85	2.94	3.48	3.65
1934	3.30	3.43	3.23	3.33
1935	2.80	2.87	3.63	3.75
1936	2.69	2.88	4.02	4.18

[1] $\frac{M^1}{C}$

[2] Standardized with the age composition of 1911 as a base. Since data are available only by ten-year groupings over 20 years of age, the standardization is not entirely satisfactory.

Table 2. Puerperal risk rates per 1,000 confinements.

for subsequent confinements.[15] As the average size of family decreases with the decline in fertility the proportion of first confinements rises, and consequently one might expect this factor to exert an upward pressure on the maternal death rate. Unfortunately, maternal deaths and confinements subdivided by order of birth are

[15] *Cf.* New York State Department of Health. 55TH ANNUAL REPORT, 1934, ii, p. xlv. Dublin, Mary: Maternal Mortality and the Decline of the Birth Rate. *Annals of the American Academy of Political and Social Science,* November, 1936, 188, pp. 107-116.

not available for Sweden. Studies based on data for Australia and New York State[16] showed that standardization of crude rates for changes in composition as regards order of birth did not change the rate significantly, the high mortality of primiparae being largely offset by the elimination of higher orders (*e.g.*, sixth, seventh, and eighth, etc.) where mortality was also high. It must be noted, however, that as average family size continues to decrease, the elimination of third and fourth confinements, where puerperal risk rates are apparently very much lower than for primiparae, declining fertility may well mask an improvement in maternal mortality. With given fertility rates an increase in primiparae would therefore tend to *lower* the mean expectation of life of females. Changes in family size may have accounted for some part of the increase in maternal mortality in urban Sweden and it is unfortunate that the influence of this factor cannot be controlled.

Perhaps the most probable source of distortion in the puerperal risk rates is the changing frequency of abortion. Little quantitative information on this problem in Sweden is available but the opinion is generally accepted that it is a very important cause of death in the puerperal state,[17] and furthermore, it is believed that abortion frequency did rise in the 1920's.[18] Obviously, other things being equal, an increase in abortion rates would tend to raise the maternal mortality rate, since the chances of death, in particular from infection, after abortion are probably greater than following a normal confinement.[19] In the most recent figures for Sweden—1935-1937—separate figures were published of deaths from septicemia following upon an abortion and after a confinement. These figures show that

[16] *Cf.* footnote 15.

[17] Data for the United States are to be found in Maternal Mortality in Fifteen States. Children's Bureau Publication No. 223, 1934, p. 103. Washington, D. C., United States Department of Labor.

[18] *Cf.*, Myrdal, Alva: NATION AND FAMILY. New York and London, Harper and Brothers, 1941, p. 206.

[19] *Cf.*, Maternal Mortality in Fifteen States. Children's Bureau Publication No. 223, 1934, p. 116. Washington, D. C., United States Department of Labor.

post-abortive infections account for around half of the deaths from puerperal septicemia.[20] Data published in the Swedish medical statistics indicate that at least from 1931 to 1935 the majority of these deaths were registered in the cities—and Sweden is a predominantly rural country—and that by far the highest rate consistently occurred in Stockholm.[21] These data are fragmentary but they do show, first that post-abortive infection is a very important cause of death assigned to puerperal causes, and secondly that, if reporting is equally accurate, it is primarily an urban phenomenon. The period for which figures are available is too short for an examination of the variations in the proportion of puerperal deaths represented by post-abortive infections to yield useful results, but it is obvious that even a slight increase in the frequency of abortion would be sufficient to mask an improvement in the mortality of mothers.

Summary

We are now in a position to draw our results together. Over the period 1911 to 1936, the potential years of life lost to puerperal causes of death by a woman in the life table population in rural Sweden declined considerably while the real puerperal risk rate fluctuated around a constant level. In urban areas, on the other hand, the years lost to puerperal causes remained almost constant while the puerperal risk rate, so far from falling, rose very considerably. Thus we may conclude, subject to the qualifications concerning changes in reporting, decreasing family size and changes in abortion rates, that in rural areas almost all the increase in life expectancy of females at the expense of puerperal causes of death is apparently due to less frequent exposure to the risk of death from diseases and accidents of childbirth, or in other words to the decline

[20] In 1935 for 49 per cent, in 1936 for 54 per cent, and in 1937 for 37 per cent. *Cf.* League of Nations. Health Organization. Annual Epidemiological Reports. Similar results were obtained from the United States Children's Bureau. *Op cit.*, p. 116.

[21] Sveriges Officiella Statistik. Halso- och Sjuk-vard. Allman Halso- och Sjuk-vard. Table 3, 1931-1935.

in fertility, especially among older women. In urban Sweden the rise in the real puerperal risk rate, which may be associated with an increase in abortion, was sufficient to offset the effect of declining fertility on the mean expectation of life of the female life table population.