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BIRTHWEIGHT, GESTATION, NEONATAL MORTALITY AND CHILD DEVELOPMENT

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THE precise relationships between birthweight, gestation length and perinatal mortality have been well established by a number of large-scale studies (e.g. Butler and Alberman, 1969, Susser *et al.*, 1972 and Hoffman *et al.*, 1974). These studies have shown a decreasing mortality with increasing birthweight up to 3500–4000 grams followed by a small increase in mortality with higher birthweights, and a decreasing mortality with increasing gestation length up to about 40 completed weeks followed by an increase in mortality. The associations of birthweight and gestation with subsequent child development have not been studied so extensively however, and there are few studies with samples large enough to provide precise estimates. Record *et al.* (1969) with a sample of over 40,000 children found an increase in verbal reasoning test scores at 11 years with increasing birthweight, and an increase in score with increasing gestation up to about 40 weeks followed by a decrease.

The first part of the present paper gives some new results on the relationship between birthweight, gestation and some aspects of development up to the age of eleven. The second part, which is a reworking of material from the Perinatal Mortality Survey (Butler and Alberman, 1969), presents population standards for neonatal mortality by birthweight and gestation in a new format.

Measurements and Method

It seems useful to divide perinatal variables into two groups. One group contains those, such as birthweight and gestation length, which are measured at the time of birth. The other group contains variables such as parity, parental height and social class which persist unchanged, or nearly so, during the child's development. It is the interpretations of the observed relationships and their practical implications which tend to differ for these two groups. The variables in the first group are limited to a well defined stage of development and their effects can be modified more easily. In the second group, the variables exist as a background to development and may affect it at any stage; as a consequence they are related not only to birthweight and gestation but also possibly to development after birth. Account must be taken therefore, of these background variables, because they may "explain" some or all of any observed associations between birthweight, gestation and subsequent development. It is mainly for this purpose that they are included in the analyses below. The data form part of the National Child Development Study (N.C.D.S.) which is a longitudinal survey conducted by the National Children's Bureau, following up the survivors of the 17,000 births in one week of March 1958, which were studied by the Perinatal Mortality Survey. At the ages of seven and eleven years social, educational and health data were collected by questioning the mothers and teachers and by school medical officers who examined the children. A detailed account of the study can be found in Davie *et al.* (1972).

Three "outcomes" measuring aspects of mental and physical development at the age of 11 years were selected. These were the height of the child, the score on a reading comprehension test and the assessed need for special schooling. The height was measured during the medical examination in school by different untrained measurers. A study carried out on the height measurements made in the same way at the age of seven, indicated that any bias which this might introduce was negligible. No precise estimate of reliability is available, but the interobserver correlation is unlikely to be less than 0·9. The reading test was a group test which had been developed by the National Foundation for Educational Research to parallel the Watts-Vernon test (Ministry of Education, 1957) and to be completed in a shorter time. An estimate of the average change in score with age was available and all the raw test scores have been divided by this estimate and adjusted to give a mean of 11 years, so that average differences can be expressed in terms of age equivalent changes. A child "in need of special schooling" was defined as one who was either receiving special schooling or was felt by his or her class teacher in a normal school to be in need of special schooling.

Birthweight, Gestation and Subsequent Development

7-year Results

When the children in the NCDS were seven years old, Davie *et al.* (1972) found a relationship between birthweight and gestation length on the one hand with reading and height measurements on the other. Birthweight was used in a regression analysis as a continuous variable, so that only average linear changes in the seven-year variables with birthweight could be estimated. Nevertheless, it was found that an increase of 1000 gm of birthweight was associated with about a 4 month increase in reading score and a 2 cm increase in height. Length of gestation was categorized into three groups; up to 37 completed weeks, 38 to 42 weeks and over 42 weeks. The "worst" readers were in the short gestation category, about 3 months behind the "best" readers in the middle gestation category. A corresponding difference of about 1 cm was found for height. Both these differences became negligible however, when allowance was made for birthweight; a point which will be dealt with more fully below.

11-year Results

The present analyses use 9 gestation groupings and 6 birthweight groupings as shown in Table 1.

This table presents the results of analyses of variance using reading score as the dependent variable, relating it to birthweight and gestation both separately and in combination. For birthweight the difference in reading age between the two extreme groups, namely weights under 2000 gm and those of 4000 gm or over, is about 1·2 years of reading age. This is about 0·4 standard deviations which compares with 0·6 standard deviations of verbal reasoning test score found by Record *et al.* An increase in test score with increasing birthweight is shown by both Record *et al.* (1964) and by the present data. For gestation, those children born before 35 completed weeks have an average reading age about 1·0 years

TABLE 1. Analysis of eleven year reading score, birthweight and gestation (For singleton births only)

Ordinary least squares-analysis of variance

Dependent variable is 11-year reading comprehension score measured in years of reading age

