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SIGNIFICANCE OF LOW BIRTH WEIGHT IN PERINATAL MORTALITY

A STUDY OF VARIATIONS WITHIN ENGLAND AND WALES

BY

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Despite improvements in economic and social standards in recent years, wide variations remain between the perinatal mortality rates of the countries of Europe (International Federations of Gynaecology and of Midwives, 1966). Considerable variations also persist between the individual regions of England and Wales (Butler and Bonham, 1963). Within populations, low socio-economic status, short stature, advanced parity, and advanced age of mother (Duncan, Baird, and Thomson, 1952) are among the factors which increase the risk of perinatal death. Standards of medical care, although not easy to measure, undoubtedly modify perinatal mortality (Baumgartner, 1962). These same factors may also be associated with low birth weight (Baird, 1964), and in England and Wales some 65 per cent. of the total of perinatal deaths occur in infants weighing less than 2,501 g. at birth.

An analysis has been carried out to measure the extent to which variations in perinatal mortality between different parts of England and Wales are correlated with the distribution of birth weight. This analysis forms the first stage of a long-term study of the biology of low birth weight.

Sources of Material

The primary source of information for this study was the annual return, L.H.S. 27/1, recording the total numbers of live and still births during 1963–65 in each local authority area in England and Wales. For infants in each birth weight group (1,000 g. or less, 1,001–1,500 g., 1,501–2,000 g., 2,001–2,250 g., and 2,251–2,500 g.) the numbers of live and still births, together with neonatal deaths within 24 hours of birth, within 1–6 days, and within 7–27 days are recorded by local authority area. Above 2,500 g. no further subdivisions of birth weight groupings are recorded.

The second source of information was the Registrar General's "Statistical Reviews of England and Wales", showing the numbers of live and still births in each local authority area together with the numbers of neonatal deaths within 0–6 days and 7–27 days of birth. Both sources of data take into account transfers into and out of each particular area. Since the two sets of data showed minor discrepancies, we have used the L.H.S. 27/1 data wherever possible in order to preserve the internal consistency of the analysis. To examine the main trends the results have been summarized:

(*a*) In terms of the eleven standard regions used by the Registrar General prior to 1965, which are for the most part defined by local authority boundaries. Where a local authority overlaps more than one region, the births in that area have been assigned to the region which contains the greatest proportion of its population. As a result of the local authority boundary changes which gave rise in 1965 to the formation of Greater London, the geographical composition of the Eastern, London, and South-Eastern, and Southern regions is slightly different from that adopted for the previous years, although the areas covered are very similar.

(*b*) Local authorities designated as county boroughs, which are for the most part urban areas, have been contrasted with the remaining local authorities which are not county boroughs and are more rural in character. In this analysis London Administrative

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County and the new London boroughs are regarded as county boroughs.

(*c*) The Registrar General defines six conurbations in England and Wales. The particular local authorities which form the central and thus more urban parts of these standard conurbations have been identified. These are contrasted with the local authority areas of which part, but not the whole, is included in one or other of the six conurbations (part-conurbation) and with the more rural local authorities which include no part of a conurbation (non-conurbation).

Although the L.H.S. 27/1 data provide detailed information about birth weight distribution below 2,501 g., comparable information about the higher birth weight groups is not given. Use has, therefore, been made of two further sources of information:

(1) The National Birthday Trust Survey (Butler and Bonham, 1963), which reported the distribution of birth weight of some 17,000 single live and still births in the United Kingdom during a single week of March in 1958, and of perinatal deaths during the following 3-month period.

(2) A United States study of all births during the first quarter of 1950 (Shapiro and Unger, 1965; Unger, 1965). This study included the birth weights corresponding to all live births during this period, divided into nine weight groups covering the complete birth weight distribution. No information about still births is available.

