Parental Stature and Birth Weight

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IN 1938 Walton & Hammond described the results of reciprocal Shire-Shetland crosses effected by artificial insemination. They showed that the weight of the foal of Shire dam and Shetland sire was about the same at birth as that of the foal of pure Shire parents, and the weight of the foal of Shetland dam and Shire sire was no greater than that of the foal of pure Shetland parents. Numbers of observations were very small, but the differences exhibited were so striking that it can hardly be doubted that the weight of the foal at birth was more highly correlated with the weight of the dam than with the weight of the sire. Walton & Hammond attributed this result to the uterine environment, and noted that after weaning "foals from the Shire mares (Shetland sires) grew much less rapidly than pure Shire foals, and the foals from the Shetland mares (Shire sires) grew much more rapidly than pure Shetlands".

In rabbits, similar results were reported by Robb (1929) on data provided by Castle who crossed Flemish Giant and Polish breeds. Hybrid animals from Giant does and Polish bucks were almost as large at birth as pure bred Giants; unfortunately Polish does and Giant bucks were not mated. Differences in growth rate were exhibited after birth, and the weight of mature hybrid animals was about midway between weights of the pure breeds.

In man, correlations between size of parents and size of offspring at birth have been examined by Lennér (1943), who found only trivial differences (a) between correlations of birth weight with mother's weight (0.19) and birth weight with father's weight (0.18), and (b) between correlations of birth length with mother's height (0.20) and birth length with father's height (0.21). When corrected for height of the other parent correlations were lowered slightly, but still indicated that the size of the child at birth is about equally affected by the size of each parent.

A preliminary inspection of a somewhat larger series of our own gave a different result, more consistent with the observations derived from the Shire-Shetland cross. We have therefore examined more exhaustively correlations at birth, and in the two years after birth, between the size of a child and the size of its parents. In another communication (McKeown & Record, 1954) we enquire to what extent these correlations are modified by changes in the prenatal environment, in particular those associated with litter size and birth order.

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MATERIAL

The observations which follow are based upon material from two sources.

(*a*) *Smethwick Data*

The data were obtained in an investigation of pregnancies of all mothers domiciled in the County Borough of Smethwick, whose children were born between April 1st, 1949 and March 31st, 1950. An attempt was made to record weight and height of both parents, and infant weight at birth, and at 3, 6, 9, 12 and 24 months after birth.

Mother's weight and height were measured at the first antenatal attendance. Father's weight and height were obtained by asking the mother, who gave values in some cases at once, and in other cases after consulting her husband. Infant birth weights were recorded in hospital to the nearest ounce, and at home to the nearest quarter pound; weights after birth were taken to the nearest ounce either at a welfare clinic, or at home if the child was not brought to a clinic within a few days of the appropriate date.

In view of the methods used, it seemed to us that we could accept the observations on the mother as being reasonably reliable. There is evidently a considerable error in observations on the father, particularly in the case of weight, and we have therefore made no use of father's weight. Distribution of father's height showed grouping, as might be expected, notably at 66, 68, and 70 inches. Our justification for regarding heights as being sufficiently accurate for our purpose is that they gave results which agree well with those based on the Birmingham enquiry ((b) below) in which heights of fathers were measured.

In the year under consideration there were 1,327 Smethwick births, which included 38 twins. Of the 1,289 singletons, 23 were stillborn, 23 died during the first month, and 1,243 were alive at one month.

(*b*) *Birmingham Data*

Experience of the Smethwick enquiry encouraged us to attempt to assemble another series in which we could verify the findings on data from an independent source, and explore the influence of placental size on the correlation between infant weight and parental height. We have therefore extracted the following information from records of the Birmingham Maternity Hospital for the years 1946 and 1948–50: birth weight, placental weight, birth rank, sex and duration of gestation (recorded as the period of amenorrhoea). During the 4 years there were 7,341 single births; the requisite data were complete in respect of 4,931.

In order to eliminate the possibility of variation associated with period of gestation, attention was confined to the 1,970 (of 4,931) children born between 273 and 286 days. Stillbirths and neonatal deaths were excluded. To reduce the

amount of home visiting a sample was selected, consisting of half the infants whose placentae weighed between 20 and 28 ozs, and all infants with placentae above and below these weights. There were 822 children in the sample and heights of both parents of 506 were measured.