A. *Independent variables are birthweight and length of gestation.*

Dependent variable mean = 11·00
Total variance = 7·91
Sample size = 9430

Fitted constants and analysis of variance table. Main effects model
(χ^2 values are adjusted for the other factor)

Source		*Fitted constant*	*D.F.*	χ^2
Constant		10·67		
	≤1999	−0·43		
	−2499	−0·54		
	−2999	−0·13		
Birthweight	−3499	0·16	5	66·8***
(gm)	−3999	0·37		
	≥4000	0·57		
	≤34	−0·20		
	35	−0·23		
Gestation	36	−0·24		
(completed weeks)	37	0·19		
	38	0·18	9	28·4***
	39	0·32		
	40	0·12		
	41	0·24		
	42	−0·05		
	≥43	−0·33		

Residual mean square = 7·83
Test interaction; $\chi^2 = 49{\cdot}5$ D.F. = 43

(Two cells of the birthweight × gestation table contain no observations)

N.B. Values of the χ^2 distribution rather than the F distribution are used for simplicity since the residual degrees of freedom are large.

Significance levels *** $0{\cdot}001 > p$
** $0{\cdot}01 > p > 0{\cdot}001$
* $0{\cdot}05 > p > 0{\cdot}01$
otherwise $p > 0{\cdot}05$

TABLE 1 (continued)

B. *Independent variable is birthweight*

Fitted constants and analysis of variance table

Source		*Fitted constant*	*D.F.*	χ^2
Constant		10·77		
	⩽1999	−0·63		
	−2499	−0·55		
Birthweight (gm)	−2999	−0·07	5	80·8***
	−3499	0·22		
	−3999	0·43		
	⩾4000	0·60		

C. *Independent variable is gestation*

Fitted constants and analysis of variance table

Source		*Fitted constant*	*D.F.*	χ^2
Constant		10·73		
	⩽34	−0·58		
	35	−0·47		
	36	−0·38		
Gestation	37	0·15		
(completed weeks)	38	0·19	9	42·2***
	39	0·42		
	40	0·27		
	41	0·41		
	42	0·15		
	⩾43	−0·16		

lower than those born at 39–41 weeks. This is about 0·3 standard deviations and is the same as that found by Record *et al.* Those children born after 42 weeks have an average reading age about 0·5 years below those born at 39–41 weeks.

When birthweight and gestation length are analysed jointly, there is a similar picture. For any given birthweight however, the gestation group differences in reading score are smaller than before, the difference between the very early and the "term" babies being about half what it was when birthweight was not allowed for. The absence of an interaction effect between birthweight and gestation in this analysis implies that the differences between gestation groups are the same for all birthweights and likewise that the difference between birthweight groups are the same for all gestation lengths.

TABLE 2. Analysis of eleven year height, birthweight and gestation.
(For singleton births only)

Ordinary least squares-analysis of variance
Dependent variable is 11-year height measurement in cm.

A. *Independent variables are birthweight and length of gestation.*

Dependent variable mean = 144·5
Total variance = 53·52
Sample size = 9353

Fitted constant and analysis of variance table. Main effects model.
(χ^2 values are adjusted for the other factor)

Source		*Fitted constant*	*D.F.*	χ^2
Constant		143·7		
	≤1999	−2·7		
	−2499	−2·7		
	−2999	−1·2		
Birthweight	−3499	0·6	5	446·8***
(gm)	−3999	2·2		
	≥4000	3·9		
	≤34	0·9		
	35	0·1		
	36	0·1		
Gestation	37	0·3		
(completed weeks)	38	0·2	9	23·2**
	39	0·3		
	40	−0·2		
	41	0·0		
	42	−0·9		
	≥43	0·8		

Residual mean square = 51·09
Test interaction; $\chi^2 = 50{\cdot}5$ D.F. = 42
(Three cells of the birthweight × gestation table contain no observations)

B. *Independent variable is birthweight*

Fitted constants and analysis of variance table

Source		*Fitted constant*	*D.F.*	χ^2
Constant		143·7		
	≤1999	−2·2		
	−2499	−2·6		
	−2999	−1·3	5	455·3***
Birthweight	−3499	0·5		
(gm)	−3999	2·1		
	≥4000	3·5		

TABLE 2. (continued)

C. *Independent variable is gestation*

Fitted constants and analysis of variance table

Source		*Fitted constant*	*D.F.*	χ^2
Constant		144·0		
	≤34	−1·2		
	35	−1·0		
	36	−0·8		
Gestation	37	−0·1	9	30·3***
(completed weeks)	38	0·2		
	39	0·8		
	40	0·6		
	41	1·0		
	42	0·3		
	≥43	0·2		

Table 2 shows the relationship of 11-year height to birthweight and gestation length. Below 2500 gm there is no decrease in mean height with decreasing birthweight, but above this there is an increase in height with increasing birthweight. The difference in height between babies with birthweights under 2500 gm and those with birthweights of 4000 gm and over, is about 6 cm. For gestation, the pattern is similar to that found with reading, the tallest children being those born at term.