Distribution of Birth Weights

The cumulative distribution of birth weights of about 700,000 live births of white infants in the United States data are shown in Fig. 1. The proportions are plotted on a non-uniform "probability" or probit scale, which has the property that a single Gaussian distribution will always appear as a straight line, the position and slope of the line corresponding to the mean and variance of the distribution. Similarly, a mixture of two well-separated Gaussian distributions will appear as two intersecting straight lines, and so on (Ashford, Fryer, and Robertson, 1967b). The results obtained suggest that the overall birth weight distribution is the aggregate of two distinct Gaussian distributions. The first of these, corresponding to 3·4 per cent. of the total births, has a mean value of about 2,000 g. birth weight. The remainder of the population belong to a second Gaussian distribution, with a mean value of about 3,400 g. birth weight. The comparable analysis of the United Kingdom National Birthday Trust data of about 17,000 single live and still births again points to the existence of two similar Gaussian distributions. The combined data for England and Wales, 1963–65, corresponding to about 2½ million live and still births, for birth weights up to 2,500 g. are also shown in Fig. 1. The general pattern is the same as that of the other two sets of data, although the L.H.S. 27/1 returns do not provide information for the remainder of the range of birth weights. For individual local authorities the birth weight distributions below 2,501 g. show a similar pattern to the combined data.

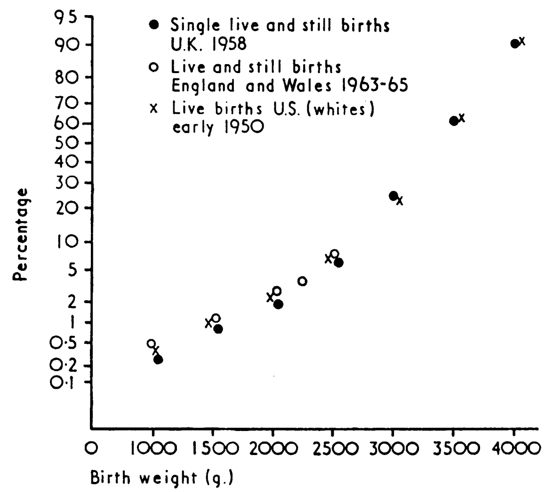

Fig. 1.—Cumulative distribution of birth weights in U.S. and U.K.

When local authorities which are county boroughs (urban) are compared with non-county boroughs (more rural), it is found that, for all birth weight groups below 2,501 g., the proportion of births is consistently higher in the more urban areas (Table I).

Table I

COMPARISON OF BIRTH WEIGHT DISTRIBUTIONS BELOW 2,501 g.
England and Wales, 1963–65

Population	Rate per 1,000 Live and Still Births (Weight in g.)					
	<1001	1001–1500	1501–2000	2001–2250	2251–2500	<2501
County Boroughs	5·1	7·9	15·3	15·9	36·7	80·9
Remainder ..	3·9	6·6	12·9	13·2	30·8	67·4
Total	4·4	7·1	13·9	14·3	33·1	72·7

If the data are plotted using the probit scale, parallel straight lines are obtained throughout the range of low birth weight groupings. In this situation properties of two distributions may be compared in terms of the proportion of births of less than any given weight, and the figure of 2,501 g. has been chosen as a standard measure in the subsequent analysis.

Comparisons of birth weight distributions within the six conurbations of England and Wales for 1963–65 (Table II) reveal that the highest proportion of low birth weights are found in South-east Lancashire and the West Midlands. With the exception of Greater London, the incidence of low birth weights is shown to be consistently higher in the conurbations than in the remainder of the country.

TABLE II

BIRTH WEIGHT DISTRIBUTIONS IN TERMS OF STANDARD CONURBATIONS
Rate per 1,000 Live and Still Births below 2,501 g.

