

RELATIONSHIPS BETWEEN BODY MEASUREMENTS, MEAT CONFORMATION, AND MILK PRODUCTION¹

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SUMMARY

Some aspects of growth, conformation, and milk production, and their interrelations were investigated. The data were milk production and various measures of size at birth, 6 mo., 1 yr., and 2 yr. of age in the Iowa State College Holstein herd. Negative genetic associations between milk production and all measures of size except wither height were found. These associations indicate that any effort to select for milk production alone would lead to animals with reduced chest girth relative to wither height, chest depth, body length, and weight. Accordingly, any effort to select both for milk production and for a conformation indicating good production of meat would require considerable compromise in both. The correlations between dam's production and daughter's size were consistently larger than the reciprocal correlations between dam's size and daughter's production. This excess was not evident at birth but was as strong at 2 yr. as it was at 6 mo. It was concluded that this extra relationship was due to some maternal effect and not to contemporary environment affecting the characters similarly.

In a study of the relations between body size and milk production reported by Gowen (7), the correlations between milk production and these measures of size—wither height, chest depth, body length, chest girth, paunch girth, and weight—were all positive though small. However, differences between herds were included, and this might account for the values being higher than the low, and mostly negative, values found by Touchberry (14) in the Iowa State College Holstein herd.

In Milking Shorthorns, Cook *et al.* (2) reported the following correlations between measures of meat production on 83 steers and 4% fat-corrected milk production of their dams:

Milk and muscle/bone ratio.....	-.07
Milk and per cent fat in the carcass.....	-.17
Milk and carcass grade.....	-.20

Lush (12) concluded that the measurements which indicated high dressing percentage and meat value most accurately were a large chest girth with relatively small chest depth and paunch girth. Black *et al.* (1) found that wither height, chest depth, and body length were negatively correlated with fat per cent, dressing per cent, slaughter grade, per cent edible meat in the carcass, and average daily gain. They also found that chest girth, the ratio of chest girth

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to wither height, and the ratio of weight to body length were positively correlated with meat traits. Some of their results are presented (Table 1). These correlations probably were influenced by their having included as a single population beef, dual purpose, and dairy animals which were all fed to a weight of 900 lb. Thus, beef animals which have been selected for compactness and meat quality would have less skeletal growth, more flesh and, hence, better carcass quality than the dairy animals, with their more pronounced skeletal development and correspondingly low carcass quality. Also, all slaughter being at 900 lb. would itself affect correlations, such as per cent edible meat with body length and chest girth. Further indication of a negative relationship between skeletal growth and meat production is presented by Cook *et al.* (2) and Yao *et al.* (17).

The influence of the dam on its calf through the prenatal environment it supplies and the level of nourishment it gives is presented and discussed in articles on beef cattle by Dawson *et al.* (4) and by Koch and Clark (9, 10, 11). Yao *et al.* (17) studied the problem in Milking Shorthorns. Koch and Clark (9) indicated that this type of maternal effect is relatively temporary. They found maternal effect in birth weight, in gain from birth to weaning, and in weaning score, but not in yearling gain and in yearling score.

TABLE 1
Relation between body measurements and meat characteristics^a

	Dress	Fat	Total edible meat	Slaughter grade	Average daily gain
		(%)			
H ^b	-.50	-.80	-.83	-.83	-.19
D	-.39	-.46	-.55	-.53	-.19
L	-.49	-.63	-.72	-.74	-.32
C	.13	.30	.22	.39	-0.05
C/H	.54	.76	.76	.83	.12
W/L	.53	.75	.77	.84	.33

^a Summarized from Black *et al.* (1).

Beyond 5% level of significance—.30 to .33

Beyond 1% level of significance—.37 and over

^b Symbols H, D, L, C, and W are those used in the present report. C/H and W/L are ratios.

Several workers, Eckles (5), McCandlish (13), and Fitch *et al.* (6), have studied the effect of age of dam on birth weight. Their results are consistent with the data available in this investigation. Birth weight increased with age of dam sharply at first, then slowly to 8 yr. of age; then it decreased.

MATERIALS, METHODS, AND RESULTS

The characteristics studied are milk production and six measures of body size taken at 6 mo., 1 yr., and 2 yr. of age. The data are all measurements at all three ages and the milk production from 334 cows and their dams in the Iowa State College Holstein herd. The data were collected from 1930 through 1953.

The body measurements are: P—Production of milk; H—wither height; D—chest depth; L—body length; C—chest girth; G—paunch girth, W—weight.

The symbols without primes refer to the daughter; those with primes refer to the dams.

