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

II. BIRTH WEIGHT

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INTRODUCTION

There are already so many observations on birth weight in the literature that at first sight it seems doubtful whether much that is new can be added by inquiries which make use of existing records. Certainly for hospital births, the mean weight and its association with variables such as sex and race have been explored exhaustively. Nevertheless, there are several important issues upon which the data are by no means conclusive usually because:

- (i) observations are confined to hospital births whose representativeness is often in doubt;
- (ii) numbers of births examined are small;
- (iii) one or more of the relevant items (for example the duration of gestation) are unknown.

Among larger series are those of Pearson (1900; 1914), Zangemeister (1917), Bruce Murray (1924), Martin (1931), Anderson and others (1943), Karn (1947), and Hosemann (1948), all on hospital populations. Perhaps the most representative is that of Anderson and others, since it was assembled in a city (Cincinnati) in which there were few facilities for deliveries at home. Two recent inquiries (Douglas, 1950; Baumgartner and others, 1950) are not restricted to hospital births.

There is another reason why existing reports are less instructive than their number might suggest. Because birth weight can be recorded more reliably than the duration of gestation, and because it is probably as good as or better than any single alternative index, weight is now widely used to assess maturity. As an administrative device this practice has a good deal to commend it. But an enormous literature has accumulated on the subject of "premature" birth, in which the identification of weight with maturity is the source of considerable ambiguity, not to say confusion. We shall discuss this more fully in a later communication.

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ASPECTS STUDIED

We here use the information on Birmingham births from which we previously drew certain conclusions regarding the duration of gestation (Gibson and McKeown, 1950) to examine three issues.

(1) RELATION OF BIRTH WEIGHT TO DURATION OF GESTATION.—As there are few large-scale investigations of duration of gestation, it goes without saying that there are even fewer which give the additional information about weight (Zangemeister, 1917; Anderson and others, 1943; Karn, 1947; Hosemann, 1948). This subject has a dual interest: first, because observations at birth provide the only reliable indication of the rate of foetal growth; and second, because the use of weight as an index of maturity (referred to above) makes an accurate knowledge of the relation of birth weight to duration of gestation a matter of first importance.

(2) ASSOCIATION OF BIRTH WEIGHT WITH MATERNAL AGE AND PARITY.—Among investigators who have considered this subject are Duncan (1864), Ingerslev (1875), Griffith and Gittings (1907), Pearson (1914), Martin (1931), and Douglas (1950). Perhaps the most satisfactory observations are those of Martin, who concluded

there is no relation between the age of the mother and the weight of the child, although there is a small negative correlation for the first rank of birth.

Most writers have believed that weight increases with birth order, but it cannot be said that the effects of the two variables (age and parity) have as yet been satisfactorily separated.

(3) WEIGHT DISTRIBUTION OF HOSPITAL AND DOMICILIARY BIRTHS.—A comparison of weight distributions of hospital and domiciliary births is of no biological interest, and of little administrative interest in countries (such as Sweden and the United States) where a high proportion of all deliveries are conducted in hospitals. In Great Britain, however, the representativeness of hospital births, upon which most observations are based, is in doubt, and we therefore give separate weight distributions of hospital and domiciliary births. We have also considered to what extent the difference in mean weight of births from the two sources is explained by differences in duration of gestation and birth rank.

DATA AVAILABLE

We have previously listed sources from which information was obtained about births in Birmingham during 1947, and have commented on the difficulty of recording the duration of gestation (Gibson and McKeown, 1950). The proportion of births of known weight is shown in Table I, and is so high in all three places of birth (hospital, home, and nursing home) that we need only consider the accuracy (and not the representativeness) of the weights recorded.

TABLE I
PERCENTAGE OF 23,279 SINGLE BIRTHS FOR WHICH BIRTH WEIGHT WAS RECORDED

Hospital		Domiciliary		Nursing-Home		All Births		Total
Live born	Stillborn	Live born	Stillborn	Live born	Stillborn	Live born	Stillborn	
99·5 (9,408)	99·1 (332)	94·6 (11,160)	96·5 (164)	96·0 (1,441)	100·0 (22)	96·7 (22,009)	98·3 (518)	96·8 (22,527)

Balances in hospitals and nursing homes were tested, and no instrument exhibited an error greater than half an ounce. It is more difficult to speak with confidence about the accuracy of the portable spring balances used in domiciliary practice. These instruments

are graduated in quarter pounds, and are checked at intervals by the Weights and Measures Department. In general, the spring balances give a reading correct to the nearest quarter pound; errors as large as half a pound are rare, and errors of a pound almost unknown. These observations on instrumental errors give no indication of the care with which the balances are used, upon which we can express no opinion.

A few words of explanation are needed for our failure to convert weights to the metric system. We had no control over the original records which were in pounds and ounces. Weights given to the nearest ounce can readily be converted, but weights given to the nearest quarter-pound (as in the case of domiciliary births) cannot be converted to a corresponding unit on the metric system without some rounding of figures and loss of precision.

