

OBSERVATIONS ON ALL BIRTHS (23,970) IN BIRMINGHAM, 1947*

VII. EFFECT OF CHANGING FAMILY SIZE ON INFANT MORTALITY

BY

J. R. GIBSON and THOMAS McKEOWN

From the Department of Social Medicine, University of Birmingham

The object of this communication is to enquire to what extent the reduction in infant mortality during the 20th century may be attributed to changes in family size. This important question was referred to in Volume XIII (Pt II) of the 1911 Census of England and Wales (p. xlix). The census recorded for each married woman the total number of children born alive, and the number living and dead at the time of the Census. This made it possible to relate mortality to family size (but not to order of birth), and it was noted that:

Whatever the ages of the parents and the duration of marriage the increase of mortality with number of births is very great, the rates being generally three to five times as high for the largest families as for the smallest.

On this evidence it was concluded that:

The recent decline in the mortality of early life must to a considerable extent be attributable to the reduction in size of the family, and must to that extent be discounted as an indication of sanitary progress. Viewed in this light the fact that infant mortality rather increased than decreased during the closing years of the nineteenth century becomes all the more remarkable, since it did so notwithstanding both sanitary progress and rapid reduction of family size.

The association between mortality and family size was not examined in the Censuses of 1921 and 1931, although it has since been confirmed by Woodbury (1926), McKinlay (1929), Burns (1942), and Woolf (1947).

MORTALITY RELATED TO BIRTH ORDER AND MATERNAL AGE

The association of mortality with birth order and maternal age is explored on data for births delivered in Birmingham during 1947. An account of the material has previously been published (Gibson and McKeown, 1950). Although we are here concerned mainly with infant mortality, results on stillbirths and neonatal deaths are also included.

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TABLE I
STILLBIRTH RATES (EXPRESSED PER THOUSAND TOTAL BIRTHS) RELATED TO MATERNAL AGE AND BIRTH RANK (BIRMINGHAM, 1947).

Birth Rank	Maternal Age (yrs)			Total
	Under 25	25-29	30 and Over	
1	22.9 (93)	29.7 (74)	46.6 (64)	29.1(231)
2	10.9 (16)	19.0 (44)	20.4 (42)	17.4(102)
3	11.1 (4)	22.5 (23)	23.3 (35)	21.5 (62)
4 and Over	17.5 (2)	17.0 (12)	34.3 (87)	30.1(101)
Total	19.2(115)	23.4(153)	30.5(228)	24.8(496)

Numbers in brackets are numbers of stillbirths.

(a) STILLBIRTHS.—Table I illustrates the well-known association between incidence of stillbirths and parity and age of mother, upon which Yerushalmy (1938), Burns (1942), Sutherland (1946), Baird (1947), and Robinson (1947), among others, have commented.

(b) NEONATAL DEATHS.—At all ages, the incidence of neonatal deaths is higher for "4th and later" births than for earlier births; there is no other consistent association with birth rank, and none with age (Table II).

TABLE II
NEONATAL MORTALITY RATES (EXPRESSED PER THOUSAND LIVE BIRTHS) RELATED TO MATERNAL AGE AND BIRTH RANK (BIRMINGHAM, 1947).

Birth Rank	Maternal Age (yrs)			Total
	Under 25	25-29	30 and Over	
1	18.2 (72)	8.3 (20)	26.0 (34)	16.4(126)
2	19.9 (29)	18.1 (41)	13.8 (28)	17.1 (98)
3	14.1 (5)	16.0 (16)	15.7 (23)	15.6 (44)
4 and Over	44.6 (5)	20.2 (14)	22.0 (54)	22.4 (73)
Total	18. (111)	14.3 (91)	19.2(139)	17.5(341)

*Numbers in brackets are numbers of deaths in the first month of life.