Conurbation	Year			
	1963	1964	1965	1963–65
1. No part	72·2	71·6	68·4	70·6
2. Some part	69·0	66·0	70·2	68·1
3. Tyneside	88·6	84·5	86·4	86·5
4. West Yorkshire	84·9	79·7	86·1	83·5
5. South-East Lancashire ..	91·6	84·9	92·5	89·6
6. Merseyside	83·9	78·5	78·9	80·5
7. West Midlands	91·3	87·9	88·1	89·1
8. Greater London ..	81·0	75·5	72·1	75·9
England and Wales	74·5	71·9	71·7	72·7

The corresponding data for the county boroughs and other local authorities in each of the eleven standard regions of England and Wales are shown in Table III. There are wide variations between different regions and also between county boroughs and other local authorities in the same region. The differences between the more urban and more rural areas are most marked in the North and Midlands. By contrast, the data which cover the South-east of South Wales show no consistent difference between the two types of local authority.

For births of less than 2,501 g., the quantity

$$\frac{\text{(Rate per 1,000 births in Region)}}{\text{(Rate per 1,000 births for England and Wales)}} \times 100$$

is shown for the various regions at Fig. 2 (overleaf). For both the county boroughs and the other types of local authority, the proportion of low birth weights is greatest in the Northern, Midland, and South Wales regions. The region designated Wales II has one of the smallest incidences of low birth weights amongst any of the regions.

TABLE III

BIRTH WEIGHT DISTRIBUTIONS IN TERMS OF STANDARD REGIONS
Rate per 1,000 Live and Still Births below 2,501 g.

Region	Local Authority	1963	1964	1965	1963–65
1. Northern	Not C.B... ..	70·9	66·9	72·2	70·0
	C.B.	85·2	84·6	83·8	84·5
2. East and West Ridings	Not C.B... ..	74·9	69·8	67·7	70·8
	C.B.	82·0	78·2	81·3	80·5
3. North-Western	Not C.B... ..	74·0	71·7	69·3	71·7
	C.B.	87·2	81·8	85·3	84·8
4. North Midland	Not C.B... ..	68·3	65·6	62·8	65·6
	C.B.	81·5	81·3	81·2	81·3
5. Midland	Not C.B... ..	73·7	73·2	68·7	71·8
	C.B.	89·5	86·0	87·3	87·6
6. Eastern	Not C.B... ..	65·5	63·4	60·6	63·3
	C.B.	76·9	72·0	73·8	74·2
7. London and South-Eastern ..	Not C.B... ..	64·8	62·5	56·9	62·5
	C.B.	84·3	78·3	71·6	76·7
8. Southern	Not C.B... ..	63·7	65·3	63·3	64·1
	C.B.	77·4	72·5	79·2	76·3
9. South-Western	Not C.B... ..	67·6	67·4	67·6	67·5
	C.B.	73·7	75·3	79·8	76·3
10. Wales I (South-East)	Not C.B... ..	80·1	82·0	77·7	79·9
	C.B.	79·7	81·1	81·5	80·8
11. Wales II (Remainder)	Not C.B... ..	62·4	64·4	61·6	62·8
	C.B.	—	—	—	—
England and Wales	Not C.B... ..	68·9	67·2	65·8	67·4
	C.B.	84·0	80·1	78·9	80·9

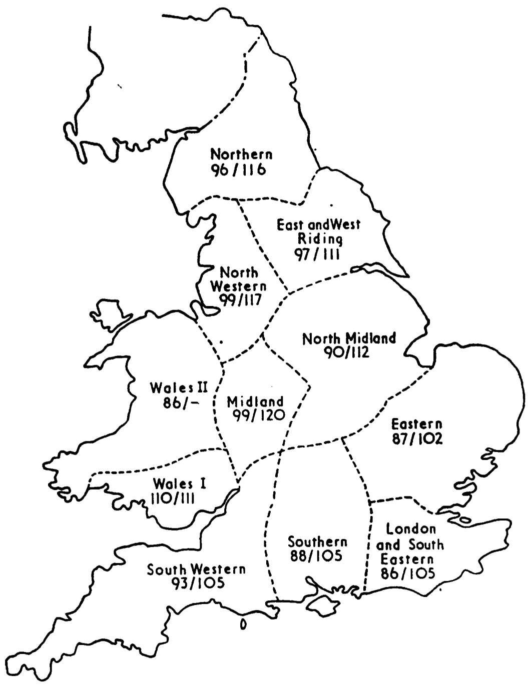

FIG. 2.—Distribution of all births less than 2,501 g., England and Wales, 1963–65.
(*Note:* Second figure on this and other maps is that for county boroughs, and first figure that for other local authorities.)