BIRTH WEIGHT RELATED TO DURATION OF GESTATION

Table II (opposite) gives weight distributions, and constants of the distributions, for 22,454 of the 22,527 births of known weight. Seventy-three births in which the duration of gestation was less than 28 weeks have been excluded, since stillbirths are not reported until the 29th week, and live births born earlier than that date are unrepresentative as regards weight. (When duration of gestation is short, heavier infants are more likely to be liveborn.) For births born after the end of the 28th week mean weights (lb.) are:

live births, 7.46 ± 0.008
 stillbirths, 5.83 ± 0.094
 total births, 7.43 ± 0.008 .

The distributions are not normal, being leptokurtic in the case of live births and total births, and platykurtic in the case of stillbirths. The distribution of total births is also slightly skew.

Before examining the relation of birth weight to duration of gestation we should consider the possible effect of errors in the estimates. We have, of course, no direct evidence of the incidence of errors, but unless they are both numerous and unevenly distributed, they are unlikely to alter seriously the means and constants of distributions of weight (as given above) or of duration of gestation (as reported previously). The situation is quite different when the two variables are taken together, and since errors are more likely in duration than in weight, our main problem is to assess the effect of mistakes in duration of gestation on mean weight at different weeks.

In weeks in the middle of the distribution, for which numbers are large, the erroneous inclusion of a few births from earlier or later weeks will have little effect on the mean weight. Even in the later weeks in which numbers are small, a few errors may not be serious unless they are very large indeed, since (as is shown below) mean weight does not change much after the 40th week. It is in the early weeks, in which numbers are small and weight is rapidly increasing, that the inclusion of a few heavy births from later weeks may profoundly alter the mean weight. (For example, an 8-lb. birth delivered at 40 weeks but recorded as 12 weeks before term, will have a considerable effect on the mean weight of the small number of births at 28 weeks.) Moreover, we may expect some errors of this kind, for it is well known that pre-marital conception (particularly of first births)

TABLE II
DISTRIBUTION OF LIVE BIRTHS, STILLBIRTHS, AND TOTAL BIRTHS BY BIRTH WEIGHT*

Birth Weight		Live Births		Stillbirths		Total Births	
Pounds	Half-Pounds	Number	Per cent.	Number	Per cent.	Number	Per cent.
1	2 3	2 8	0·05	2 11	2·53	4 19	0·10
2	4 5	26 30	0·26	23 30	10·30	49 60	0·49
3	6 7	43 60	0·47	25 29	10·50	68 89	0·70
4	8 9	139 195	1·52	31 28	11·48	170 223	1·74
5	10 11	538 946	6·76	42 31	14·20	580 977	6·93
6	12 13	2,062 3,042	23·26	45 38	16·14	2,107 3,080	23·09
7	14 15	4,294 3,580	35·88	64 37	19·65	4,358 3,617	35·52
8	16 17	3,316 1,654	22·65	34 14	9·33	3,350 1,668	22·35
9	18 19	1,112 435	7·05	15 3	3·50	1,127 438	6·97
10	20 21	324 80	1·83	7 2	1·75	331 82	1·83
11	22 23	37 11	0·22	2	0·39	39 11	0·22
12	24 25	3 1	0·02	1	0·19	4 1	0·02
13	26 27						
14	28 29	1	0·01			1	0·01
15	30 31						
16	32 33	1				1	
TOTALS		21,940	100	514	100	22,454	100
Mean		7·46		5·83		7·43	
Error of Mean		0·008		0·094		0·008	
Standard Deviation		1·20		2·14		1·25	
B ₁		0·044		0·002		0·166	
B ₂		4·46		2·352		4·83	

* Of 22,527 single births of known weight, 73 were excluded because the duration of gestation was less than 28 weeks.

is not uncommon, and provides the mother with a motive for post-dating the last menstrual period in order to reduce the apparent duration of gestation.

Inspection of the data showed that each of the early weeks included a few births whose weights suggested that they were misplaced (unless we assume gross errors in weighing or bimodal distributions of weight). It seemed advisable to remove such births from the distribution, and we decided to exclude the highest and lowest 1 per cent. of the values when births are distributed by duration of gestation within each pound of weight.*

Duration of gestation was recorded for 17,145 single births of known weight, of which 73 were born before the end of the 28th week. Table III shows that 323 of the remaining 17,072 births were excluded, and it will be noted that the constants of the distributions at each pound of weight are only slightly changed as a result. Subsequent examination of the relation of weight to duration of gestation is therefore based on 16,749 births.

