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ANALYSIS OF FACTORS AFFECTING PERINATAL MORTALITY
A MULTIVARIATE STATISTICAL APPROACH

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Despite important progress during recent decades, perinatal mortality is still a problem of major national importance. Today nearly 3 per cent. of all births result in perinatal death. To reduce this loss requires a better understanding of the way in which a large number of inter-related social and medical factors influence perinatal mortality risk.

We are developing a series of studies to separate and examine the effects of these factors. For this purpose we shall employ a method of multivariate statistical analysis. The present paper discusses this method and illustrates it by analysing the effects of maternal age, parity, and social class. (Our social class categories are based on husband's occupation, according to the classification of the Registrar General (General Register Office, 1951)).

The data used in these analyses was provided by the Perinatal Mortality Survey (Butler and Bonham, 1963). During one week in March, 1958, the Survey directed by Dr Neville Butler obtained information on 16,994 single births, some 98 per cent. of all births during the week. Perinatal deaths (defined to include the 4-week neonatal period) of babies born during March, April, and May were also recorded. The 7,119 survey deaths represent an estimated 94 per cent. of all deaths during this period.

The first section of this paper presents the crude effects on perinatal mortality of maternal age, parity, and social class. The interdependence among these three factors is assessed in the second section. We then discuss the inadequacy of studying the crude effects and explain the methods of "adjusted deviations". The crude effects of each factor and the effects which remain after eliminating the influences of the associated factors are compared. A final section indicates other studies currently in progress.

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Crude Effects of Maternal Age, Parity, and Social Class

Various writers have shown that perinatal mortality rates differ substantially by age group, parity, and social class (Daly, Heady, and Morris, 1955; Heady, Daly and Morris, 1955; Heady, Stevens, Daly, and Morris, 1955; Morris and Heady, 1955a, b; Heady and Heasman, 1959). This was further confirmed by the Perinatal Mortality Survey. Table I presents the crude effects of age, parity, and social class. Each effect is expressed as a percentage deviation from the average perinatal mortality rate of 33·58 perinatal deaths per 1,000 single births. Thus, for example, mothers of less than 20 years of age showed a crude mortality rate of 35·88 per 1,000 births, or 6·86 per

TABLE I

CRUDE EFFECTS OF AGE, PARITY, AND SOCIAL CLASS ON PERINATAL MORTALITY
UNADJUSTED PERCENTAGE DEVIATIONS§

Factor (1)	Subclass (2)	No. of Cases‡ (3)	Percentage Deviation§ (4)	Standard Error (5)
Age	<20	978	+6·86	16·63
	20–	4,929	−13·44	6·44
	25–	5,451	−14·19	5·97
	30–	3,422	+6·56	8·20
	35–	1,754	+36·31	12·13
	40+	449	+104·22	24·96
	Not known	11	+360·11	161·53
Parity‖	0	6,284	+6·12	5·32
	1	5,215	−25·89	6·10
	2 and 3	3,977	+3·61	7·39
	4+	1,516	+53·77	13·03
	Not known	2	+346·53	378·97
Social Class	I and II	2,817	−22·85	9·23
	III	9,736	−4·50	3·55
	IV	1,954	+7·72	11·41
	V	1,576	+28·08	12·86
	No husband	490	+39·75	23·87
	Not known	421	+69·72	25·81

‡ Number of births in survey population.
§ Percentage deviation from mean perinatal mortality rate of 33·58 per 1,000 births.
‖ First birth is parity 0.

cent. above the average. This is indicated in column 4. Estimated standard errors are given in column 5.*

Effects Adjusted for Interdependence of Maternal Age, Parity, and Social Class

If we wish to assess the specific effects of age, parity, and social class, the analysis of Table I is insufficient. The perinatal mortality rate of young mothers, for example, reflects not only age but also the proportion of women who are having their first child, as well as their distribution by social class. The existence of more than one factor influencing perinatal mortality does not in itself create a problem. The difficulty arises because these factors do not occur independently of each other (as factors might in an experiment). Age and parity are highly correlated with each other; older mothers generally, but not always, being of higher parity than younger ones. Similarly, the age groups and parities differ in social class composition.