When birthweight and gestation are analysed jointly, there is an absence of interaction and the relationship of height with birthweight for given gestation is little altered. However the relationship of height with gestation shows a quite different pattern. For a given birthweight the earlier gestations are not associated with smaller children. This may be a reflection of the fact that, for a given birth-weight, a pre-term child is relatively heavier in relation to all babies with the same gestation, than a full-term baby, which presumably reflects a faster inter-uterine growth rate.

Further analyses of these data have been carried out which make allowance for social class, sex, maternal age, maternal height and the number of younger and older children in the child's family or household. The latter variable roughly corresponds to parity, which gives very similar results if used in the analysis. By including older and younger children separately we obtain a breakdown of family size into two mathematically unrelated variables (see Goldstein, 1971 for a further discussion of this point).

Tables 3 and 4 show the results of the joint analysis of these variables, and Figs. 1 and 2 present these results in diagrammatic form. Each "bar" in the figures represents the difference between the categories shown for fixed sets of values of the other variables.

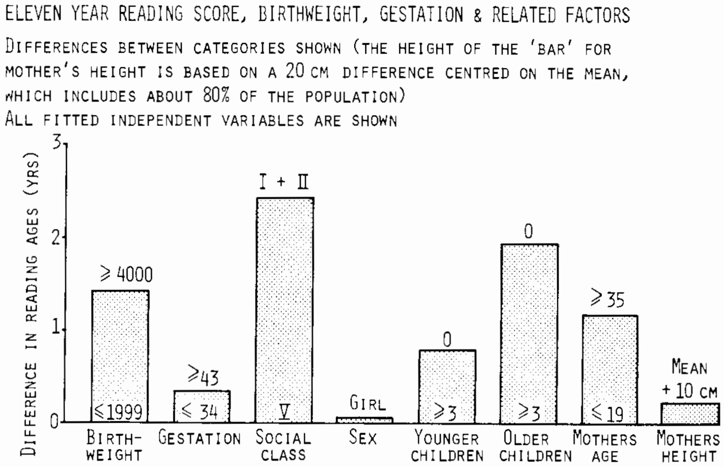

FIG. 1

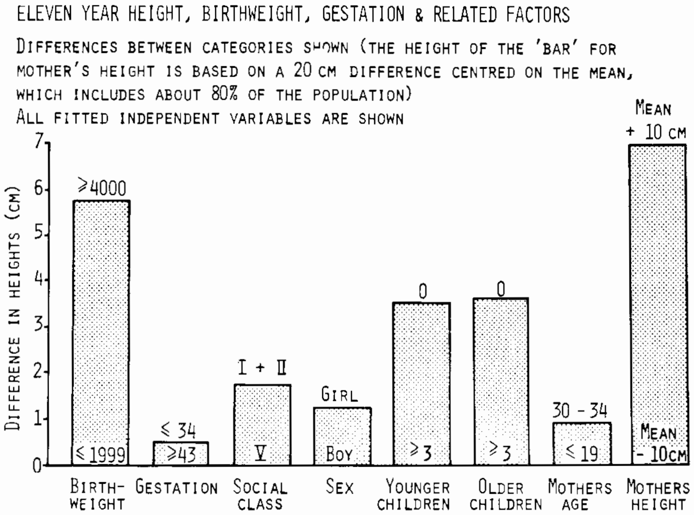

FIG. 2

TABLE 3. Analysis of eleven year reading score, birthweight, gestation and related factors
(For singleton births only)

Dependent variable is 11-year reading comprehension score measured in years of reading age.

A. *Independent variables as categorised below are:*

Birthweight
Length of Gestation
Social class of father when child was 11 years
Sex of child
Number of younger children in household+family at 11 years
Number of older children in household+family at 11 years
Mother's age at birth of child
Mother's height (continuous variable measured about mean=161·3 cm)

Dependent variable mean=11·00
Total variance=7·91
Sample size=9430

Fitted constants and analysis of variance table. Main effects model
(χ^2 values are adjusted for the other factor)

Source		*Fitted constant*	*Standard error*	*D.F.*	χ^2
Constant		10·01			
	≤1999	−0·83			
	−2499	−0·38			
Birthweight	−2999	−0·03			
(gm)	−3499	0·20		5	64·8***
	−3999	0·43			
	≥4000	0·61			
	≤34	−0·26			
	35	−0·08			
	36	−0·07			
Gestation	37	0·18			
(completed weeks)	38	0·08		9	12·6
	39	0·18			
	40	0·01			
	41	0·13			
	42	−0·90			
	≥43	−0·08			
	I & II	1·29			
	III Non Man.	0·82			
11-year	III Man	−0·32		4	883·6***
Social class	IV	−0·65			
	V	−1·14			
Sex	Boy-Girl	−0·05	0·05	1	0·8

