CAUSES OF VARIATION IN LENGTH OF GESTATION IN DAIRY CATTLE

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Sources of part of the variation in the length of gestation periods have been identified. Sex of the young has been reported to have an effect on gestation length by Knott (1932), Knoop and Hayden (1934), and Littlewood (1937) in cattle and by Uppenborn (1933) in the horse. No effect of sex was observed in sheep (Kelley, 1943; Terrill and Hazel, 1947) and in swine (Carmichael and Rice, 1920). Some studies have indicated an effect of age of the cow on the gestation (Knott, 1932; Knoop and Hayden, 1934) but others (Copeland, 1930; Knapp et al., 1940) report there is no effect. Knapp et al. (1940) and Terrill and Hazel (1947) indicate that their data give no evidence of an effect of the weight of dam on the length of gestation in cattle and sheep, respectively. A positive correlation of the birth weight and the length of gestation has been observed in cattle (Knapp et al., 1949), sheep (Phillips, 1928; Chapman, 1931) and swine (Lush et al., 1934). Alexander (1950) reports a somewhat shorter gestation period preceding summer calvings but others (Copeland, 1930; Knapp et al., 1940) have stated that their data did not show any effect of season of calving on the length of gestation.

Several studies have indicated an influence of the sire of the calf on the length of gestation (Knott, 1932; Rife et al., 1943; Rife, 1948; Alexander, 1950). Terrill and Hazel (1947) have stated that “the heredity of the lambs exerts a strong influence upon the length of gestation, augmented further by individual differences between ewes. . . .”

Data Studied

The data for this study were collected from a herd of Holstein-Friesian cattle belonging to the Wisconsin State Department of Public Welfare (Winnebago State Hospital) during the years 1941-1945. The cows were examined in most cases at 35-49 days after breeding, a stage at which an error of about 21 days in the breeding date would be easily detectable because of the rapid embryonic growth rate (Wisnicky and Casida, 1948).

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2 The authors are grateful to Dr. W. Wisnicky and Mr. Tom Webster for their assistance in the collection of data. They also wish to acknowledge the help of Dr. J. F. Crow in the statistical analysis.

3 All of the pregnancy examinations were made by Dr. W. Wisnicky of the Department of Veterinary Science and by one of the authors (L.E.C.).
This made it possible in most cases to tell by which breeding a cow settled if she was bred at two or more consecutive heat periods.

All gestations that resulted in dead calves or calves that died within one week of birth were excluded from this study. Gestations resulting in multiple births were also excluded because of the small numbers of such gestations. No records were omitted on the basis of the length of gestation. There was a total of 384 gestation periods used, with an average length of gestation (interval from day of breeding to day of calving) of 278.2 days and a standard deviation of 4.8 days. Individual gestations ranged from 259 to 294 days.

Results

Bang's Test

Some of the gestation periods of cows infected with Brucellosis resulted in dead fetuses and hence were not used. The gestation periods resulting in living calves from cows which reacted positively to Bang's test were compared with those which did not react. No significant differences were found.

Sex of calf, calving sequence and age of dam

There were disproportionate numbers in the sex and calving sequence classes. The method of expected subclass numbers (Snedecor and Cox, 1935) was therefore used to analyse the data for the effects of these variables on gestation period. The mean squares for sex and the sex × calving sequence interaction were significant but the mean square for calving sequence was not, (table 1). Since the interaction was found to be significant the differences between calving sequences were analyzed separately for the two sexes, (table 2). Only the gestations in which female calves were carried showed a significant effect of the calving sequence, but there was no obvious trend. The regression of gestation length on calving sequence was studied for the
female calves. It was found to be non-significant. Male calves were carried on the average 1.97 days longer than the female calves. This difference was highly significant.

Year and season of calving

An intrasire analysis of the effects of the year and season on the length of gestation (corrected for sex and calving sequence) was made on the records of mates of the four sires which furnished enough data for study. No effect of year or season was indicated.

TABLE 2. NUMBERS AND MEANS OF GESTATION LENGTHS ACCORDING TO SEX OF THE CALF AND THE CALVING SEQUENCE OF DAM

<table>
<thead>
<tr>
<th>Calving sequence</th>
<th>Male</th>
<th></th>
<th>Female</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Mean</td>
<td>Number</td>
<td>Mean</td>
</tr>
<tr>
<td>1</td>
<td>54</td>
<td>278.7</td>
<td>52</td>
<td>276.5</td>
</tr>
<tr>
<td>2</td>
<td>37</td>
<td>279.6</td>
<td>34</td>
<td>276.5</td>
</tr>
<tr>
<td>3</td>
<td>37</td>
<td>279.6</td>
<td>37</td>
<td>279.0</td>
</tr>
<tr>
<td>4</td>
<td>37</td>
<td>279.7</td>
<td>28</td>
<td>275.8</td>
</tr>
<tr>
<td>5 and over</td>
<td>46</td>
<td>278.3</td>
<td>31</td>
<td>278.6</td>
</tr>
<tr>
<td>Total</td>
<td>202</td>
<td>279.0</td>
<td>182</td>
<td>277.0</td>
</tr>
</tbody>
</table>

Mode

<table>
<thead>
<tr>
<th>F (Between calvings)</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.8</td>
<td>3.4*</td>
</tr>
</tbody>
</table>

* P > 0.01 < 0.05.