TABLE III
EFFECT OF EXCLUSION OF HIGHEST AND LOWEST ONE PER CENT. OF THE DISTRIBUTIONS BY DURATION OF GESTATION WITHIN EACH POUND OF BIRTH WEIGHT*

Pounds	1	2	3	4	5	6	7	8	9	10 and over	Total
<i>(a) Constants of distributions before exclusion of highest and lowest one per cent.</i>											
No. of births ..	14	78	115	292	1,193	4,047	6,057	3,790	1,128	358	17,072
Mean (weeks) ..	31·71	32·09	34·29	36·20	38·29	39·44	39·86	40·24	40·43	40·52	39·65
Error of mean ..	0·58	0·42	0·34	0·17	0·07	0·03	0·02	0·03	0·06	0·11	0·02
Standard deviation ..	2·18	3·62	3·61	2·91	2·64	2·12	1·88	1·74	1·86	2·08	2·26
B ₁ ..	—	—	—	0·017	0·118	0·014	0·096	0·005	0·004	1·24	0·698
B ₂ ..	—	—	—	2·92	4·45	3·02	8·03	7·07	6·79	10·63	7·12
<i>(b) Constants of distributions after exclusion of highest and lowest one per cent.</i>											
No. of births ..	14	77	114	288	1,169	3,963	5,955	3,710	1,109	350	16,749
Mean (weeks) ..	31·71	31·93	34·17	36·21	38·28	39·47	39·90	40·27	40·44	40·56	39·67
Error of mean ..	0·58	0·40	0·32	0·16	0·07	0·03	0·02	0·02	0·05	0·09	0·02
Standard deviation ..	2·18	3·54	3·38	2·80	2·38	1·83	1·61	1·48	1·61	1·64	2·03
B ₁ ..	—	—	—	0·007	0·220	0·027	0·009	0·101	0·007	0·017	1·17
B ₂ ..	—	—	—	2·29	3·16	3·60	4·16	3·99	4·20	4·19	6·87

* The duration of gestation was unknown for 5,382 of the 22,527 births. Of the 17,145 births for which duration of gestation was known, 73 were excluded because the duration of gestation was less than 28 weeks.

Table IV gives the mean weight of births delivered in each week after the 28th; all births after the 46th week are among the 323 births eliminated. The Figure illustrates the change in mean weight of total births as gestation progresses, the lines

* An alternative considered was the exclusion of values more than a stated number of standard deviations from the mean. But since the distributions of births by duration of gestation are not identical at different weights this would have resulted in a different standard at each pound.

having been drawn to include all values of the mean within two standard errors of the mean weight at each week. The data are readily assimilated from Table IV (overleaf) and the Figure, and we need only draw attention to three points:

(1) Lines drawn through mean weights of live births or total births are S shaped. Growth is relatively slow between conception and the end of the 28th week, when mean weight is a little over 2½ lb. There is a sharp increase in weight after 29 completed weeks of gestation, and weight continues to increase until the 40th week, from which time the mean is almost constant.

(2) The distribution of weights within each week of duration of gestation is approximately normal (B_1 and B_2 have only been calculated for weeks with more than 200 births).

(3) A comparison of mean weights of the 16,749 births with means for all births (22,454) of known weight suggests that no serious error has been introduced in the totals. This does not, of course, insure that the births are representative of the individual weeks.

FIGURE.—Mean birth weight related to duration of gestation (see text for description of method).

BIRTH WEIGHT RELATED TO MATERNAL AGE AND PARITY

Records of maternal age and parity were complete for 19,414 births, or for 86.2 per cent. of births of known weight (Table V). In a few hundred additional cases, age only or parity only were known, but it seemed advisable to restrict the examination to births in which both variables were recorded. Since we are not here concerned with duration of gestation (which has previously been shown to be unaffected by age and parity) it has been considered possible to include some

births in which the length of pregnancy was unknown. This explains the difference in the totals of Tables IV and V.