TABLE 3. (continued)

Source		*Fitted constant*	*Standard error*	*D.F.*	χ^2
	0	0·37			
No. of younger	1	0·11			
children	2	−0·05		3	76·4***
	⩾3	−0·43			
	0	0·98			
No. of older	1	0·24		3	425·4***
children	2	−0·24			
	⩾3	−0·98			
	⩽19	−0·74			
	−24	−0·29			
Mother's age	−29	0·18			
at birth	−34	0·39		4	118·1***
	⩾35	0·46			
Mother's height (Measured about mean=161·3cm)		0·011	0·004	1	6·2**

Residual mean square=6·52

B. *Independent variables as above except for gestation*

Fitted constants and analysis of variance table for birthweight

Source		*Fitted constant*	*D.F.*	χ^2
	⩽1999	−1·00		
	−2499	−0·36		
Birthweight	−2999	0·02	5	78·2***
(gm)	−3499	0·25		
	−3999	0·47		
	⩾4000	0·62		

C. *Independent variables as above except for birthweight*

Fitted constants and analysis of variance table for gestation

Source		*Fitted constant*	*D.F.*	χ^2
	⩽34	−0·74		
	35	−0·28		
	36	−0·18		
Gestation	37	0·16		
(completed weeks)	38	0·10	9	26·0**
	39	0·28		
	40	0·15		
	41	0·30		
	42	0·11		
	⩾43	0·10		

TABLE 4. Analysis of eleven-year height, birthweight, gestation and related factors
(For singleton births only)
Dependent variable is 11-year height measurement

A. *Independent variables are as in Table 3A*

Dependent variable mean = 144·5 cm.
Total variance = 53·52
Sample size = 9353

Fitted constants and analysis of variance table. Main effects model
(χ^2 values are adjusted for the other factors)

Source		*Fitted constant*	*Standard error*	*D.F.*	χ^2
Constant		141·9			
Birthweight (gm)	⩽1999	−2·7			
	−2499	−2·0			
	−2999	−0·9			
	−3499	0·5		5	323·1***
	−3999	2·0			
	⩾4000	3·1			
Gestation (completed weeks)	⩽34	0·0			
	35	0·3			
	36	0·5			
	37	0·4			
	38	0·3		9	23·8**
	39	0·2			
	40	−0·3			
	41	−0·1			
	42	−0·8			
	⩾43	−0·5			
11-year Social class	I & II	0·8			
	III Non Man.	0·5			
	III Man.	0·0		4	52·5***
	IV	−0·4			
	V	−0·9			
Sex	Boy–Girl	−1·2	0·1	1	75·2***
No. of younger children	0	1·1			
	1	0·5		3	110·8***
	2	−0·2			
	⩾3	−2·4			
No. of older children	0	1·7			
	1	0·5			
	2	−0·3		3	188·7***
	⩾3	−1·9			
Mother's age at birth	⩽19	−0·4			
	−24	−0·2			
	−29	0·2		4	14·1**
	−34	0·5			
	⩾35	−0·1			

TABLE 4. (continued)

Mother's height (Measured about mean=161·3 cm)	0·35	0·01	1	986·0***

Residual mean square=43·26

B. *Independent variables as in Table 3B*

Fitted constants and analysis of variance table for birthweight

Source		*Fitted constant*	*D.F.*	χ^2
	≤1999	−2·6		
	−2499	−1·8		
Birthweight	−2999	−0·9	5	311·2***
(gm)	−3499	0·5		
	−3999	1·9		
	≥4000	2·9		

C. *Independent variables as in Table 3C*

Fitted constants and analysis of variance table for gestation

Source		*Fitted constant*	*D.F.*	χ^2
	≤34	−1·9		
	35	−0·6		
	36	−0·3		
Gestation	37	0·1		
	38	0·3	9	22·2**
	39	0·6		
	40	0·4		
	41	0·7		
	42	0·2		
	≥43	0·5		

In the case of reading, allowance for the additional factors makes little difference to the fitted constants for birthweight and gestation. The difference in reading age between the lightest and heaviest birthweight groups is about the same as the difference between the groups of oldest and youngest mothers, is about half the difference between social classes I and II and social class V, is somewhat larger than the difference between children with three or more and those with no younger children, and is somewhat smaller than the corresponding difference for numbers of older children. Both length of gestation and sex have small effects which are non-significant and the effect for maternal height, although formally significant at the 5 per cent level, is likewise small.

In the case of height, the birthweight difference is of the same order as the maternal height effect, and much larger than the social class difference, and also larger than the separate differences for older and younger children. The gestation effect, although now significant at the 1 per cent level, is small.