Perinatal Mortality

The United States data and the United Kingdom National Birthday Trust data illustrate the relationship between birth weights and perinatal mortality over the whole range of birth weights (Fig. 3). The use of a probit scale demonstrates that there is a linear relationship between mortality and birth weight below 2,251 g. Above this weight, the mortality continues to decline, although much less steeply, reaching a minimum between 3,501–4,000 g. It then rises slightly again in the heaviest birth weight groups. Fig. 3 also includes the perinatal mortality for infants below 2,501 g. for England and Wales, 1963–65. The results show a lower mortality than that found by Butler and Bonham (1958), but confirm the linear relationship between birth weight and mortality in the lower birth weight groups.

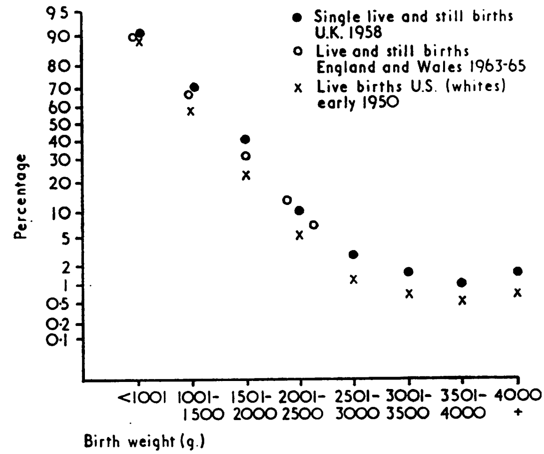

FIG. 3.—Perinatal mortality, by birth weight, in U.S. and U.K.

Table IV shows that the perinatal mortality in each of the low birth weight groups is lower in the county boroughs than in the remainder of England and Wales. By contrast, the perinatal mortality above 2,500 g. is greater in the county boroughs. The overall effect is of a substantially higher mortality in the county boroughs despite their advantage in the low birth weight groups. Within the standard conurbations of England and Wales, the overall perinatal mortality is substantially higher than in the remainder of the country (Table V, opposite).

Greater London retains its exceptional character in that the perinatal mortality remains appreciably below the average in all weight groups, the advantage increasing as the birth weight diminishes.

TABLE IV

PERINATAL MORTALITY IN TERMS OF BIRTH WEIGHT
Rate per 1,000 Live and Still Births in England and Wales, 1963–65

Population	Weight Group (g.)							
	<1001	1001–1500	1501–2000	2001–2250	2251–2500	<2501	Over 2500	All
County Boroughs	870	638	292	120	61	223	12·7	29·8
Remainder	917	668	312	127	69	235	11·9	26·9
Total	895	655	303	124	66	230	12·2	28·0

TABLE V

PERINATAL MORTALITY IN TERMS OF STANDARD CONURBATIONS
Rate per 1,000 Live and Still Births, 1963–65

Conurbation	Weight Group (g.)							
	<1001	1001–1500	1501–2000	2001–2250	2251–2500	<2501	Over 2500	All
1. No part	904	660	302	124	65	229	12·1	27·4
2. Some part	929	672	318	130	73	243	12·0	27·7
3. Tyneside	938	675	276	132	71	240	12·3	32·0
4. West Yorkshire ..	923	627	329	128	69	238	12·5	31·3
5. South-East Lancashire	929	679	343	137	64	254	14·2	35·6
6. Merseyside	914	646	313	149	63	229	14·2	31·5
7. West Midlands ..	931	651	283	106	54	213	13·1	30·9
8. Greater London ..	791	608	273	106	58	207	11·8	26·6
England and Wales ..	895	655	303	124	66	230	12·2	28·0