TABLE IV
BIRTH WEIGHT RELATED TO DURATION OF GESTATION*

Duration of Gestation (weeks)	Live Births				Stillbirths				Total Births					
	Number of births	Mean w't (lb.)	Error of mean	S.D.	Number of births	Mean w't (lb.)	Error of mean	S.D.	Number of births	Mean w't (lb.)	Error of mean	S.D.	B ₁ †	B ₂ †
28	13	2.67	0.16	0.57	3	3.08	0.28	0.47	16	2.75	0.14	0.58	—	—
29	8	3.06	0.22	0.62	8	2.50	0.12	0.35	16	2.78	0.14	0.57	—	—
30	15	3.39	0.13	0.52	8	2.81	0.36	1.02	23	3.18	0.16	0.78	—	—
31	33	3.91	0.20	1.18	17	3.07	0.30	1.25	50	3.63	0.18	1.27	—	—
32	31	4.20	0.17	0.98	13	3.18	0.35	1.26	44	3.89	0.18	1.18	—	—
33	58	4.67	0.11	0.83	18	3.39	0.28	1.18	76	4.37	0.12	1.06	—	—
34	102	5.47	0.08	0.82	9	3.47	0.38	1.14	111	5.31	0.10	1.00	—	—
35	243	6.25	0.08	1.31	23	4.68	0.33	1.57	266	6.11	0.09	1.40	0.00	4.02
36	407	6.67	0.06	1.26	28	5.08	0.29	1.53	435	6.57	0.06	1.35	0.01	3.14
37	736	6.79	0.04	1.11	26	5.90	0.39	1.99	762	6.76	0.04	1.19	0.03	3.91
38	1,440	7.09	0.03	1.08	45	6.20	0.22	1.45	1,485	7.06	0.03	1.17	0.02	3.69
39	3,343	7.40	0.02	1.05	51	6.45	0.21	1.52	3,394	7.38	0.02	1.09	0.00	3.63
40	4,725	7.63	0.01	1.04	59	7.31	0.22	1.72	4,784	7.61	0.01	1.07	0.05	4.61
41	2,988	7.77	0.02	1.06	31	7.26	0.32	1.78	3,019	7.76	0.02	1.10	0.03	3.53
42	1,386	7.83	0.03	1.13	37	7.11	0.23	1.40	1,423	7.81	0.03	1.17	0.03	3.41
43	486	7.83	0.05	1.18	11	8.06	0.48	1.61	497	7.83	0.05	1.22	0.50	4.46
44	225	7.81	0.07	1.03	6	7.66	0.45	1.10	231	7.80	0.07	1.08	0.07	3.35
45	108	7.91	0.09	1.03	4	7.25	—	—	112	7.88	0.10	1.00	—	—
46	5	—	—	—	—	—	—	—	5	—	—	—	—	—
All Births of known Duration of Gestation	16,352	7.45	0.009	1.19	397	5.88	0.108	2.17	16,749	7.42	0.009	1.23	0.10	4.78
All Births known Weight	21,940	7.46	0.008	1.20	514	5.83	0.094	2.14	22,454	7.43	0.008	1.25	0.17	4.83

* Of 17,145 births for which duration of gestation and birth weight were known, 73 were excluded because the duration of gestation was less than 28 weeks, and 323 as indicated in Table III.

† B₁ and B₂ have been calculated in weeks with more than 200 births.

TABLE V
NUMBER OF BIRTHS OF KNOWN WEIGHT FOR WHICH MATERNAL AGE AND PARITY WERE RECORDED

Data Available							Total Births	
							Number.	Per cent.
Maternal age and parity	..	..	..	..	..	..	19,414	86.2
Maternal age only	..	..	..	..	..	..	185	0.9
Parity only	..	..	..	..	..	..	687	3.0
Neither	..	..	..	..	..	..	2,241	9.9
Total	..	..	..	..	..	..	22,527	100.0

The relation between weight and age is considered first in Table VI, which gives

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TABLE VI
PERCENTAGE DISTRIBUTION OF BIRTH WEIGHT RELATED TO MATERNAL AGE (ALL PARITIES)

Maternal Age (years)	Birth Weight (lb.)						Total	Number of Births
	Less than 5·5	5·5–	6–	7–	8–	9 and over		
20 and under	8·71	6·17	27·31	35·79	16·71	5·30	100	1,263
21–22	6·18	5·49	26·70	36·83	19·46	5·34	100	2,004
23–24	6·43	4·97	25·13	37·47	19·90	6·09	100	2,674
25–26	5·64	4·44	24·83	35·65	21·96	7·48	100	2,996
27–29	5·96	3·93	24·47	34·18	22·84	8·62	100	3,306
30–34	5·48	4·01	21·18	34·10	24·34	10·88	100	4,088
35 and over	6·55	4·02	19·69	33·02	23·81	12·91	100	3,083
All Births of Known Maternal Age and Parity	6·17	4·49	23·58	35·03	22·02	8·70	100	19,414
All Births of Known Maternal Age	6·14	4·53	23·52	35·57	21·42	8·81	100	19,599

$$\chi^2 = 284·69, n = 30, p < 0·0001.$$

the distribution of births by weight in various maternal age groups. Groupings of age are somewhat arbitrary, and have been chosen to provide reasonable numbers in each group; groupings of weight need no comment, though it should perhaps be said that births under 6 lb. have been sub-divided only to permit separate examination of those under 5½ lb. The data show that weight increases with age; there is no consistent change in the proportion of births between 7 and 8 lb., but below and above this weight age trends are quite marked. That this is not the result of chance variation is confirmed by the χ^2 test. The data provide no support for the view sometimes stated that the incidence of “premature” birth increases with the mother’s age; indeed, the proportion of births less than 5½ lb. undoubtedly decreases. Table VI also gives the weight distribution of all births (19,599) of known maternal age, and shows as might be expected that the distribution is unaffected by the exclusion from Table VI of the few births of unknown parity.

The same treatment has been adopted in Table VII in an investigation of the relation between weight and parity. Weight increases with parity to the third birth rank, but above the third there is no consistent change (at least none is evident when “3” is compared with “4 and over”). The proportion of births under 5½ lb. decreases with parity, being approximately 7 per cent. for first births, and 4·9 per cent. for third births. Weight distributions of all births of known parity (20,101) are very much the same as for the 19,414 births of known age and parity. The χ^2 test is again used to confirm what is shown in the Table.