The body measurement values are the average of two (three in the early years before the error of measure was found to be so small) independent measurements by different people. The method of measuring is described by Touchberry and Lush (15).

The measure of milk production was the 305 day-2 $\times$ M.E. 3.5% fat-corrected milk. The formula for correcting to 3.5% milk is: (.43 milk + 16 fat). The 3.5% basis was used because it was nearer to the Holstein average than the more conventional 4.0% FCM. The production used for each cow was the average of all its lactations, coded to the nearest 100 lb. However, since the cows did not all have the same number of lactations, the correlation coefficients were corrected to the basis of a correlation using single lactations. The formula used for correcting to a single lactation basis was:

$$r_s = r_a \left(\frac{1}{K} \sum_{j=1}^k \left[\frac{1 + (n_j - 1) r_o}{n_j} \right]^{1/2} \right)$$

where r_s is the correlation based on a single lactation

r_a is the correlation based on the average

r_o is the correlation between records by the same cow
(repeatability)

n_j is the number of records by the j^{th} cow

K is the number of cows

The formula is based on the variance of an average being less than the variance of a single observation; whereas, the covariance is not expected to be affected by using an average.

All correlations were computed within groups of daughters by the same sire, to eliminate the effects of time trends. The reciprocal phenotypic correlations between production in one member of the daughter-dam pair and measurements at three different ages in the other member are presented (Table 2). The phenotypic correlations between dam's production (P') and daughter's measurements are consistently higher than the reciprocals between daughter's production (P) and dam's measurements.

TABLE 2

Phenotypic correlations between production of one member and various body measurements of the other member of a daughter-dam pair at 6 mo., 1 yr., and 2 yr. of age among 334 pairs

p' with	H	D	L	C	G	W
At 6 mo.	.07	.08	.11	.04	.14	.13
1 yr.	.05	.02	.07	.04	.09	.06
2 yr.	.08	.08	.10	.06	.10	.11
p with	H'	D'	L'	C'	G'	W'
At 6 mo.	.02	-.02	-.02	-.04	-.02	.00
1 yr.	.02	-.02	-.02	-.06	-.02	.00
2 yr.	.03	-.03	-.02	-.04	-.01	.00

The genetic correlations calculated by the method of Hazel (8) are presented (Table 3 in the "b" columns). Since Hazel's method assumes that the reciprocal correlations differ only because of random nongenetic influences, its validity seems questionable here, where the one kind of correlation so consistently exceeds the other. Therefore, genetic correlations using in the numerator only the correlation between daughter's production and dam's measurement are presented (Table 3 in the "a" columns).

TABLE 3
Genetic correlations between milk production and various body measurements at three ages

	Six months		One year		Two years	
	a	b	a	b	a	b
H	.17	.34	.21	.32	.23	.34
D	-.30	.35	-.22	-.03	-.23	.14
L	-.50	.25	-.35	.32	-.12	.35
C	-.51	.05	-.66	-.13	-.34	.10
G	-.30	.68	-.22	.46	-.13	.37
W	.01	.10	.00	.17	-.02	.14

Whether the thing which produced the excess correlations shown in Table 2 was a permanent characteristic of the cow, or only affected the lactation which commenced at the birth of the daughter whose measurements were being studied, was examined in the data concerning the 287 daughter-dam pairs, where the dam had a record for the lactation commenced at birth of the daughter and also had at least one other lactation record. The intrasire correlations between measurements of the daughter and production of the dam in the contemporary lactation were compared with the correlations between measurements of the daughter and average production of the dam in its other lactations. The correlations are presented (Table 4).

The excess relationship shown in Table 2 could result if:

1. The environmental conditions affecting the dam during production and the daughter during postnatal growth were correlated more closely than the environmental conditions affecting the daughter during production and the dam during postnatal growth (later referred to as common environment).

TABLE 4
Correlations between production of the dam and body measurements of the offspring at various ages

		H	D	L	C	G	W
P'l	Birth	—	—	—	—	—	.05
	6 mo.	.13	.08	.12	.07	.08	.12
	1 yr.	.11	.08	.14	.10	.05	.13
	2 yr.	.13	.09	.13	.10	.06	.10
P'a	Birth	—	—	—	—	—	.02
	6 mo.	-.02	.02	.03	.02	.01	.08
	1 yr.	.03	.01	.04	.07	.00	.06
	2 yr.	.04	-.01	.00	-.01	.02	.07

P'l indicates the dam's production in the lactation commencing with this daughter's birth.
P'a indicates dam's production in its other lactations.