The regional differences in relative perinatal mortality, the numbers quoted being

$$\frac{\text{(Rate per 1,000 births in Region)}}{\text{(Rate per 1,000 births in England and Wales)}} \times 100$$

(Fig. 4 and Table VI, overleaf), show a variation similar to that already illustrated for birth weight distribution (Fig. 2), in that perinatal mortality tends to be lower in the South and East and higher in the North and Midlands. If the results for infants of birth weights below 2,501 g. are considered separately (Fig. 5), the differences are greatly reduced and the previously consistent differences in mortality between county and non-county boroughs are much less apparent. The mortality in the North and in South Wales still remains perceptibly higher than in the remainder of the country. For

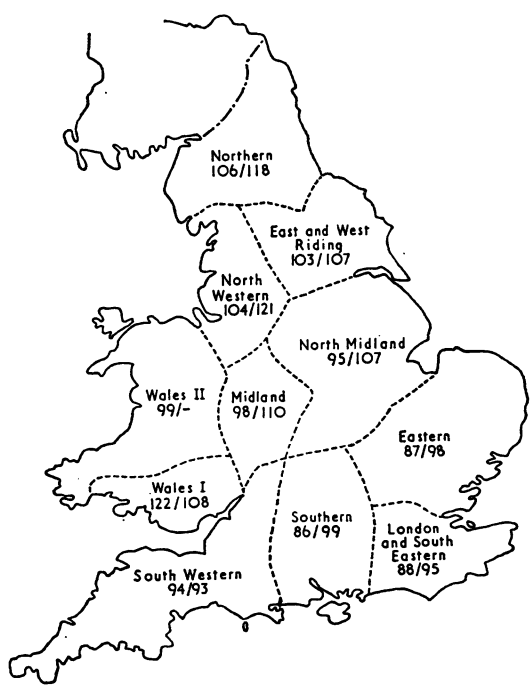

FIG. 4.—Perinatal mortality, all birth weights, England and Wales, 1963–65.

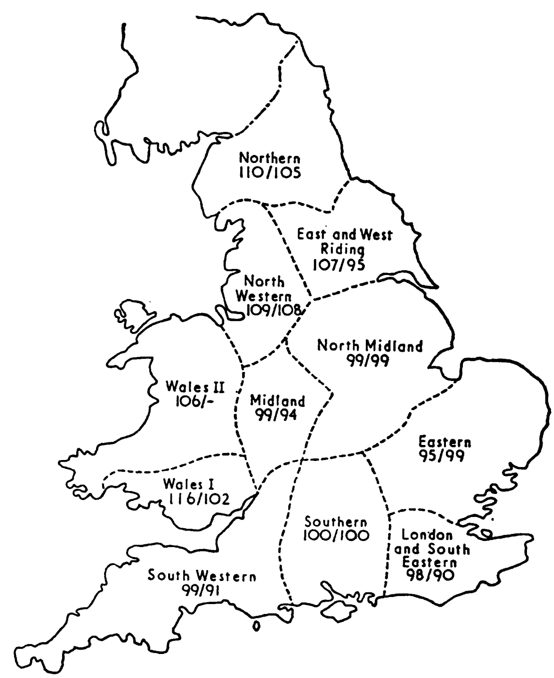

FIG. 5.—Perinatal mortality, birth weights less than 2,501 g., England and Wales, 1963–65.

TABLE VI

PERINATAL MORTALITY IN TERMS OF STANDARD REGIONS
Rate per 1,000 Live and Still Births, England and Wales, 1963–65