Since the two variables (age and parity) are highly correlated, it is important, where the data permit, to separate their effects. This can be done on the material used in Tables VI and VII by examining the relation of weight distribution to:

- maternal age at different parities (Table VIII),
- parity at different maternal ages (Table IX).

TABLE VII
PERCENTAGE DISTRIBUTION OF BIRTH WEIGHT RELATED TO PARITY (ALL AGES)

Parity	Birth Weight (lb.)						Total	Number of Births
	Less than 5.5	5.5-	6-	7-	8-	9 and over		
1	7.04	5.64	28.66	36.17	17.82	4.66	100	7,694
2	5.64	3.89	22.14	35.98	23.70	8.66	100	5,659
3	4.87	3.48	18.61	33.64	26.71	12.68	100	2,815
4 and over	6.16	3.70	18.36	31.92	24.98	14.88	100	3,246
All Births of Known Parity and Maternal Age	6.17	4.49	23.58	35.03	22.02	8.70	100	19,414
All Births of Known Parity	6.05	4.52	23.43	35.45	21.58	8.98	100	20,101

$$\chi^2 = 676.66, n = 15, p < 0.0001.$$

TABLE VIII
PERCENTAGE DISTRIBUTION OF BIRTH WEIGHT RELATED TO MATERNAL AGE AT DIFFERENT PARITIES

Parity	Maternal Age (years)	Birth Weight (lb.)						Total	Number of Births	
		Less than 5.5	5.5-	6-	7-	8-	9 and over			
1	20 and under	8.11	6.91	28.29	35.21	16.04	5.44	100	1,085	$\chi^2 = 29.4$ $n = 30$ $0.25 < p < 0.50$
	21-22	5.93	5.57	27.66	36.55	19.90	4.37	100	1,417	
	23-24	7.06	5.61	28.69	36.15	18.07	4.42	100	1,516	
	25-26	6.19	5.88	27.92	36.81	18.17	5.02	100	1,293	
	27-29	7.25	5.20	31.32	35.68	16.64	3.90	100	1,076	
	30-34	7.61	4.37	28.78	37.18	17.13	4.93	100	893	
	35 and over	8.94	5.79	28.02	35.54	17.87	4.83	100	414	
2	22 and under	8.63	5.18	24.80	36.42	18.84	6.12	100	637	$\chi^2 = 60.05$ $n = 25$ $p < 0.001$
	23-24	5.23	3.77	21.64	40.49	21.40	7.42	100	822	
	25-26	4.99	3.05	24.32	34.87	24.23	8.51	100	1,081	
	27-29	5.02	3.03	20.19	35.61	26.08	10.05	100	1,154	
	30-34	5.11	4.02	21.44	34.75	25.62	9.05	100	1,292	
	35 and over	6.39	5.35	21.40	34.77	22.44	9.66	100	673	
3	24 and under	5.41	3.70	17.38	38.46	24.79	10.26	100	351	$\chi^2 = 20.41$ $n = 20$ $0.25 < p < 0.50$
	25-26	4.50	4.75	18.00	34.50	27.25	11.00	100	400	
	27-29	5.59	3.29	22.37	30.75	25.49	12.50	100	608	
	30-34	4.04	3.34	17.18	33.67	27.80	13.96	100	867	
	35 and over	5.26	2.89	17.99	33.10	27.16	13.58	100	589	
4 and over	26 and under	8.06	2.98	20.59	36.12	21.49	10.75	100	335	$\chi^2 = 28.76$ $n = 15$ $0.01 < p < 0.05$
	27-29	5.78	4.06	22.04	31.67	25.68	10.91	100	468	
	30-34	5.30	4.24	17.66	30.98	26.05	15.73	100	1,036	
	35 and over	6.87	3.53	16.58	31.59	24.92	16.48	100	1,407	

When parity is fixed, as in Table VIII, the relationship between weight distribution and the mother's age is quite irregular. At birth ranks 1 and 3 there are no changes which cannot be attributed to chance variation. At birth rank 2 differences

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TABLE IX
PERCENTAGE DISTRIBUTION OF BIRTH WEIGHT RELATED TO PARITY AT DIFFERENT MATERNAL AGES