Size of dam

A significant correlation of 0.23 ± 0.14 was obtained between the length of gestation (unadjusted for calving sequence) and heart girth on 92 dams. When the length of gestation was adjusted for sex and calving sequence, and heart girth was adjusted to a mature equivalent, the correlation was non-significant.

Correlation of gestation length and birth weight of calf

The correlation of gestation length and birth weight for 76 calves was 0.61 ± 0.09 in the unadjusted data, whereas for the sex adjusted data it was 0.52 ± 0.10.

Effect in inbreeding

The effect of inbreeding on the length of gestation was estimated from the intrasire partial regressions of gestation length on the inbreeding of the calf,
holding the inbreeding of the dam constant, (column 3, table 3) and on the inbreeding of the dam, holding the inbreeding of the calf constant, (column 4). Cows were inbred up to 25 percent and the calves up to 31 percent. The regressions did not show a significant departure from homogeneity in either column. The average intrasire regression for each column was non-significant.

**Heritability of the length of gestation**

The length of gestation was adjusted for sex and calving sequence before studying its heritability. The paternal half-sib correlation (intrauterine interval of calves sired by the same sire but carried by different dams), maternal half-sib correlation (intrauterine interval of calves carried by the same dam in different pregnancies, sired by different sires), intrasire regression of offspring on dam (the number of days the calf is carried by its dam on the number of days the dam was carried as a calf by her dam), and full-sib correlation (intrauterine interval of calves by the same sire and dam, carried by the same dam in different pregnancies) were used to estimate the heritable part of variation in the length of gestation and the relative importance of the genetics of the calf and of the dam. The correlations and regression used in this analysis are given in table 4.

Since a few sires were used on a large number of cows, the maternal half
sib correlation was studied in a population of paternal half-sibs. The estimate of maternal half-sib correlation in this case was 0.23 ± 0.08. From this the maternal half-sib correlation in a random bred population was estimated as 0.29 ± 0.08.

A paternal half-sib correlation could arise through partial similarity in the genotypes of the calves. A maternal half-sib correlation could result not only from a like degree of autosomal genotypic similarity in the calves but also from additional similarity due to common sex-linked genes and common maternal factors (cytoplasmic and uterine) in maternal half-sibs. If it is assumed that length of gestation is not dependent on major sex-linked genes then the difference between the maternal and paternal correlations should give an estimate of the maternal effects. The genotypic similarity of the calves whose records are used in these correlations would, on the average, result from one-fourth of the gene effects classified as additive and about one-sixteenth of those classified as epistatic deviations from the additive scheme (Wright, 1935). Intrasure regression of offspring on dam would be composed of one-half of the additive and about one-fourth of the epistatic fraction of variance acting through the genotype of the calf and a similar fraction acting through the hereditary maternal characteristics. Correlation of the full-sibs

\[ r = r_m + r_p - r_m r_p \]

where:

- \( r \) = correlation of maternal half-sibs in random bred population.
- \( r_m \) = correlation of maternal half-sibs in a population of paternal half-sibs.
- \( r_p \) = correlation of paternal half-sibs in a random bred population.

### Table 4. Correlation Coefficients and the Breakdown of the Variance into Potential Biological Components

<table>
<thead>
<tr>
<th>Relationship between calves</th>
<th>No.</th>
<th>Correlation coefficient</th>
<th>Potential biological components</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Calf1</td>
</tr>
<tr>
<td>Paternal half-sibs</td>
<td>348</td>
<td>0.08**</td>
<td>( g_s^2 + i_s^2 + d_s^2 + e_s^2 )</td>
</tr>
<tr>
<td>Maternal half-sibs</td>
<td>144</td>
<td>0.29**</td>
<td>( g_d^2 + i_d^2 + d_d^2 + e_d^2 )</td>
</tr>
<tr>
<td>Regression of offspring on dam</td>
<td>108</td>
<td>0.19*</td>
<td>( g_o^2 + i_o^2 )</td>
</tr>
<tr>
<td>Full sibs</td>
<td>34</td>
<td>0.41**</td>
<td>( g_o^2 + i_o^2 + d_o^2 + e_o^2 )</td>
</tr>
</tbody>
</table>

** P < 0.01.
* P > 0.01 < 0.05.
would be comprised of one-half of the additive, one-fourth epistatic and one-fourth dominance deviations acting through the calf and all of the hereditary and "permanent" non-hereditary maternal effects.