The substantial interdependence of age, parity, and social class raises a number of questions. Are the high crude perinatal mortality rates of women under 20 really due to age or do they reflect the parity and social class distributions of these mothers? Is the high risk of the para 4+ women anything more than a reflection of high age and low social class? And is the social class gradient in perinatal mortality risk caused by the distribution among social classes of high-risk age and parity mothers?

To answer these questions we might try to look at more detailed information showing perinatal mortality rates by age-parity or age-parity-social class combinations. Doing so, however, has three disadvantages. First, it is difficult for the eye and mind to abstract and assimilate this much data. If the breakdowns which we have used were employed, an age-parity Table would require 35 separate rates while an age-parity-social class Table would require 210. The second problem arises from the small numbers of births and deaths that would be assigned to many of the combinations. The estimated rates for these combinations would be subject to very large sampling error and would be of little value. The third problem results from these first two. Although detailed breakdowns would be possible for two or three factors, the problems of interpretation and sample size would rapidly become worse as additional factors were added. The problem of small numbers for individual combinations would also be an important drawback in the use of an index number method of calculating standardized rates (Daly and others, 1955; Benjamin, 1959).

* Appendix I discusses the interpretation of these estimated standard errors.

A multivariate statistical method (described briefly in Appendix II and in Feldstein, 1965a), has been developed to replace the crude values of Table I with rates that are adjusted for the effects of the other factors. The adjusted values are estimates of the perinatal mortality rates that would be expected to prevail if the factors that have been "adjusted out" had no effect. Two examples will help to clarify this. The perinatal mortality rate of women under 20 was shown in Table I to be 6·86 per cent. above average. This reflects in part the fact that this group contains a high proportion of primiparae and of mothers of lower social class. If we eliminate the effects of parity and social class, we find that women under 20 actually enjoyed a perinatal mortality rate of 11·76 per cent. below average. As a second example we may consider women of para 4+. Although the crude perinatal mortality rate of these women is 53·77 per cent. above average, this again is partly due to the risk introduced by older age and lower social class. When adjusted for these factors the para 4+ mother has a risk of only 24·16 per cent. above average.

Age

Table II presents the percentage deviations in perinatal mortality rates by maternal age with adjustments for parity and social class. Column (3) shows the unadjusted crude deviations as originally given in Table I. Columns (4) and (5) show the effects of age after separate adjustments for parity and social class. Simultaneous adjustment for both parity

TABLE II

ADJUSTED PERCENTAGE DEVIATIONS IN PERINATAL MORTALITY RATES, BY MATERNAL AGE†

Maternal Age (yrs)	No. of Cases	Adjustment			
		None	Parity	Social Class	Parity and Social Class
(1)	(2)	(3)	(4)	(5)	(6)
<20	978	+6·86 (16·63)	−·94 (17·19)	−3·03 (17·06)	−11·76 (17·54)
20–	4,929	−13·44 (6·44)	−13·36 (6·69)	−15·41 (6·64)	−16·43 (6·86)
25–	5,451	−14·19 (5·97)	−11·07 (6·05)	−12·38 (5·98)	− 9·61 (6·03)
30–	3,422	+6·56 (8·20)	+7·42 (8·41)	+8·79 (8·22)	+10·52 (8·55)
35–	1,754	+36·31 (12·13)	+31·69 (12·68)	+37·97 (12·06)	+35·53 (12·74)
40+	449	+104·22 (24·96)	+94·01 (25·59)	+103·13 (24·64)	+96·25 (25·34)
Not known	11	+360·11 (161·53)	+356·29 (161·47)	+309·05 (163·19)	+307·19 (163·14)

† Percentage deviations from mean perinatal mortality rate of 33·58 per 1,000 births.
Standard error indicated in parentheses.