The analyses so far have considered only averages of the 11-year measurements. Often however, interest lies in predicting or accounting for the children who belong to an extreme group, for example those who have an educational handicap. Whilst an average difference in a test score will generally be associated with a difference in the proportion falling into an extreme group, it may be more useful to attempt to study a complex phenomenon such as educational handicap, by directly identifying the children in the group.

Table 5 shows that there is a marked birthweight trend in the proportion of children in need of special schooling. It is five times as high in those with birthweights under 2000 gm as in those with birthweights of 3000 gm or over. There is also a small increase in the proportion in need of special schooling for short and long gestations. When birthweight and gestation are analysed jointly, the pattern is unchanged. The total number of children in need of special schooling is too small to permit further analyses which allow for related background factors.

Birthweight, Gestation and Mortality

Figures 3 and 4 show the well-known relationship between birthweight, gestation and neonatal mortality. Less is known however, about the way mortality varies when birthweight and gestation are considered together. Susser *et al.* (1972), however, give crude perinatal rates for seven birthweight groups down to about 30 weeks of gestation and Hoffman *et al.* (1974) present detailed estimates of foetal death rates for an even wider range of birthweights and gestations. The purpose of the present analysis is to present the birthweight, gestation, mortality relationship in an easily useable form with special application to the identification of "high risk" newborns. It uses data from the Perinatal Mortality Survey which sampled 16,625 singleton livebirths, 4675 singleton late foetal deaths and 3059 singleton neonatal deaths (all the livebirths in one week of March 1958, and all the late foetal and neonatal deaths in March, April and May 1958).

TABLE 5. Analysis of need for special schooling at 11 years, birthweight and length of gestation
(For singleton births only)

Dependent variable is proportion of children considered by teacher in need of special schooling at eleven, or receiving it (see table 6 for description of statistical model)

Independent variables are birthweight and length of gestation

Sample size = 8993

Fitted constants and analysis of variance table: (main effects logit model)
(χ^2 values are adjusted for the other factors)

Source		*Fitted constant*	*D.F.*	χ^2
Constant		−1·31		
	⩽1999	0·54		
	−2499	0·23		
	−2999	−0·06	5	26·5***
Birthweight	−3499	−0·20		
(gm)	−3999	−0·27		
	⩾4000	−0·24		
	35	0·04		
	36	0·17		
	37	−0·01		
	38	−0·13		
Gestation	39	−0·09	8	9·3
(completed weeks)	40	−0·02		
	41	−0·11		
	42	0·05		
	⩾43	0·10		
Test quadratic trend, given linear trend:			1	3·8*
Test linear trend:			1	1·0

Test for 'goodness of fit' of model $\chi^2 = 28{\cdot}9$ D. F. = 39.

Test differences between lengths of gestation, fitting gestation only; $\chi^2 = 14{\cdot}8$ D.F. = 8

Test quadratic trend, given linear trend: $\chi^2 = 9{\cdot}7$ *D.F.* = 1**

Test linear trend: $\chi^2 = 1{\cdot}2$ D. F. = 1

Test differences between birthweight groups, fitting birthweight only; $\chi^2 = 32{\cdot}1$ D.F. = 5***

Observed percentages in need of special schooling

Length of gestation

35	*36*	*37*	*38*	*39*	*40*	*41*	*42*	*43+*	*Total*
8·1	9·0	6·0	4·2	4·0	4·4	3·5	4·9	5·8	4·5

Birthweight

⩽1999	*−2499*	*−2999*	*−3499*	*−3999*	*⩾4000*	*Total*
20·0	9·5	5·3	4·0	3·7	4·0	4·5