On data recorded for New York State, 1936, Yerushalmy (1938) reported that the incidence of neonatal deaths was related to age and birth order in very much the same way as the incidence of stillbirths. It is scarcely surprising that there should be

some difference between results obtained in New York, 1936, and Birmingham, 1947, since the neonatal mortality rates were respectively 31.2 and 17.5, and the relationship of incidence with age and birth rank is determined by the relative frequencies of different causes of death. Moreover, because of the smaller number of Birmingham births, it has been necessary to group the lower maternal ages at which a high incidence was observed on New York data.

(c) INFANT DEATHS.—Table III indicates that infant mortality rates increase with increasing birth rank, and decrease with increasing maternal age.

TABLE III
INFANT MORTALITY RATES (EXPRESSED PER THOUSAND LIVE BIRTHS) RELATED TO MATERNAL AGE AND BIRTH RANK (BIRMINGHAM, 1947).

Birth Rank	Maternal Age (yrs)			Total
	Under 25	25-29	30 and Over	
1	31.3(124)	16.9 (41)	37.4 (49)	27.8(214)
2	47.4 (69)	34.0 (77)	25.7 (52)	36.2(208)
3	76.1 (27)	44.1 (44)	25.2 (37)	38.3(108)
4 and Over	98.2 (11)	59.2 (41)	45.7(112)	56.4(164)
Total	39.2(231)	31.8(203)	34.5(250)	35.6(694)

The Infant Mortality rate is lower than that recorded for Birmingham by the Registrar-General mainly because all multiple births and births delivered after less than 28 weeks gestation have been excluded.

Table IV (see also Fig. 1) shows that this association is due to deaths from infection, for there is no variation with maternal age and birth rank in the incidence of deaths from all causes other than infection. Rates are here expressed as deaths in the 2nd to 12th months per thousand infants alive at one month.

On this evidence we are able

(a) to attribute the association of infant mortality with birth rank and maternal age mainly to deaths from infection,

(b) to interpret the association as evidence of environmental influence.

What we are unable to do is to specify the nature of environmental influence, which we may consider briefly before proceeding to an examination of the effect of changing family size on mortality.

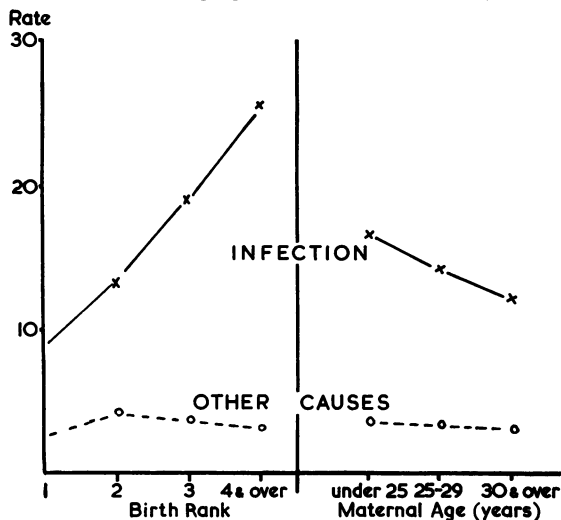


FIG. 1.—Incidence of deaths in 2nd to 12th month related to birth rank and maternal age. All Ward Groups (see Table IV).

A classification of all births in a city by maternal age and order of birth (as in Tables I-IV) is inevitably to some extent a classification by economic circumstances of parents, since in general, well-to-do mothers are older and have fewer children than poor mothers. We therefore enquire whether the association of incidence of deaths from infection with the two variables exists independently of differences in economic circumstances. For this purpose births have been assigned by place of domicile to one of three Ward Groups, identified essentially on the basis of the standard of housing (Record and McKeown, 1949). Results exhibited in Fig. 2 indicate, first, that the relation between incidence and birth rank is present in all ward groups, but is most marked in

TABLE IV
INCIDENCE OF DEATHS FROM INFECTION AND OTHER CAUSES IN 2ND TO 12TH MONTH (EXPRESSED PER THOUSAND INFANTS ALIVE AT 1 MONTH) RELATED TO BIRTH RANK AND MATERNAL AGE (BIRMINGHAM, 1947).