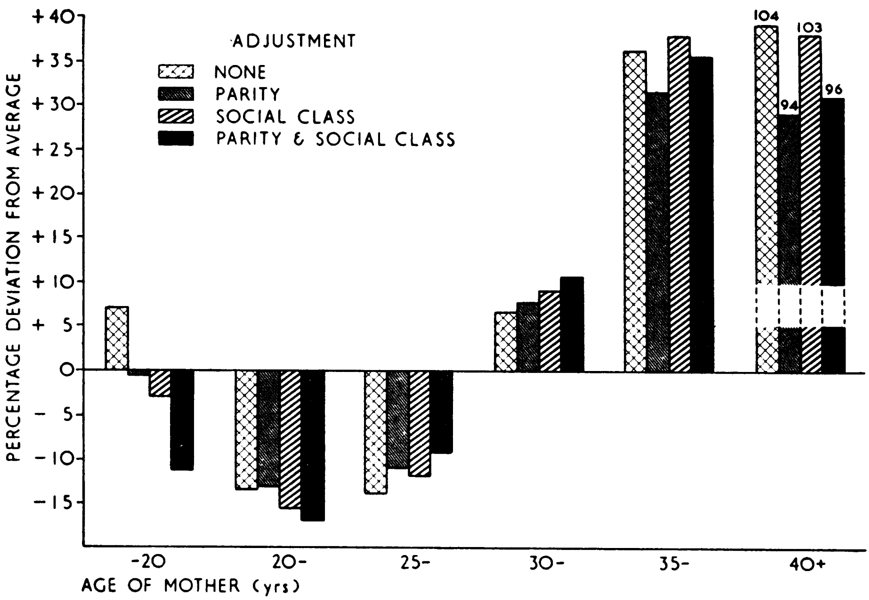

FIG. 1.—Effect of maternal age on perinatal mortality.

and social class reveals the age specific effects indicated in column (6). Estimated standard errors appear in parentheses. These results are also shown in Fig. 1.

As stated above, the effect of adjustment is most substantial for women less than 20 years old.

Parity and social class each make a separate contribution to the risk of this age group. The social class adjustment indicates that much of the observed high risk of these younger women reflects their social class. Adjusting for parity alone shows that the risk of women less than 20 is not different from average despite their unfavourable social class distribution. This way of separating the effect of age from that of parity and social class may be helpful in providing clues to the physiological nature of perinatal mortality risks and in indicating the directions in which preventive measures might be most usefully developed. The evidence is that, contrary to common observation, youth itself is an asset rather than a liability.

The risk of women aged 20–24 is also increased by their parity and social class distribution. After adjustment for these effects, we see that this is the least risky age group. In contrast, women aged 25–29 have a parity and social class composition which decreases the average risk. Instead of being the most favourable group, adjustment shows that these women run a greater risk than those aged less than 20. Similarly, women aged 30–34 have a social class-parity adjusted risk which is somewhat higher than the crude risk.

For women aged 40+ the effect of adjustment is slight. While parity is seen to contribute to the observed high risk, the social class-parity adjusted risk is still nearly twice the average.

PARITY

The adjusted effects of parity are presented in Table III and Fig. 2 (opposite). The crude deviation for

TABLE III

ADJUSTED PERCENTAGE DEVIATIONS IN PERINATAL MORTALITY RATES, BY PARITY*

Parity (1)	No. of Cases (2)	Adjustment: None (3)	Adjustment: Age (4)	Adjustment: Social Class (5)	Adjustment: Age and Social Class (6)
0	6,284	+6·12 (5·32)	+12·65 (6·13)	+6·05 (5·68)	+14·54 (6·28)
1	5,215	−25·89 (6·10)	−22·61 (6·08)	−24·47 (6·15)	−21·27 (6·13)
2 and 3	3,977	+3·61 (7·39)	−2·54 (7·52)	+3·46 (7·47)	−4·44 (7·39)
4+	1,516	+53·77 (13·03)	+31·55 (14·05)	+49·66 (12·82)	+24·16 (13·52)
Not known	2	+346·53 (378·97)	+344·84 (378·78)	+281·14 (379·73)	+292·62 (379·55)

* Percentage deviations from mean perinatal mortality rate of 33·58 per 1,000 births.
Standard error indicated in parentheses.