BIRTH WEIGHT ACCORDING TO PARENTAL HEIGHT

Birth weight, heights of both parents, birth rank, sex and duration of gestation were available for 1,028 of the 1,243 Smethwick single births alive one month after birth. Table 1 gives mean birth weight according to parental height and shows that birth weight increases regularly as height of mother increases. The association between birth weight and height of father is less marked and less consistent. In view of the correlation between heights of parents (0.20 for parents of the 1,028 children) it seemed desirable to standardise in each case for height of the other parent; the results are also given in table 1 (and fig. 1). The association between birth weight and mother's height is virtually unchanged, but the association between birth weight and father's height is less evident.

The same data are given in table 2 for the 506 Birmingham children alive at one month; the results are also consistent with the conclusion that mean birth weight increases with height of mother, but shows no consistent association with height of father. It should be noted that these data were entirely independent of the Smethwick material from which they differ in three respects: (a) father's height was measured for the purposes of the enquiry, and hence can

TABLE 1. MEAN BIRTH WEIGHT (LB.) ACCORDING TO HEIGHT OF PARENTS (SMETHWICK DATA)

Height of Mothers (Inches)	Height of Fathers (Inches)						Total	Mean Standardized for Height of Father
	Under 64	64–	66–	68–	70–	72 and over		
Under 60	6.28 (8)	5.69 (4)	6.86 (8)	6.58 (9)	7.13 (6)	7.15 (3)	6.61 (38)	6.73
60–	6.90 (16)	7.12 (11)	6.61 (24)	7.10 (39)	6.81 (27)	7.09 (12)	6.92 (129)	6.91
62–	7.06 (17)	7.07 (38)	7.21 (63)	7.27 (63)	7.52 (56)	7.52 (38)	7.30 (275)	7.31
64–	7.37 (9)	7.26 (47)	7.21 (97)	7.40 (65)	7.41 (84)	7.49 (45)	7.34 (347)	7.35
66–	7.22 (4)	7.75 (16)	7.68 (40)	7.50 (46)	7.26 (44)	7.90 (27)	7.56 (177)	7.55
68 and over	8.41 (2)	7.79 (3)	7.62 (4)	7.81 (11)	7.53 (28)	7.86 (14)	7.70 (62)	7.74
Total	7.01 (56)	7.21 (119)	7.22 (236)	7.32 (233)	7.35 (245)	7.57 (139)	7.31 (1028)	—
Mean standardized for height of mother	7.22	7.25	7.23	7.34	7.33	7.53	—	—

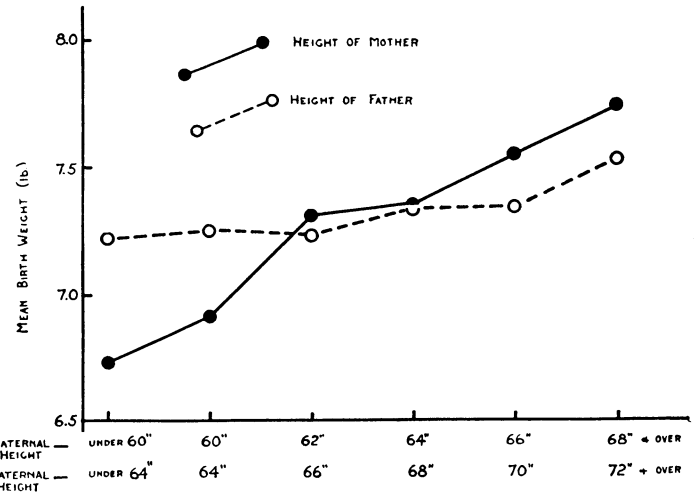

FIG. 1. Birth weight (standardized for height of other parent) according to parental height (Smethwick data).

TABLE 2. MEAN BIRTH WEIGHT (LB.) ACCORDING TO HEIGHT OF PARENTS (BIRMINGHAM DATA)

Height of Mother (Inches)	Under 60	60–	62–	64–	66 and Over
Mean birth weight	6.67	7.28	7.45	7.42	7.59
	(44)	(120)	(154)	(120)	(68)
Mean standardized for height of father	6.62	7.32	7.46	7.41	7.76
Height of Father (Inches)	**Under 66**	**66–**	**68–**	**70–**	**72 and over**
Mean birth weight	7.13	7.46	7.36	7.33	7.66
	(108)	(93)	(134)	(116)	(55)
Mean standardized for height of mother	7.25	7.55	7.33	7.33	7.65