NEONATAL MORTALITY RATE BY BIRTHWEIGHT
(1958 PERINATAL MORTALITY SURVEY)
MEAN RATE = 100 LOG SCALE

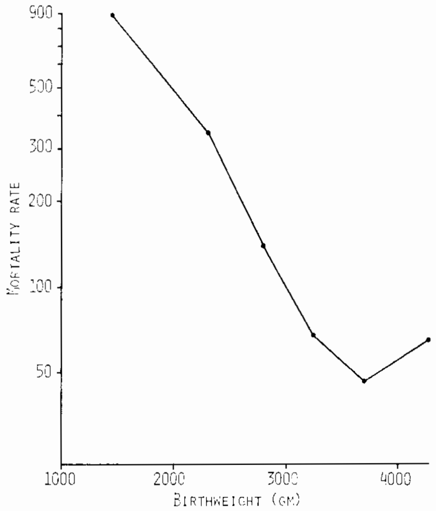

FIG. 3

NEONATAL MORTALITY RATE BY GESTATION
(1958 PERINATAL MORTALITY SURVEY)
MEAN RATE = 100 LOG SCALE

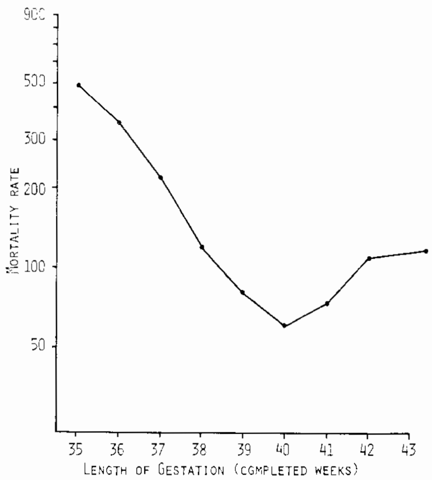

FIG. 4

Table 6 shows an analysis of variance with neonatal death rate as dependent variable and birthweight and gestation length as independent variables (the category ⩽34 weeks was excluded because of small numbers). A "main effect" model with 14 parameters is used to estimate mortality rates for the 54 combinations of birthweight and gestation, and the "non-significant" test for goodness of fit indicates that this model provides an adequate summary of the data.

TABLE 6. Analysis of neonatal death rate, birthweight and length of gestation (For singleton births only)

The analysis uses the logit model

$$\tfrac{1}{2}\log\left(\frac{P_i}{1-P_i}\right)=\alpha+\beta_{ij}$$

Where the proportion P_i is the proportion of deaths in the ith birthweight-gestation group and β_{ij} are constants fitted to categories of birthweight and gestation. A 'main effects' model is used with the categories shown in the table below.
The observed value of each P_i is the ratio of all neonatal deaths in the 'main week' cohort plus those in the 3-month sample of deaths, to this number plus the livebirths in the 'main week' cohort. In order to convert the P_i to estimated mortality rates per 1000 livebirths, a multiplying factor of 0·118 is used.

(Overall survey, neonatal death rate = 14·9 per 1000)

Sample size = 15886

Fitted constants and analysis of variance table: Main effects model
(χ^2 values are adjusted for the other factor)

Source		*Fitted constant*	*D.F.*	χ^2
Constant		−0·81		
Birthweight (gm)	⩽1999	1·28		
	−2499	0·40		
	−2999	−0·09		
	−3499	−0·45	5	703·9***
	−3999	0·64		
	⩾4000	−0·50		
Gestation (completed weeks)	35	0·34		
	36	0·22		
	37	0·11		
	38	−0·12		
	39	−0·23	8	125·9***
	40	−0·29		
	41	−0·18		
	42	−0·07		
	⩾43	0·42		

Test for 'goodness of fit' of model $\chi^2=51{\cdot}6$ D.F. = 40

These "smoothed" estimates of neonatal mortality rates can be displayed graphically as follows. For selected mortality rates, for example the mean or twice the mean mortality, interpolation between the estimated rates will give the corresponding birthweights and gestations. If these points are joined up, "contours" are obtained as in Fig. 5. The contour 100 signifies the mean mortality rate, 50 signifies mortality at half the mean rate, 200 at twice the mean rate. For any given birthweight and gestation, a live newborn can be directly assigned to a mortality region. For example, a 4000 gm baby born at 40 weeks falls within the 50 contour line, and has an estimated neonatal mortality risk less than half the mean.

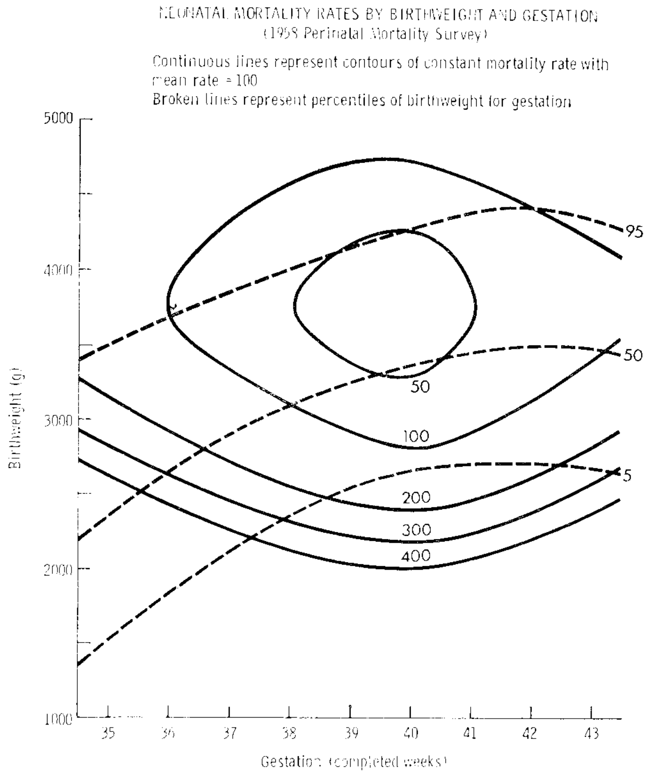

FIG. 5

About 6 per cent of all livebirths lie beyond the 200 contour. From Fig. 5 it is clear that only some of the babies below the 6th percentile are also below the 200 contour. In fact only about one-third of those below the 200 contour line also lie below the 6th percentile. For the purpose of assessing neonatal mortality risk therefore, the use of birthweight-for-gestation percentiles is inefficient, and especially for short gestation lengths will lead to some high risk babies being classified as "normal". In fact it would be more appropriate to use birthweight alone as an estimator of mortality risk. For example, the widely used criterion of under 2500 gm selects about 7 per cent of livebirths, and about 90 per cent of these also fall below the 200 contour line.