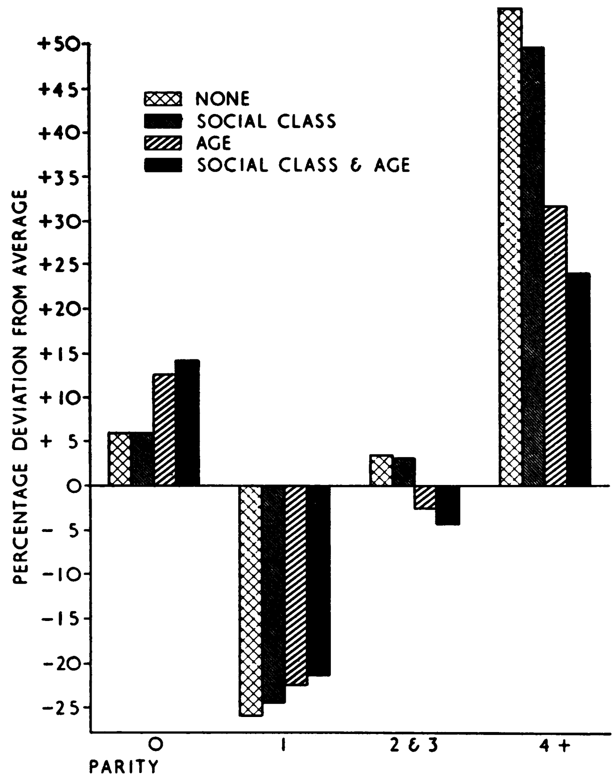

FIG. 2.—Effect of parity on perinatal mortality.

primiparae (+6·12 per cent.) underestimates the risk of having the first child; the age-social class adjusted value is +14·54 per cent., which primarily reflects their favourable age distribution. It is interesting to note that, although age and parity are strongly associated with each other, there is sufficient departure from complete association to permit the observation that the crude risk of young primiparae results from the increased risk of the first child and the decreased risk of youth. The risk of women of para 4+ is also substantially affected by age and parity; adjusting for these factors decreases the deviation from 53·77 to 24·16 per cent. above average. For each of the parity groups the effect of age distribution is more important than that of social class. Adjusting for social class alone has hardly any effect. When the interdependence between age and social class is taken into account, it is seen that the social class distribution does affect the crude parity-specific rates (compare columns (4) and (6) of Table III).

SOCIAL CLASS

The adjusted percentage deviations by social class, presented in Table IV and Fig. 3 (overleaf), show that the substantial interclass differences in crude perinatal mortality rates are not attenuated by adjustment for age and parity. In general, age adjustment increases the deviation of social class-specific rates from the average, while parity adjustment decreases it. Further studies are in progress to analyse these class differences by determining the types of perinatal death that are most affected by social class and by identifying other important factors associated with social class (*e.g.*, height, region of residence, occupation during pregnancy, type of obstetrical care).

FUTURE STUDIES

The method of multifactor "adjusted deviations" illustrated by this paper is being extended in many directions. With the use of electronic computers we can increase the number of factors considered simultaneously to ten or more. Information about forty factors believed to influence perinatal mortality has now been prepared for analysis. These can be related to perinatal deaths occurring at different times and from different