Region	Local Authority	Weight Group (g.)							
		< 1001	1001–1500	1501–2000	2001–2250	2251–2500	<2501	Over 2500	All
1. Northern	Not C.B.	918	690	322	133	73	253	13·0	29·7
	C.B. ..	932	659	294	132	65	241	13·7	33·0
2. East and West Ridings	Not C.B...	934	700	318	140	78	247	12·4	29·0
	C.B. ..	918	616	295	112	62	218	13·7	30·1
3. North-Western.. ..	Not C.B...	955	691	335	138	70	250	12·2	29·2
	C.B. ..	921	680	331	145	67	248	14·1	33·9
4. North Midland.. ..	Not C.B...	911	669	308	124	55	228	12·3	26·5
	C.B. ..	938	655	269	131	61	228	12·4	30·0
5. Midland	Not C.B...	942	664	307	129	62	227	12·0	27·5
	C.B. ..	944	653	290	113	57	216	13·0	30·8
6. Eastern	Not C.B...	906	646	285	124	67	219	11·1	24·3
	C.B. ..	887	659	292	101	62	227	11·5	27·5
7. London and .. .. South-Eastern	Not C.B...	889	634	301	114	71	225	11·4	24·8
	C.B. ..	770	603	270	105	58	206	11·8	26·6
8. Southern	Not C.B...	904	649	304	125	69	230	9·9	24·1
	C.B. ..	900	637	294	117	62	229	11·2	27·8
9. South-Western ..	Not C.B...	904	659	316	120	70	227	11·9	26·4
	C.B. ..	941	621	258	123	58	210	11·0	26·2
10. Wales I (South-East) ..	Not C.B...	900	716	348	129	85	266	14·0	34·2
	C.B. ..	713	572	303	124	62	234	12·2	30·2
11. Wales II (Remainder)	Not C.B...	937	706	315	140	65	244	13·4	27·8
	C.B. ..	—	—	—	—	—	—	—	—
England and Wales	Not C.B...	917	668	312	127	69	235	11·9	26·9
	C.B. ..	870	638	292	120	61	223	12·7	29·8

infants weighing above 2,500 g., the relative perinatal rates show similar changes (Fig. 6, opposite). Where the proportion of low birth weights is low, the survival rate of infants with birth weights above 2,500 g. is consistently high. In order to compare perinatal mortality rates which take into account the differences in birth weight distributions in the various regions, the following theoretical calculation was made. For county boroughs and other local authorities in each region, the actual number of infant deaths in each weight group was expressed as a percentage of the expected number, calculated on the assumption that the average level of perinatal mortality in England and Wales in each birth weight group applies to the particular region in each successive year. Fig. 7 (opposite) shows the considerable theoretical reduction in the differences between the regions and between the county and non-county boroughs. A persistent, although small, difference between the South and the North and North-west remains. This calculation is subject to the disadvantage that it is based on data which are available only in birth weight groups. A more satisfactory form of standardization would be obtained if the data were available as a continuous tabulation of birth weight and mortality throughout the entire range of birth weights rather than as discrete groups below 2,501 g. and as a single group above 2,500 g. Alternatively, a mathematical adjustment which takes due account of the shape of the distribution of birth weights would provide a practical alternative.

DISCUSSION

The main objective of this study of the L.H.S. 27/1 returns was to assess the significance of birth weight in determining the levels of perinatal mortality in England and Wales. In the event it was found that the chance of survival is very closely related to birth weight. Thus the knowledge of birth weight distribution is of fundamental importance in infant mortality studies.

On general grounds it might be anticipated that the majority of births would correspond to a normal pattern of foetal growth and a normal gestation period and would collectively form the primary component of the birth weight distribution. A minority of pregnancies might:

(*a*) end in a curtailed period of gestation without retardation of foetal growth (Lubchenco,