Figure 6 shows a very similar pattern for late foetal plus neonatal mortality.

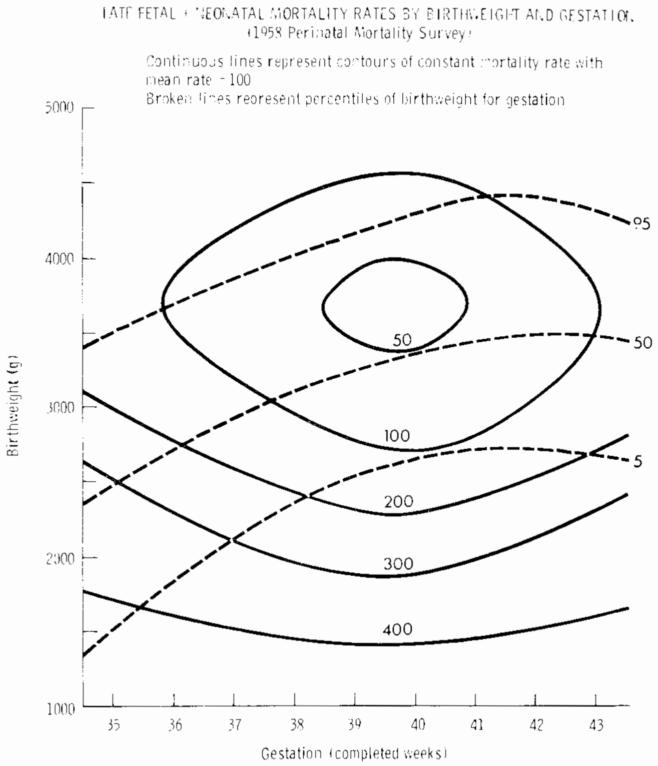

FIG. 6

The accurate estimation of mortality rates requires samples containing large numbers of deaths. The standard errors of the estimated neonatal mortality rates in the above analyses have been calculated, and show that the estimates are reasonably accurate. For example, at 39 weeks of gestation and 2000–2499 gm of birthweight the estimated neonatal mortality is 2·8 times the mean, with an approximate 95 per cent confidence interval extending from 2·4 to 3·3 times the mean. Apart from the two extreme gestation groups, the width of this interval (for this estimated mortality rate) is nearly constant over the range of birthweights and gestations.

TABLE 7. Analysis of late fetal plus neonatal death rate, birthweight and length of gestation
(For singleton births only)

Model as for table 6, but with dependent variable the proportion of late foetal plus neonatal deaths.

To convert observed P_i to estimated rate per 1000 a multiplying factor 0·116 is used. (Overall survey, late foetal plus neonatal death rate=34·9 per 1000)

Sample size=18192

Fitted constants and analysis of variance table: Main effects model
(χ^2 values are adjusted for the other factor)

Source		*Fitted constant*	*D.F.*	χ^2
Constant		−0·23		
	≤1999	1·44		
	−2499	0·34		
	−2999	−0·20	5	1813·3***
Birthweight	−3499	−0·54		
(gm)	−3999	−0·63		
	≥4000	−0·41		
	35	0·40		
	36	0·15		
	37	0·10		
Gestation	38	−0·13		
(completed weeks)	39	−0·28	8	330·0***
	40	−0·29		
	41	−0·20		
	42	0·03		
	43+	0·22		

Test for 'goodness of fit' of model χ^2=49·0 D. F. =40

Discussion

Birthweight is more closely associated with neonatal and late fetal mortality and with height, reading comprehension and need for special schooling at the age of eleven, than is gestation.

The analyses show that if birthweight and gestation are used to assess the risk of neonatal death or to predict physical and mental development, to the extent that these are measured by height, reading and the need for special education, then the simple use of birthweight for gestation percentiles is inappropriate. It is certainly true that at a given gestation an increase in mortality rate and "poor development" at 11 years is associated with a decrease in birthweight below the median. However, the mortality which corresponds to a given birthweight percentile increases as the length of gestation moves away from 40 completed weeks. For the purpose of predicting neonatal mortality the clinical use of a chart based on Fig. 5, perhaps with different colourings for the different mortality regions, would be preferable to the simple use of birthweight for gestation percentiles*. These data therefore, fully confirm the points made by Thomson and Billewicz (1975) during the discussion of this problem in their own paper in this volume (pp. 69–79).