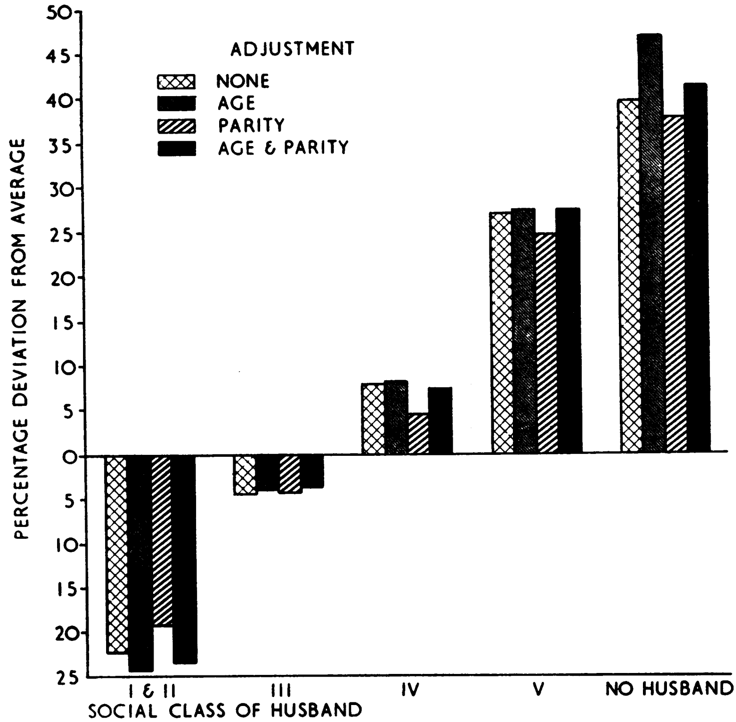

FIG. 3.—Effect of social class on perinatal mortality.

TABLE IV

ADJUSTED PERCENTAGE DEVIATIONS IN PERINATAL MORTALITY RATES, BY SOCIAL CLASS*

Social Class of Husband (1)	No. of Cases (2)	Adjustment			
		None (3)	Age (4)	Parity (5)	Age and Parity (6)
I and II	2,817	−22·85 (9·23)	−24·66 (9·29)	−19·28 (9·28)	−23·46 (9·42)
III	9,736	−4·50 (3·55)	−3·94 (3·58)	−4·10 (3·56)	−3·75 (3·58)
IV	1,954	+7·72 (11·41)	+7·84 (11·42)	+4·87 (11·40)	+7·15 (11·43)
V	1,576	+28·08 (12·86)	+28·54 (12·88)	+24·70 (12·87)	+28·36 (12·93)
No husband	490	+39·75 (23·87)	+46·57 (24·40)	+37·40 (24·12)	+41·07 (24·47)
Not known	421	+69·72 (25·81)	+58·64 (26·07)	+65·20 (25·87)	+56·44 (26·13)

* Percentage deviations from mean perinatal mortality rate of 33·58 per 1,000 births.
Standard error indicated in parentheses.

causes; for this purpose we have classified deaths into 45 different categories.

In addition to perinatal mortality we shall study the factors affecting such things as birthweight, gestation, toxaemias of pregnancy, and complications of delivery. The problems and risks of primiparae will receive separate analysis. Special studies will also be devoted to women delivered at home and those transferred to hospital during labour.

The available information includes details of the care received by mothers before and during delivery. The effects of care on maternal health and perinatal risk can therefore be studied. We shall also analyse the factors influencing the care that mothers receive.

A knowledge of the way in which various factors affect perinatal mortality can be used to assess the risk of individual cases. This method of evaluating perinatal mortality risk, illustrated with a model incorporating age, parity, and social class information, is described by Feldstein (1965b).

SUMMARY

A multivariate statistical method is described for assessing the factors which influence perinatal mortality, and it is applied to the analysis of the effects of maternal age, parity, and social class. The study uses data on 16,994 single births and 7,117 perinatal deaths collected by the Perinatal Mortality

Survey during a period in 1958. The interdependence of the three factors makes mortality rates for specific age groups, parities, and social classes of little value. The statistical adjustment process separates the specific effects of each factor from the others. Crude rates for age and parity sub-classes are shown to be misleading. In contrast, the social class gradient of crude perinatal mortality rates is not altered by adjusting for the effects of age and parity. The paper concludes with an outline of studies in progress.