Maternal Age (years)	Parity	Birth Weight (lb.)						Total	Number of Births	
		Less than 5·5	5·5–	6–	7–	8–	9 and over			
22 and under	1	6·87	6·16	27·94	35·97	18·22	4·84	100	2,502	$\chi^2=13·78$ $n=5$ $0·01 < p < 0·05$
	2 and over	8·10	4·44	23·66	37·91	18·95	6·93	100	765	
23–24	1	7·06	5·61	28·69	36·15	18·07	4·42	100	1,516	$\chi^2=55·12$ $n=10$ $p < 0·0001$
	2	5·23	3·77	21·65	40·51	21·41	7·42	100	822	
	3 and over	6·55	5·06	17·56	36·01	24·40	10·42	100	336	
25–26	1	6·19	5·88	27·92	36·81	18·17	5·03	100	1,293	$\chi^2=68·87$ $n=15$ $p < 0·0001$
	2	4·99	3·05	24·32	34·87	24·23	8·51	100	1,081	
	3	4·50	4·75	18·00	34·50	27·25	11·00	100	400	
	4 and over	7·65	2·25	21·62	34·68	23·42	10·35	100	226	
27–29	1	7·25	5·20	31·32	35·68	16·64	3·90	100	1,076	$\chi^2=119·08$ $n=15$ $p < 0·0001$
	2	5·02	3·03	20·19	35·61	26·08	10·05	100	1,154	
	3	5·59	3·29	22·37	30·75	25·49	12·50	100	608	
	4 and over	5·78	4·06	22·01	31·62	25·64	10·91	100	468	
30–34	1	7·61	4·37	28·78	37·18	17·13	4·93	100	893	$\chi^2=143·33$ $n=15$ $p < 0·0001$
	2	5·11	4·02	21·44	34·75	25·62	9·05	100	1,292	
	3	4·04	3·34	17·18	33·67	27·80	13·96	100	867	
	4 and over	5·30	4·24	17·66	30·98	26·05	15·73	100	1,036	
35 and over	1	8·94	5·79	28·02	35·54	17·87	4·83	100	414	$\chi^2=88·84$ $n=15$ $p < 0·0001$
	2	6·39	5·35	21·40	34·77	22·44	9·66	100	673	
	3	5·26	2·89	17·99	33·10	27·16	13·58	100	589	
	4 and over	6·87	3·53	16·58	31·59	24·92	16·48	100	1,407	

are unlikely to result from chance variation, but the consistent relationship between age and weight observed in Table VI is not present. Indeed, the only substantial age change in the second birth rank occurs between the first two age groups, and it is the weight distribution of births of mothers “22 and under” which explains the low “ p ” in the χ^2 test. The same is true of birth ranks “4 and over”, in which age changes are even less consistent. It therefore seems reasonable to conclude that there is no regular relationship between birth weight and maternal age when parity is fixed.

The relationship between weight and parity when age is fixed is much more consistent, as is shown in Table IX. Not only are values for “ p ” low in every age group, but more important, the change in weight distribution as parity increases (noted in Table VII) is preserved. Once again the effect is limited to the first three birth ranks, for there are no regular differences in weight distributions between birth ranks “3” and “4 and over”.

TABLE X
MEAN BIRTH WEIGHT* RELATED TO MATERNAL AGE AND PARITY

Parity	Maternal Age (years)						All Ages
	22 and under	23-24	25-26	27-29	30-34	35 and over	
1	7.17 ±0.026	7.17 ±0.031	7.22 ±0.033	7.12 ±0.036	7.19 ±0.041	7.12 ±0.065	7.17 ±0.014
2	7.14 ±0.066	7.43 ±0.042	7.46 ±0.039	7.57 ±0.038	7.52 ±0.034	7.43 ±0.053	7.46 ±0.017
3	7.70 ±0.100	7.52 ±0.083	7.62 ±0.064	7.56 ±0.058	7.73 ±0.045	7.70 ±0.053	7.65 ±0.026
4 and over	—	7.47 ±0.146	7.46 ±0.097	7.48 ±0.064	7.70 ±0.044	7.72 ±0.040	7.65 ±0.026
All Parities	7.21 ±0.021	7.29 ±0.024	7.38 ±0.023	7.41 ±0.023	7.54 ±0.020	7.57 ±0.020	7.41 ±0.009

* Means calculated from the weights in lb.

An alternative method of considering the association of birth weight with maternal age and parity is by examining the mean weights given in Table X. The increase in mean weight with age is exhibited in the column totals (as Table VI) and the increase with the first three birth ranks in the row totals (as Table VII). The change in mean weight with age is, however, quite irregular when parity is fixed (reading along the rows), but the change with parity when age is fixed (reading down the columns) is again fairly consistent to the third birth rank. In this Table means have been calculated from the weights in pounds, and this accounts for a mean weight for all births (7.41) slightly lower than the mean (7.43) given in Table II.

We may therefore conclude that:

- (a) weight increases with parity;
- (b) there is no consistent association between weight and maternal age when birth rank is fixed.

The data do not, however, permit us to state unequivocally that a mother's second child is likely to be heavier at birth than her first. We know the weight of only one individual in each fraternity, the last member at the time the record was made. It follows that we have compared first births, some of which are only births, with second births, all of which have at least one sib. If mean birth weight is different for only births and for the first-born of larger families, this will clearly affect the comparison. The same considerations arise when second and third births are compared. But although it is by no means unlikely that mean weight at any birth rank is related to size of family, it seems improbable that this alone explains the differences noted. For example, there is undoubtedly a higher proportion of births of well-to-do mothers among first than among later births, and if birth weight is related to the economic circumstances of the parents, this will also effect a comparison of mean weights.