TABLE 3. CORRELATION BETWEEN BIRTH WEIGHT AND PARENTAL HEIGHT

Sex of Infants	Correlation Between Birth Weight and Height of	Smethwick Data				Birmingham Data		
		Total	Corrected for height of other parent	Corrected for gestation and height of other parent	No. of observations and standard error	Total	Corrected for height of other parent	No. of observations and standard error
Males	Mother	0.20	0.18	0.18	545	0.22	0.18	248
	Father	0.10	0.07	0.06	(0.04)	0.13	0.05	(0.06)
Females	Mother	0.21	0.18	0.19	483	0.17	0.15	258
	Father	0.16	0.12	0.10	(0.05)	0.10	0.05	(0.06)
Both sexes	Mother	0.20	0.18	0.18	1028	0.19	0.16	506
	Father	0.13	0.09	0.08	(0.03)	0.11	0.05	(0.04)

be accepted with considerably more confidence; (b) observations are confined to infants born in hospital who are probably weighed somewhat more accurately, and differ slightly in distribution according to parity; and (c) only births delivered between 273 and 286 days gestation are included.

Table 3 gives correlations between birth weight and parental height. For each sex, and for both sets of data, birth weight is more highly correlated with height of mother than with height of father. The same is true of partial correlations, holding constant height of the other parent, for which values (based on both sexes) are respectively 0.18 and 0.09 (Smethwick data) and 0.16 and 0.05 (Birmingham data).

POST-NATAL GROWTH ACCORDING TO PARENTAL HEIGHT

As mentioned above, weights of Smethwick children were recorded at regular intervals during the two years after birth. Weights were accepted only if measured within three weeks of the appropriate date. In exploring the influence of parental height on post-natal growth it was thought desirable to restrict examination to the 625 (of 1,028) children for whom observations at all intervals were available. No adjustment was made for the error introduced by accepting weights obtained at periods up to three weeks before or after the appropriate dates but the effect of this error was examined, and found to be substantial at three months (when weight is still changing rapidly) and trivial at all subsequent intervals. For this reason correlations at 3 months have been excluded.

Table 4 gives correlations at 6, 9, 12, and 24 months between infant weight and parental height, before and after correction for height of other parent. At every interval infant weight is more highly correlated with height of mother than with height of father, and indeed the partial correlations at two years (0.20 and 0.13 respectively for 605 infants) are not very different from those noted at birth (0.18 and 0.09, for 1,028 infants).

TABLE 4. CORRELATION BETWEEN INFANT WEIGHT AND PARENTAL HEIGHT

Sex of Infants	Correlation Between Infant Weight and Heght of:	Age of Infants (Months)								
		Total	6 Corrected for height of other parent	Total	9 Corrected for height of other parent	Total	12 Corrected for height of other parent	Total	24 Corrected for height of other parent	Standard error
Males (328)	Mother	0.22	0.21	0.19	0.19	0.20	0.19	0.20	0.19	0.06
	Father	0.13	0.11	0.12	0.11	0.14	0.12	0.14	0.12	
Females (297)	Mother	0.20	0.18	0.20	0.18	0.21	0.18	0.25	0.22	0.06
	Father	0.10	0.06	0.13	0.10	0.15	0.11	0.18	0.14	
Both sexes (625)	Mother	0.20	0.18	0.19	0.17	0.19	0.18	0.22	0.20	0.04
	Father	0.11	0.09	0.13	0.10	0.14	0.12	0.16	0.13	

TABLE 5. CORRELATION BETWEEN INFANT WEIGHT AND PARENTERAL HEIGHT CORRECTED FOR HEIGHT OF OTHER PARENT, DURATION OF GESTATION, BIRTH RANK AND MATERNAL AGE

Sex of Infants	Correlation Between Infant Weight and Height of	Age of Infants (Months)			
		6	9	12	24
Males	Mother	0.22	0.20	0.21	0.21
	Father	0.12	0.12	0.13	0.13
Females	Mother	0.17	0.17	0.17	0.21
	Father	0.07	0.10	0.11	0.13

Since rate of post-natal growth is affected substantially by duration of gestation and birth rank, and to a lesser extent by maternal age (Cawley, McKeown & Record, 1954) it was thought worthwhile to examine the effect of correction for these variables, as well as for height of the other parent. The results given in table 5 indicate that correlations between infant weight and parental height are only very slightly influenced by these corrections.

DISCUSSION

Investigations of inheritance of size have been concerned mainly with mature animals, and numerous crosses (such as those reported by Punnett & Bailey, 1918; Castle, 1922; Pearse, 1928; Green, 1931; and Livesay, 1930) have provided few data relating size of offspring at birth to the size of their parents. It was the observations of Walton & Hammond (1938) on the Shire-Shetland cross which drew attention to the profound influence which the maternal environment may have on weight at birth, and for a time at least on post-natal development.