Birth Rank	Maternal Age (yrs)						Total	
	Under 25		25-29		30 and Over		Deaths from Infection	Deaths from Other Causes
	Deaths from Infection	Deaths from Other Causes	Deaths from Infection	Deaths from Other Causes	Deaths from Infection	Deaths from Other Causes		
1	10.6	2.8	5.8	2.9	9.4	2.3	8.8 (67)	2.8 (21)
2	21.7	6.3	13.0	3.1	7.5	4.5	13.2 (75)	4.4 (25)
3	57.2	5.7	23.3	5.1	6.9	2.8	19.0 (53)	3.9 (11)
4 and Over	55.6	0.0	35.5	4.4	21.2	2.9	25.5 (81)	3.1 (10)
Total	16.9 (98)	3.8 (22)	14.3 (90)	3.5 (22)	12.3 (88)	3.2 (23)	14.4(276)	3.5(67)

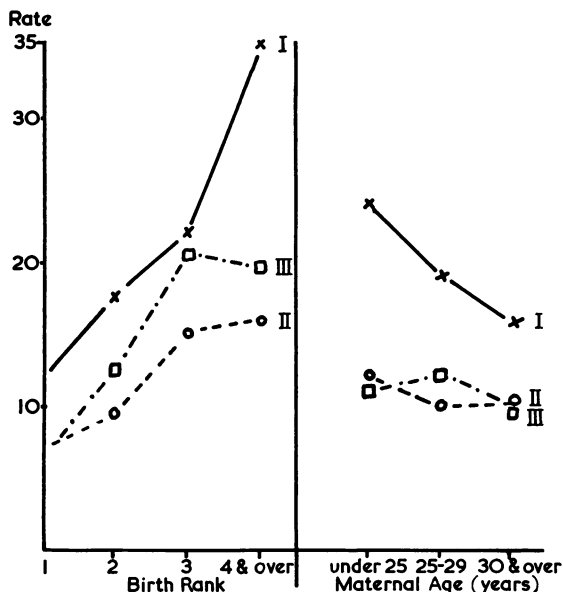


FIG. 2.—Incidence of deaths from infection in 2nd to 12th month related to birth rank and maternal age. Ward Groups I, II, and III.

Ward Group I (the poorest); and second, that incidence is definitely related to age in Ward Group I only.

There are of course differences in economic circumstances of parents within the same ward group. This difficulty may partly be overcome by comparing children of mothers in the same age group, as in Fig. 3. (Nevertheless differences remain, for, of two families with the same gross income, the larger will in effect be the poorer.) Because their respective death rates from infection (shown in Fig. 2) are not very different, Ward Groups II and III have been combined. The most satisfactory result of this treatment is that it permits us to identify a group of children (of mothers aged "30 and over" in Groups II and III) whose risk of death from infection is not consistently related to birth rank. As would be expected, the same treatment has exaggerated the increment in the younger maternal age groups, and for children of mothers "under 25" in Group I the incidence of death from infection is about eight times higher for "4th and later" children than for the first born.

We conclude that the incidence of death from infection in the first year of life (which mainly determines the association of infant mortality with birth rank) is not consistently related to position in family for children in the most favourable environmental circumstances, but is greatly increased