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TABLE XI

PERCENTAGE DISTRIBUTIONS OF HOSPITAL, DOMICILIARY, AND NURSING-HOME BIRTHS BY BIRTH WEIGHT*

Birth Weight (lb.)	Hospital			Domiciliary			Nursing-Home		
	Live born	Still-born	Total	Live born	Still-born	Total	Live born	Still-born	Total
1	0.08	3.01	0.18	0.02	1.87	0.04	0.00		—
2	0.43	11.74	0.81	0.13	7.50	0.24	0.07		0.14
3	0.70	11.74	1.08	0.28	8.75	0.40	0.42		0.55
4	2.39	12.04	2.72	0.88	11.25	1.03	0.83		0.89
5	9.14	13.24	9.28	4.92	13.12	5.04	5.55		6.02
6	28.18	16.86	27.78	19.14	14.37	19.07	23.19		23.12
7	35.49	18.06	34.88	35.89	21.87	35.69	38.54		38.37
8	18.53	8.13	18.17	25.86	13.12	25.68	24.72		24.35
9	4.19	3.01	4.14	9.66	5.00	9.60	5.48		5.40
10	0.84	1.81	0.88	2.77	1.87	2.76	1.11		1.09
11	0.04	0.30	0.05	0.39	0.63	0.40			
12	0.01		0.01	0.03	0.63	0.03			
13									
14				0.01		0.01			
15							0.07		
16									0.07
Total	100	100	100	100	100	100	100		100
No. of Births	9,367	332	9,699	11,133	160	11,293	1,440	22	1,462
Mean (lb.)	7.20	5.64	7.15	7.68	6.21	7.65	7.50	—	7.46
Error of Mean	0.012	0.118	0.018	0.011	0.17	0.012	0.029	—	0.03
Standard Deviation	1.19	2.15	1.25	1.18	2.15	1.21	1.09	—	1.21
B ₁	0.155		0.370	0.003		0.035	0.02	—	0.00
B ₂	4.36		4.74	3.94		4.28	6.46	—	6.43

* This table is based on 22,527 single births of known weight; 73 were excluded because the duration of gestation was less than 28 weeks.

HOSPITAL AND DOMICILIARY BIRTHS

Since most data on birth weight hitherto available have been derived from hospital practice, it is of interest to compare weight distributions of hospital and domiciliary births exhibited in Table XI (nursing home births are also included, but in view of the relatively small numbers are of secondary interest). Mean weight is about half a pound greater for domiciliary than for hospital births, and the difference is also reflected in the weight distributions. (For example, 42 per cent. of hospital total births and only 26 per cent. of domiciliary total births, are less than 7 lb.)

There are, of course, numerous differences between hospital and domiciliary births which may contribute to their mean weights, in particular differences in duration of gestation and birth rank. We are, moreover, unable to exclude the possibility of some error in weighing; indeed, if weights of domiciliary births are consistently overstated, such an error could conceivably explain the association of weight with birth rank. We have examined this possibility by considering separately for hospital and domiciliary births the percentage distribution and mean

birth weight in relation to parity. The results are reassuring, since births from both sources exhibit the association between weight and birth rank (Table XII).

TABLE XII
PERCENTAGE DISTRIBUTION OF BIRTH WEIGHT RELATED TO PARITY

Parity	Birth Weight (lb.)						Total	No. of Births	Mean (lb.)	Error of Mean	Standard Deviation
	Less than 5·5	5·5–	6–	7–	8–	9 and over					
(a) <i>Hospital Births</i>											
1	8·78	6·88	30·70	34·87	15·67	3·09	100	4,883	7·01	0·017	1·20
2	7·50	5·11	26·15	34·54	20·65	6·04	100	2,600	7·22	0·026	1·32
3	6·85	5·74	23·49	34·77	22·07	7·06	100	992	7·31	0·041	1·30
4 and over	10·74	4·74	21·78	33·40	19·36	9·97	100	1,033	7·25	0·049	1·53
All Births of Known Parity	8·43	6·05	27·73	34·61	18·10	5·06	100	9,508	7·13	0·013	1·28
(b) <i>Domiciliary Births</i>											
1	4·47	3·46	24·73	39·30	20·05	7·98	100	2,369	7·40	0·023	1·17
2	4·39	3·08	18·74	38·45	24·96	10·37	100	2,892	7·57	0·022	1·17
3	2·44	2·38	15·69	33·99	29·16	16·31	100	1,759	7·84	0·028	1·19
4 and over	3·87	3·04	16·17	30·82	26·30	19·78	100	2,300	7·85	0·027	1·37
All Births of Known Parity	3·92	3·04	19·07	35·94	24·84	13·21	100	9,320	7·65	0·013	1·25

We have attempted to assess to what extent the difference in mean weights of hospital and domiciliary births (0·5 lb.) is explained by differences in duration of gestation and parity (two variables with which weight is certainly correlated). Table XIII shows that mean weight is consistently higher for domiciliary births at different weeks of gestation; standardization for duration of gestation reduces the difference in mean weights of total births by 0·08 lb. Table XIII also gives the parity distribution of births, and indicates that the proportion of births in the first birth rank is consistently lower in the case of domiciliary births. Standardization for parity further reduces the difference in mean weight by 0·13 lb. Since we have previously shown that for the population under consideration parity and duration are independent of one another, we conclude that about three-fifths of the difference in the mean weights must be attributed to other variables.