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APPENDIX I

Interpretation of Estimated Standard Errors

Three approximations have been introduced in the calculation of the standard errors presented in this paper:

(1) We have assumed that the sample size refers to the relevant number of births during the survey week, and the observed number of deaths during the following months were scaled down accordingly. If we wished to interpret the results as a scaling up of the births from 1 week to 3 months, we should have to divide the standard errors by $\sqrt{13}$, *i.e.*, the new standard errors would be about one-fourth (28 per cent.) as large as those presented.

(2) Because of the multivariate method used to calculate the "adjusted" deviations presented in the subsequent Tables, it has been necessary to simplify the calculation of the standard errors by assuming that there is the same random variation within each sub-class (homoskedasticity). The importance of this will be greater in some sub-classes than others, particularly in those sub-classes whose rates depart substantially from the average.

(3) A further approximation is introduced by expressing deviations and their standard errors as percentages of the average. Since this average perinatal mortality rate is itself only an estimate, we introduce a further source of variation without specifically taking this into account. Nevertheless, because the average rate is estimated on the basis of the total sample of nearly 17,000 births, its standard error is quite small. To avoid this problem, all the results could be treated as absolute deviations from the average by multiplying the percentage deviation and their standard errors by ·3358.

APPENDIX II

CALCULATION OF ADJUSTED PERCENTAGE DEVIATIONS

The adjusted percentage deviations in perinatal mortality rates are derived from a multiple regression equation in which all variables are binary. The method of calculation is explained below.

For concreteness, consider the case in which we wish to estimate the effects of age adjusted for the effects of parity. Let age be divided into four groups, and parity into three groups. We may then express the relationship between perinatal mortality and the two effects as:

$$Y_t = \sum_{i=1}^{6} \alpha_i X_{it} + U_t \qquad t=1, 2, \ldots, T.$$

where

Y_t =1 if birth t results in a perinatal death
=0 if birth t does not result in a perinatal death.
X_{1t}=1 if mother is in age group I.
=0 if mother is not in age group I.
X_{2t}=1 if mother is in age group II.
=0 if mother is not in age group II.
X_{3t}=1 if mother is in age group III.
=0 if mother is not in age group III.
X_{4t}=1 if mother is in parity group 1.
=0 if mother is not in parity group 1.
X_{5t}=1 if mother is in parity group 2.
=0 if mother is not in parity group 2.
X_{6t}=1 for all t. (this is used in calculation of constant term α_6).
U_t is an unobservable stochastic error term.

The method of estimating the αs is discussed by Feldstein (1965a, b). We now take these estimates ($a_1 \ldots a_6$) as given and show how the adjusted percentage deviations in risk by age are derived.

The coefficients a_1, a_2, and a_3 are estimates of the effects of perinatal mortality risk of the mother being in age groups I, II, III after "eliminating" the effects of parity (the effect of being in the omitted age group IV is implicitly zero). To find the effect of being "average" with respect to age, we calculated the weighted mean of the three αs, weighting by the fraction of the total number of mothers in each age group; thus the age effect in the "average" age group is:

$$a^* = \frac{1}{N}(a_1 n_1 + a_2 n_2 + a_3 n_3),$$

where n_i is the number of women in age group i and N is the total number of women. Note that this definition of the effect of being "average" with respect to the factor being studied can be applied to qualitative factors such as geographical regions or past obstetric history. A woman who is average with respect to both parity and age would have an expected perinatal mortality rate of 33·58 per 1,000 births. By being in age group I but "average" with respect to parity, she increases her risk by $(a_1 - a^*)$; this may of course be negative. Expressed as a percentage of the mean risk the adjusted percentage deviation of women in age group I is:

$$\frac{a_1 - a^*}{33 \cdot 58} \times 100.$$

Since a^* is a weighted mean of the coefficients a, so is $(a_1 - a^*)$; we may therefore estimate the standard deviation of $(a_1 - a^*)$—and therefore approximately of the adjusted percentage deviation—from a knowledge of the variances and covariances of the coefficients a, statistics which can be derived in the process by which the αs are calculated. This method and other aspects of the calculation of the adjusted percentage deviation are discussed more fully elsewhere (Feldstein, 1965a, b).