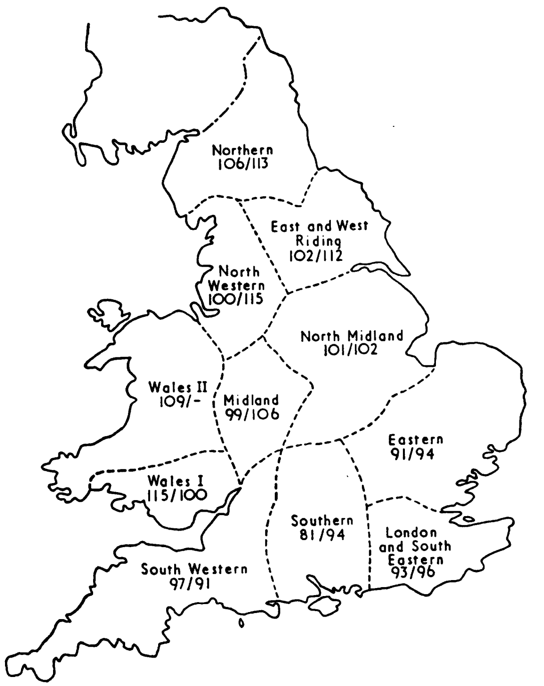

FIG. 6.—Perinatal mortality, birth weights more than 2,500 g., England and Wales, 1963–65.

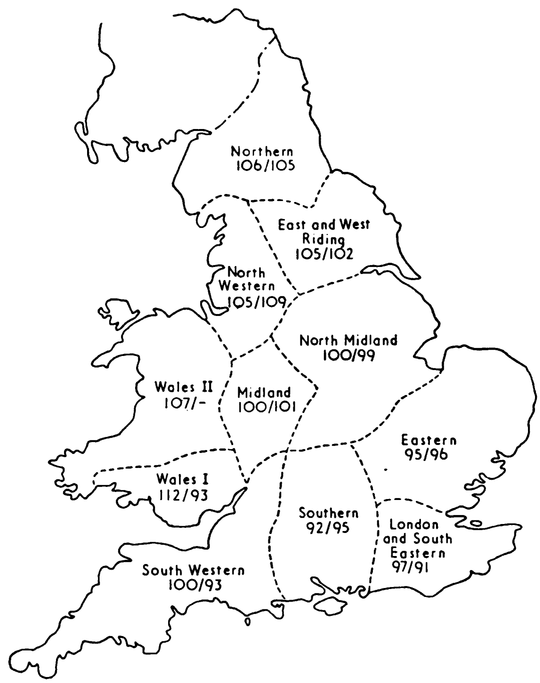

FIG. 7.—Relative perinatal mortality standardized for birth weight distribution, England and Wales, 1963–65.

Hansman, Dressler, and Boyd, 1963; Gruenwald, 1964);

(*b*) be complicated by a retardation of foetal growth without a curtailment of gestation;

(*c*) be complicated by a retardation of foetal growth with a curtailment of gestation.

The primary component is certainly present in the data, but our analysis can only suggest the existence of a single secondary component of the birth weight distribution which accounts for some 3 to 4 per cent. of all births. This secondary component also follows a Gaussian distribution which is clearly distinct from the Gaussian distribution forming the primary component. A similar result also holds for both white and non-white births in the United States.

The distribution of multiple births in relation to the primary and secondary components of the birth weight distribution could not be assessed on the basis of the L.H.S. 27/1 data, since no distinction is made between single and multiple births. However, the existence of two separate components in the National Birthday Trust data for single births, which are present in about the same proportions as in the L.H.S. 27/1 data, rules out the possibility that any substantial part of the secondary component may be attributed to multiple births. More information about gestational age is required before an assessment can be made of the biological significance of the secondary Gaussian component. Unfortunately, such data as are at present available about gestational age in relation to birth weight in large populations are of doubtful accuracy. The United States study provides what is possibly the most reliable body of information of this kind. These results point to the fact that the secondary component corresponds to the births which are of short gestation as well as of low weight. On the other hand, there is increasing evidence that an appreciable proportion of infants of low birth weight are small for reasons other than, or additional to, true premature births (Gruenwald, 1965; Neligan, 1965; Dawkins, 1965). Genetic factors, inhibition of foetal growth, and congenital malformation are among the explanations advanced, but the full reasons are not yet apparent. An accurate assessment of the gestational age of individual infants of low birth weight will greatly assist in future research programmes (Neligan, 1965; Mitchell and Farr, 1965; Koenigsberger, 1966; Usher, McLean, and Scott, 1966; Naeye and Kelly, 1966; Farr, Kerridge, and Mitchell, 1966a; Farr, Mitchell, Neligan, and Parkin, 1966b). By accurate gestational identification coupled with other information, it should be possible to isolate most of the individuals comprising the secondary Gaussian distribution of low birth weights and to investigate their particular biological characteristics.