For the purpose of estimating subsequent mental development, gestation length has little predictive value as compared with birthweight and with background variables such as social class, family size and maternal age. Similarly, gestation has little value in predicting physical development when compared with birthweight, maternal height and family size.

One difficulty in using the results of these analyses is that they are based on births in 1958. Since then the mortality rate has fallen considerably with alterations in the distributions of birthweight and gestation and changes in obstetric practice. It is not known how this may have changed the pattern shown in Figs. 5 and 6, and it would be useful to have more up-to-date information for Britain as well as from other countries. The mortality contours presented by Hoffman *et al.* (1974), although for foetal deaths only, do show a reasonably similar pattern to the present data. They also indicate that between about 30 and 35 weeks of gestation the higher mortality contours become nearly parallel to the gestation axis.

Finally, it should be pointed out that birthweight and gestation, although the most important, are not the only pregnancy variables which are related to outcome. Smoking in pregnancy has already

* See page 80. A colour chart is available from the authors, at The National Children's Bureau, 8 Wakley Street, Islington, London EC1V 7QE.

been extensively studied (Butler, Goldstein and Ross, 1972; Butler and Goldstein, 1973). Butler and Alberman (1969) studied many others in relation to the immediate outcome of pregnancy, and the NCDS is currently analysing their association with later outcomes.

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Summary

The paper examines the association between birthweight, gestation and 11-year old mental and physical status. Data from the National Child Development Study show a weak association for gestation and a somewhat stronger one for birthweight, after allowance is made for associated social and biological factors.

The use of birthweight for gestation standards in the neonatal period is discussed, and it is suggested that the widely used "birthweight for length of gestation" standards are misleading. New standards are presented which classify babies directly in terms of the risk of neonatal mortality.

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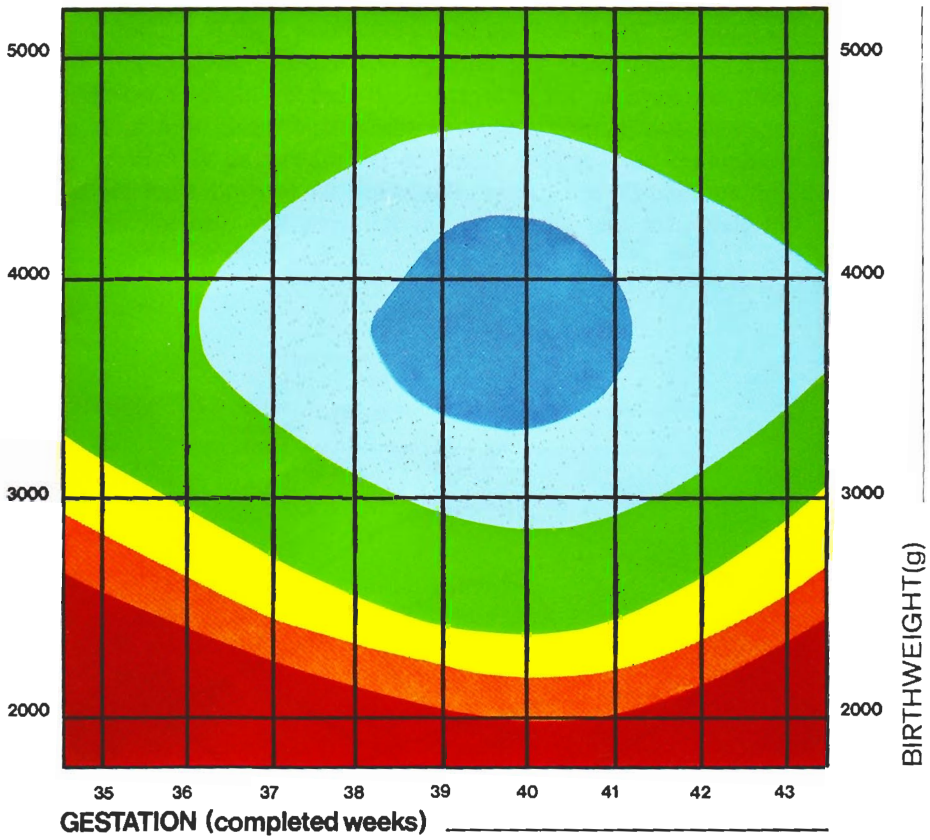
Chart for predicting neonatal mortality of livebirths



To find the neonatal mortality risk for a liveborn baby select the vertical line corresponding to the gestation length and move up to the measured birthweight. Then refer to colour key. 100 is average.

Based on data from the British Perinatal Mortality Survey (1958)