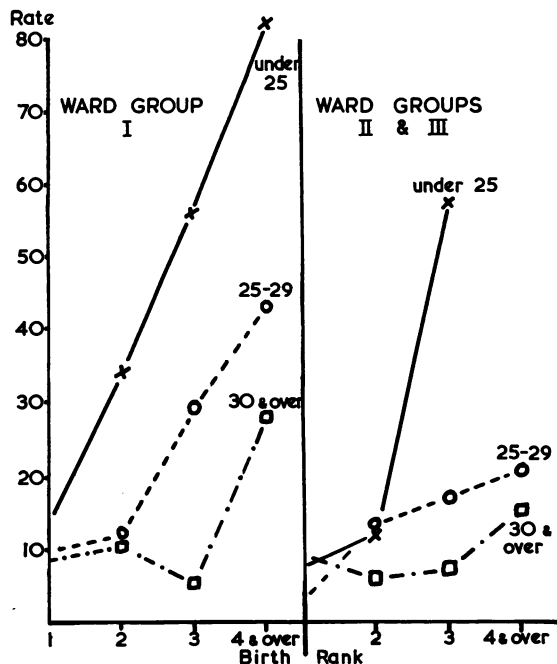


FIG. 3.—Incidence of deaths from infection in 2nd to 12th month related to birth rank and maternal age in Ward Group I, and in Ward Groups II and III.

for later born children in an unfavourable environment. It seems reasonable to suppose that the increased risk to later births in poor circumstances is due, at least in part, to increased infection conveyed by older siblings.

EFFECT OF CHANGING FAMILY SIZE ON MORTALITY

The observation that mortality is associated with size of family has inevitably provoked the suggestion that changes in family size must have contributed to the reduction in infant mortality. The relevant passage in Volume XIII of the 1911 Census has already been quoted in the opening paragraph, and one of a number of remarkable conclusions drawn by Burns (1942) from useful data is as follows:

A major factor in the reduction of the infant death rate in this century has been just the substitution of the small for the large family.

As a preliminary to an assessment of the effect of changing family size on infant mortality we have estimated for children born in England and Wales in the period 1906-10 the distribution according to order of birth and maternal age. This information has been published in the Registrar-General's Reviews only since 1938.

Details of the method are given in the Appendix, and

TABLE V
DISTRIBUTION BY BIRTH RANK AND MATERNAL AGE OF LEGITIMATE LIVE BIRTHS DELIVERED
IN ENGLAND AND WALES, 1906-10 (ESTIMATED*) AND 1947 (OBSERVED).

Birth Rank	Maternal Age (yrs)						Total	
	Under 25		25-29		30 and Over		1906-1910	1947
	1906-1910	1947	1906-1910	1947	1906-1910	1947		
1	10.0	20.6	7.0	14.8	4.7	9.1	21.7	44.5
2	5.0	6.2	6.9	11.1	7.2	12.3	19.1	29.6
3	2.1	1.3	5.5	4.2	8.1	7.8	15.7	13.3
4 and Over	1.2	0.3	6.8	2.1	35.5	10.2	43.5	12.6
Total	18.3	28.4	26.2	32.2	55.5	39.4	100 (848,570)	100 (808,961)

*For method of estimation see Appendix.

Table V compares the estimated distribution of births in 1906-10 with that observed in 1947. The increased proportion of children in the later birth ranks in the earlier period is of course expected; the higher proportion of mothers in the upper age groups may not be, unless it is recognized that the distribution by maternal age is affected more by the later age to which reproduction continued than by the early age at which it began.

Finally we have applied the Birmingham 1947 mortality rates for each birth rank and maternal age group (recorded in Tables I, II, and III for stillbirths, neonatal deaths, and infant deaths respectively) to the births of England and Wales distributed as in Table V,

- (a) for 1906-10 (estimated),
(b) for 1947 (observed).

The results (given in Table VI) show that the change in the distribution of births between the two periods would have had very little effect on stillbirth and neonatal mortality rates, had mortality rates for each birth rank and maternal age group remained unchanged. The effect on infant mortality is more substantial, the expected rates for 1906-10 and 1947 being 39.8 and 33.2 respectively. But the observed rates were 117.1 (1906-10) and 41.4 (1947), so that only a small part of the reduction can be attributed to the changed distribution of births by birth order and maternal age.

Before accepting this conclusion we should consider the possible effect of error in the estimate of the

distribution of children born in 1906-10. As explained in the appendix, it was necessary to assume that fertility remained unchanged in the 30 years preceding the Census, which quite certainly it did not. The trends observed between 1906-10 and 1947 (to smaller families completed at younger maternal ages) existed earlier, and it can be shown that the distribution 1906-10 is overweighted with children in the later birth ranks and at higher maternal ages. That is to say the differences between the distributions at the two periods are probably not as great as is indicated in Table V, and we have therefore exaggerated the difference in mortality rates which can be attributed to changes in the distribution of births by birth rank and maternal age.