The analysis has shown that there are consistent differences in the distribution of birth weights between the more urban and the more rural areas, between different regions and between different conurbations in England and Wales. In order to describe these differences in precise quantitative terms as a supplement to the somewhat crude indices based upon the cumulative distribution used in the present study the development of suitable mathematical techniques is required. Ashford and others (1967b) have described a method of estimating the parameters of the primary and secondary components and the proportion of each present in the population. This method will be applied to the available data.

The causes of the consistently higher proportion of infants of low birth weight in the more urban populations and in the Northern, Midland, and South Wales regions are at present unexplained. Economic and social conditions and standards of medical care may be implicated. Ethnic differences may also be involved, although a similar pattern of variation between rural and urban areas was found in the United States when the analysis was restricted to white infants.

The analysis has also shown the considerable extent to which variations in perinatal mortality are associated with the distribution of low birth weight in the community. For any given year, the linear relation between the probit of mortality rate and birth weight in the smaller infants is consistent with the pattern observed in many types of biological assay. It is highly significant that the corresponding response lines are all parallel and are shifted progressively to the left with each successive year between 1963 and 1965. This indicates that, when due account is taken of differences in birth weight, there has been a general improvement in mortality experience which has not been concentrated in any particular part of the range of low birth weights. Mathematical techniques have been developed (Ashford, Fryer, and Pethybridge, 1967a) to determine the mortality-birth weight relation in quantitative terms, and these will be applied to the available data. Only when this has been done will it be possible to compare the mortality experience of infants of low birth weight in different populations and at different times in precise numerical terms.

This present analysis has confirmed the basic regional variations in perinatal mortality as between the Southern regions on the one hand and the Northern and Midland regions of England on the other found by Bonham and Butler (1963), although with some small but important changes. Even when account is taken of birth weight, the small residual differences between the North and South remain unexplained, although some of the causes may prove to be the same as those which give rise to the consistent variations between urban and rural populations throughout England and Wales and the United States. This suggestion is based on the supposition that the population of the Northern and Midland regions of England is more urban in character than the population of the Southern and Eastern regions.

The inferences to be drawn from the present study are limited by the character of the available data. The results described above are based upon summaries of the basic returns, in terms of the type and location of local authorities. There are, however, substantial variations between individual local authorities of the same type situated within the same general area. It is proposed to examine these individual results in conjunction with social and economic data derived from census returns together with other data in order to further examine possible sources of variation such as social class, maternal height and possibly, standards of medical care. Furthermore, the L.H.S. 27/1 data are subdivided by place of birth, and studies are also being made of this factor. Nevertheless, the limitation of dealing with grouped data for a whole local authority is an obvious disadvantage when many of the factors which affect perinatal and neonatal mortality vary widely within the same local authority. For this reason a record linkage exercise is being carried out in association with the General Register Office and the Health Departments of certain local authorities to match individual birth notifications which provide the basic material for the L.H.S. 27/1 returns for a large population of births in the South-West of England. At the same time, detailed studies of gestational age in terms of the physiological development of the child and a reliable obstetric history of the mother are being undertaken in one of the main maternity hospitals in Exeter.

SUMMARY

In England and Wales about 7 per cent. of all infants weigh less than 2,501 g. at birth, but this small proportion of the total birth weight distribution gives rise to about 65 per cent. of the total

perinatal mortality. The present statistical analysis suggests that a separate Gaussian distribution of infants of low birth weight is found within the total birth weight distribution of England and Wales and of the U.S.A. Within England and Wales, the incidence of low birth weights varies significantly between the Southern regions on the one hand and the Northern, Midland, and South Wales regions on the other. Equally wide variations occur between the urban and more rural areas. It is found that variations in perinatal mortality rates in different areas of England and Wales are highly correlated with variations in the distribution of low birth weight.

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