2. Some physiological condition of the dam affects growth of the daughter as well as production of the dam (later referred to as maternal). Such a physiological condition could be: (a) Expressed on the calf prior to parturition and on the dam's subsequent production; (b) initiated prior to parturition but expressed postnatally in dam's production and daughter's growth.

If the excess correlations are caused by things which are expressed prenatally on the calf, one would expect the correlation between the birth weight of the daughter and the production of the dam to exceed the correlation between birth weight of the dam and production of the daughter. This would discriminate between 2a and 2b. Birth weights were available on only 254 daughter-dam pairs. These weights were corrected for age of the dam by adding to each individual birth weight the difference between the average for 6-year-old dams and the average for the age group from which the dam came. The corrected birth weights (B) were correlated with the average production in all lactations. The values obtained were:

$$r_{P'B} = .04$$

$$r_{PB'} = .07$$

These correlations indicate that the excess relationship is not evident at birth. The correlation between birth weight of the daughter and production of the dam in the lactation commenced at birth of the daughter was .05; whereas, the correlation between birth weight of the daughter and production of the dam in its other lactations was .02, as shown in Table 4.

DISCUSSION

The most striking feature of the correlations in the "a" columns of Table 3 is the existence of genetic antagonisms between milk production and all measures of size except wither height and body weight. Thus, selection for milk production alone would eventually lead to animals with some decrease in chest depth, body length, and pannch girth, with an even more drastic reduction in chest girth but with an increase in height at withers and practically no change in weight, at least through the ages concerned here.

The other correlations (the "b" columns) are all larger in the positive direction because of the larger correlations (upper part of Table 2). The other chief difference is that they do not indicate any real changes in the size of wither height, body length, and pannch girth relative to each other. However, they do indicate a reduction in the relative size of chest depth and an even greater relative reduction in chest girth.

If the true situation is somewhere between the "a" and the "b" columns, the over-all result of selecting for milk production would be a reduction in chest girth relative to skeletal measures and weight. Such a result, according to the reports of Lush (12), Black *et al.* (1), Cook *et al.* (3), and Yao *et al.* (16) is opposite to the relationships desired for producing meat, as indicated by dressing per cent, slaughter grades, per cent total edible meat, etc.

Even if the genetic correlations were zero, or slightly positive, selecting simultaneously for several characters would require considerable compromise.

When some of the relations are opposite to the direction of desired progress, the compromise necessary is even greater and improvement made per generation would be small.

Since the correlation between milk production and weight for age is practically zero, it seems possible to make some simultaneous progress in these two characteristics. However, selection for weight for age makes no allowance for such factors as muscle/bone ratio, tissue distribution, per cent fat in the carcass, slaughter grade, etc. It seems, on the basis of the results obtained here, that simultaneous selection for milk production and meat type will yield little net progress.

Two things seem, on the surface, to indicate that the excess correlations (upper part of Table 2) are the result of common environment. These two things are (a) the excess is not evident in the correlation between average production and birth weight, and (b) the correlations (Table 4) show more excess relationship in the correlation between daughter's measurements and dam's production in the lactation started at birth of the daughter than in the correlations between the daughter's measurements and the dam's production in the other lactations. However, the effect of contemporary environment of the dam and calf seems unsuitable as an explanation here, because in the Iowa State College herd the practice is to remove the calves from the cows at four days of age. Many of the calves are then used on experiments in nutrition and are housed in a different barn from the cows. Thenceforth, the only environment, apart from atmospheric conditions, which is possibly common to a cow and its calf is provided when some of the calves are housed in a wing of one of the cow barns. During this period, of course, the other dams share the environment of that dam, and the other contemporary calves share the environment of that calf. Even if the cow and calf did have a common environment which resulted in a positive relationship, the results of that would dissipate during subsequent development. However, the difference between reciprocal correlations in Table 2 is as large at 2 yr. as it is at 6 mo.

Another bit of evidence against effects of contemporary environment is the set of correlations between daughter's measures and dam's production in lactations not contemporary with early growth of the daughter (Table 4). In spite of the fact that these are consistently smaller than the correlations with the contemporary lactation, they themselves are larger than the correlations between dam's measures and daughter's production (as shown in Table 2).

Accordingly, it was concluded that the excess relation is the result of some factor or factors initiated prenatally and expressed postnatally. The correlations between dam's production and daughter's birth weight (Table 4) could be taken as an indication of prenatal expression, but this evidence is somewhat invalidated by the absence of excess correlation in the reciprocal correlations.

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