SUMMARY

(1) Birth weight was recorded for 22,527 of the 23,279 single births born in Birmingham during 1947. The data are used to give weight distributions, and constants of the distributions, for live births, stillbirths, and total births (Table II).

(2) Mean weights (lb.) of births born after the end of the 28th week are:

live births, $7·46 \pm 0·008$
stillbirths, $5·83 \pm 0·094$
total births, $7·43 \pm 0·008$.

Birth weights are not normally distributed.

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TABLE XIII
MEAN BIRTH WEIGHT RELATED TO DURATION OF GESTATION

Duration of Gestation (weeks)	Hospital Births		Domiciliary Births							
	Number of Births	Mean Weight (lb.)	Number of Births	Mean Weight (lb.)						
28	12	2.85	4	2.50						
29	11	2.75	3	2.90						
30	13	2.95	10	3.50						
31	35	3.55	15	3.80						
32	31	3.85	11	3.95						
33	51	4.20	21	4.85						
34	73	5.20	34	5.55						
35	152	5.95	102	6.40						
36	241	6.35	177	6.90						
37	426	6.45	304	7.00						
38	738	6.70	650	7.35						
39	1,590	7.20	1,578	7.60						
40	2,124	7.40	2,282	7.80						
41	1,520	7.60	1,295	7.95						
42	736	7.40	689	8.05						
43	247	7.65	235	8.05						
44	84		136	7.90						
45	44		64							
46	—		5							
All Births of Known Duration of Gestation	8,128	7.17	7,535	7.67						
All Births of Known Weight	9,699	7.15	11,293	7.65						
Duration of Gestation (weeks)	Percentage Distributions by Parity									
	1	2	3	4 and over	Total	1	2	3	4 and over	Total
28-34	52.0	26.0	6.2	15.8	100	32.0	32.0	11.8	24.2	100
35	51.9	26.9	6.8	14.4	100	21.0	34.4	17.6	26.9	100
36	44.4	28.4	10.7	16.5	100	27.6	29.8	14.4	28.2	100
37	51.1	27.1	9.1	12.6	100	25.4	26.4	20.9	27.3	100
38	51.7	26.3	9.8	12.2	100	25.1	31.5	18.3	25.1	100
39	50.6	29.8	11.1	8.5	100	25.0	32.1	20.4	22.5	100
40	52.0	27.5	11.2	9.3	100	26.2	33.0	20.0	20.8	100
41	53.7	28.0	9.6	8.7	100	27.4	27.6	19.3	25.7	100
42	54.8	26.3	9.8	9.1	100	25.8	27.6	19.1	27.5	100
43	51.4	28.7	8.9	11.0	100	24.0	27.0	17.7	31.3	100
44	53.6	25.0	10.7	10.7	100	26.6	33.1	10.8	29.5	100
45-46	54.4	22.3	11.7	11.7		23.5	31.6	16.2	28.7	
All Births of Known Duration of Gestation	52.0	27.7	10.2	10.1	100	26.0	30.8	19.1	24.1	100
All Births of Known Weight	51.4	27.3	10.4	10.9	100	25.4	31.1	18.9	24.6	100

(3) Duration of gestation and birth weight were known for 17,145 single births. Mean birth weight has been estimated for births delivered in each week after the 28th week of gestation (Table IV). There is a sharp increase in weight after 29

completed weeks of gestation; and weight continues to increase until the 40th week, from which time the mean is almost constant.

(4) Maternal age and parity were recorded for 19,414 single births of known weight. Birth weight (as indicated by weight distribution) increases with maternal age (Table VI) and with parity (Table VII). These two variables are, of course, highly correlated, and it is shown that:

- (a) there is no consistent relationship between weight and maternal age when parity is fixed (Table VIII);
- (b) weight increases with parity when maternal age is fixed (Table IX).

These observations on weight distributions are confirmed by examination of mean birth weights (Table X).

(5) Mean birth weight is about half a pound greater for domiciliary than for hospital births (Table XI). Standardization for parity reduces this difference by about 0.1 lb., and for duration of gestation by about 0.1 lb. Since duration of gestation has been shown to be not associated with parity, we conclude that about three-fifths of the difference in mean weights of hospital and domiciliary births must be attributed to other variables.

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