SUMMARY

(1) Data for births delivered in Birmingham during 1947 are used to explore the association between stillbirth, neonatal mortality, and infant mortality rates and maternal age and birth order. It is shown that infant mortality increases with increasing birth order and decreases with increasing maternal age, and that in both cases the association is mainly due to deaths from infection. There is no consistent relationship between the incidence of deaths from infection and position in family for children in the most favourable environmental circumstances.

(2) The effect on stillbirth, neonatal mortality, and infant mortality rates of changes which have occurred

TABLE VI
OBSERVED AND EXPECTED MORTALITY RATES.

Rate	Birmingham, 1947	England and Wales, 1947		England and Wales, 1906-10	
		Expected*	Observed	Expected*	Observed
Stillbirth	24.8	25.4	24.1	26.6	40.1 (in 1928)†
Neo-Natal Mortality	17.5	17.1	22.7	18.9	40.2
Infant Mortality	35.6	33.2	41.4	39.8	117.1

*See text for method of estimation.

†1928 is the first year for which the stillbirth rate is available.

in the distribution of births by birth rank and maternal age during the 20th century is examined. For this purpose Birmingham 1947 mortality rates are applied to births delivered in England and Wales

(a) in the period 1906–10, whose distribution by maternal age and birth order is estimated from data supplied in the 1911 Census,

(b) in 1947, whose distribution is given in the Registrar-General's Annual Review.

(3) The results suggest that had mortality rates for each birth rank and maternal age group remained unchanged, the change in the distribution of births between the two periods would have had very little effect on stillbirth and neonatal mortality rates, and could account for only a small part of the observed reduction in infant mortality.

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APPENDIX

METHOD OF ESTIMATING THE DISTRIBUTION BY BIRTH RANK AND MATERNAL AGE OF CHILDREN BORN IN THE PERIOD 1906–1910

(1) Volume XIII, Part II, of the 1911 Census of England and Wales gives, according to age of wife at marriage and duration of marriage,

(a) the number of wives (shown as the number of couples in Table 18),

(b) the number of children in families of stated size (Table 20B).

From (b), the number of children in each birth rank is estimated for each group defined by age at marriage and duration of marriage.

(2) By relating the number of children in each birth rank to the number of wives [1(a)], an estimate is made of the distribution by birth rank of children born to 1,000 wives in each group.

(3) We require for each group the distribution by birth rank of children born in the 5 years preceding the Census (1906–10). This can be obtained if we assume that fertility did not change over the period under consideration. For example, from the calculations in (2) we know, for women married at ages 30–34, the birth rank distribution of children

- (i) of 1,000 wives married 0–4 years,
- (ii) of 1,000 wives married 5–9 years.

By subtracting the values of (i) from the corresponding values of (ii) we obtain the distribution of

children born to women, aged 30–34 at marriage and married 5–9 years, in the second 5 years of marriage (i.e. the 5 years preceding the Census). In the same way we can estimate, for wives at each age and duration of marriage, the birth rank distribution of children born in the period 1906–10.

(4) The distribution of children by birth rank in (3) is given for 1,000 women in each group. The actual number of children in each birth rank is obtained by applying the estimated incidence per 1,000 to the actual number of wives in each group [1(a) above].

(5) To obtain the distribution of births (1906–10) by maternal age and birth rank it is only necessary to translate age of wives at marriage into maternal age in the period of 1906–10. This is readily done, since we know the duration of marriage.

(6) The estimated total number of live births (848,570) corresponds closely with the mean annual number of live births reported by the Registrar-General for the period 1906–10 (883,937). Some error is undoubtedly introduced by the necessary assumption that fertility did not change in the preceding 30 years.