The only comparable data of which we are aware are those of Robb on the rabbit (referred to above) which are consistent with the report of Walton & Hammond, and those of Kopec (1924), also on the rabbit, which are not. Kopec crossed Himalayan and Silver breeds, and noted that although birth weight of young from the S ♀ × H ♂ cross were approximately the same as of young from pure Silver parents (a result in keeping with the Shire-Shetland cross), offspring from the reciprocal H ♀ × S ♂ cross were intermediate in weight between the two breeds. But having regard to the relatively small differences in birth weight between the pure breeds, numbers of litters examined were small, and it is not certain that account was taken of the influence of parity (since results are based on consecutive matings of the same mothers it is possible that females were mated with males of the same breed before being crossed). Kopec (1922) also mated Himalayan does with both Himalayan and Silver bucks during the same rutting period, and stated that weights of young within the same litter were characteristic of the breed of the male parent. We have not been able to examine the original report of this interesting observation, but substantial numbers would be needed to establish it in view of the con-

siderable variation in weight normally observed among foetuses of the same litter.

In man birth weight is more closely related to height of mother than to height of father. The same association between infant size and the height of the two parents is present in the two years after birth (table 4), and was observed by Paton & Findlay (1926) in children aged 2 weeks to 13 years. They recorded the following correlations (corrected for age of child) between height of children and height of parents:

Mother-son:	0.1585 ± 0.025
Father-son:	0.0767 ± 0.047
Mother-daughter:	0.2829 ± 0.023
Father-daughter:	0.1230 ± 0.044

These discrepancies are apparently eliminated before adult life. They were not observed by Pearson & Lee (1903) who examined correlations between height of parents and height of offspring aged 18 or over, and concluded that "the son and daughter are equally influenced by their father, and equally influenced by their mother".

Mother-son:	0.494
Father-son:	0.514
Mother-daughter:	0.507
Father-daughter:	0.510

Moreover in the Shire-Shetland cross sharp differences between growth rates of hybrid and pure bred foals were established after birth, although the greater influence of the maternal parent was still present at 40 months (the latest period reported). Most other experimental crosses were made by observers interested in the size of mature offspring according to breed of parents, but it seems unlikely that if there had been substantial differences according to sex of parent they would have passed unnoticed.

There is therefore evidence in man and in experimental animals that at birth and for some time after birth size of offspring is related more closely to size of mother than to size of father, but the difference appears to be eliminated before adult life. This result can most reasonably be attributed to the maternal environment, which may have some influence after birth (for example there is a marked difference between the milk supply from Shire and Shetland dams), but is of far greater significance before birth, when the association of infant size with maternal size is established.

The maternal environment may influence size of offspring at birth by an effect on one or both of (a) duration of foetal growth and (b) rate of foetal growth. On the evidence here referred to, the greater association of size of offspring with size of mother than with size of father must be attributed to the influence of the maternal environment on the rate rather than on the duration

of foetal growth. For in man, correction for duration of gestation has virtually no effect on correlations between birth weight and parental height (table 3), and there were only trivial differences between durations of gestation of Shire and Shetland mares. (Although they have no direct bearing on the interpretation of these results, two crosses between animals with different periods of gestation are of interest. Hagedoorn & Hagedoorn (1928) stated that in reciprocal rabbit x hare crosses—a difficult cross to bring about, but one of great interest in view of the substantial difference in length of gestation—duration of gestation was characteristic of the mother. Rife, Gorlaugh, Kunkle, Brandt & Snyder (1943), on the other hand, crossed Aberdeen and Angus breeds of cattle, and noted that the duration of gestation was roughly midway between the periods characteristic of the two breeds.)

Inspection of the results published by Walton & Hammond suggests that the influence of the maternal environment on rate of foetal growth may be determined to some extent by the size of the placenta. Differences between placental weights from the two crosses were as marked as differences in foetal weights, and indeed ratios of foetal to placental weight were very nearly the same. But variation in placental size only partly accounts for variation in rate of foetal growth in relation to litter size (McKeown & Record, 1953a) and birth rank (McKeown & Record, 1953b), and it is quite possible that it does not wholly explain the association between birth weight and mother's size. Moreover by attributing foetal size to placental size we do not greatly advance understanding of the way in which the maternal environment regulates growth, for the placenta is also a foetal structure, and we must then enquire in what way the maternal environment limits the size of the placenta.

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SUMMARY

Association between infant weight and parental stature is examined in two independent series of 1,028 and 506 children. It is shown that at birth, and during two years after birth, infant weight increases with height of mother, but is only slightly affected by height of father. This result is independent of duration of gestation, and it is suggested that it must be attributed to the influence of the maternal environment on rate of foetal growth.

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