Since there were only four of these relationships (correlations and regression) and the number of biological components to be determined was seven (table 4), it was not possible to solve the equations simultaneously without reducing the number of unknowns. To do this the "permanent" non-hereditary effects and the dominance deviations in the dam were lumped together and it was assumed that there were no epistatic effects operating through the dam or the calf. On this basis the additive scheme accounted for

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Percentage of variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex of calf</td>
<td>28.6</td>
</tr>
<tr>
<td>Sex X calving sequence</td>
<td>0.1</td>
</tr>
<tr>
<td>Genotype of calf within sexes</td>
<td></td>
</tr>
<tr>
<td>a. Additive</td>
<td>32.0</td>
</tr>
<tr>
<td>b. Dominance deviations</td>
<td>16.0</td>
</tr>
<tr>
<td>Permanent maternal characteristics</td>
<td></td>
</tr>
<tr>
<td>a. Additive</td>
<td>6.0</td>
</tr>
<tr>
<td>b. Dominance deviations and permanent environment</td>
<td>15.0</td>
</tr>
<tr>
<td>Residual</td>
<td>2.3</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
</tr>
</tbody>
</table>

32 percent of the variation ascribed to the calf itself and the variance due to dominance deviations from the additive scheme explained another 16 percent of the variation assignable to the calf. The genotype of the calf (within sexes) was thus responsible for 48 percent of the variance. Maternal characteristics were responsible for 21 percent of the variance—six percent additive gene effects, and 15 percent permanent environment and dominance deviations.

Table 5 shows the relative importance of all the genetic and environmental sources of variation analyzed on the basis of the assumptions given.

Discussion

The results show very clearly that male calves are gestated longer than females. Analysis of the data within the sexes indicated a significant effect of calving sequence on gestations of female calves but not of males. The reason for this is not clear. It may be that there is a maximum gestation
length compatible with viability and that the male calves are closer to this maximum by virtue of their sex. Calving sequence, therefore, may not have an appreciable effect over and above this characteristically greater length of gestation for living male calves.

Birth weight and the length of gestation have a high positive correlation. This study throws no light on the causal relationship of the two characteristics. An earlier study in sheep by Chapman (1931) showed that a significant positive correlation between the length of gestation and birth weight became smaller and insignificant when the direct effects of age and weight of dam, and number born on birth weight were removed. From this it could be postulated that variation in length of gestation does not have a direct effect on variation in birth weight. Hence, common causes may be considered as responsible for variation in both of them. Any factor causing a delay in parturition should also cause an increase in the birth weight by allowing a longer time for growth of the fetus (Wright, 1934). Birth weight on the other hand, may ultimately become a factor in bringing about parturition by virtue of a direct effect of size or weight of the fetus upon the parturition mechanism.

The breakdown of variation into its biological components is only approximate because of the large sampling errors of the correlation coefficients, and because the expected fractions due to additive gene effects and dominance and epistatic deviations from the additive scheme have not been established experimentally but rest on certain assumptions. Based on these assumptions and assuming further that the effects of the dam and of the fetus are independent of each other, it may be concluded that the combined heredity of the calf (excluding sex) and the dam was responsible for 50–70 percent of the total variance out of which 38 percent was due to additive gene effects. Genotype (including sex) of the calf was responsible for 77 percent of the variance. On the basis of these figures the genotype of the calf is about three times as important as the characteristics of the dam. Some workers have emphasized the importance of the dam whereas others have stated that genotype of the calf is all important (Rife et al, 1943, Rife, 1948). The results of this study point to the influence of the dam on the length of gestation through two channels—through her own characteristics and through her contribution of a sample half of her genes to the fetus. Maternal characteristics were responsible for 21 percent of the variation and in addition the dam’s genetic contribution to the similarity of her calves accounted for eight percent. Thus the similarity in the gestations of the same cow, i.e. "repeatability," would be expected to be 29 percent if the cow were bred to a different bull for each calving. If the cow were bred to the same sire each time this "repeatability" would be increased to 41 percent (full sib $r = 0.41$).
How the genotypes of the calf or the maternal characteristics affect the length of gestation is not known.

If it were desirable to change the length of gestation in cattle it should be possible to do so with such high heritability of gestation period. It is impossible to say how much change in the length of gestation could occur without affecting the survival of the fetus, which may in turn limit the modification possible in the length of gestation period.

Summary

The average length of 384 gestation periods was 278.2 days with a standard deviation of 4.8 days. Male calves were carried a significantly longer period of time than females. The order of calving had a significant effect in the female calves but not in the males. There was a positive correlation between the length of gestation period and the heart girth measurement. No effect of year and season of calving on the length of gestation was indicated. There was a highly significant positive correlation between the length of gestation and the birth weight of the calf. Neither the inbreeding of the dam nor the inbreeding of the calf had a significant effect.

The genotype of the calf was responsible for 48 percent of the total variance in sex adjusted records, of which 32 percent was due to the additive gene effects and 16 percent due to dominance deviations. The dam was responsible for 21 percent of the variance (six percent due to the additive gene effects and 15 percent due to permanent environmental causes and dominance deviations effective directly through the dam). Characteristics of the calf seemed about three times as important as the characteristics of the dam.

Literature Cited