Interrelationships Between Production and Reproductive Diseases in Holstein Cows. Age and Seasonal Patterns

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ABSTRACT
Influences of age and season on occurrence of dystocia, retained placenta, metritis, cystic follicle, and luteal cyst were studied retrospectively. The 6 yr of data were from 2960 lactation records of 1401 registered Holstein cows from 20 commercial herds that participated in the dairy herd health program of the Ontario Veterinary College.

For each disease, odds ratio analyses compared the risk of disease in each age group to the risk in all other age groups pooled. The following age groups were at increased risks of diseases: dystocia, 2 to less than 4 yr; retained placenta and metritis, 7 to less than 10 yr and 10 or more yr; cystic follicle and luteal cyst, 10 yr or more. For all diseases except dystocia, age 2 to less than 4 yr was at decreased risk.

Formal statistical methods were used to test for unimodal seasonal patterns in monthly calvings, in monthly disease incidence (number of diagnoses), and in risk (lactational incidence rate) of disease according to month of calving. There were the following significant peaks: fall calvings in the age group 2 to less than 4 yr, summer-fall risk of metritis, fall-winter incidence of dystocia and metritis, and fall-winter risk of dystocia.

INTRODUCTION
Age and seasonal patterns are basic to descriptive epidemiology of disease (22). Knowledge of variations in risk of disease according to age or to season may provide clues to causes of disease. Some reasons for seasonal distributions of disease risk include the direct effect of climatic factors or changes in environment (management, housing, feed, pests, etc.) resulting from changes in climate.

The objective of this study was to test for age and seasonal patterns in the occurrence (incidences) and risk (incidence rates) of dystocia/assisted delivery (AD), retained placenta (RP), metritis (MET), cystic follicle (CF), and luteal cyst (LC).

METHODS
The data set was the full set of 2960 Holstein lactation records described in (7).

Relationships between age and disease were studied by odds ratio analyses (9). The odds ratios were calculated by comparing each age group to all other age groups pooled. No adjustment was made for the 43% of all calvings in the youngest age group that dominated the three pooled control groups of which it was a member.

All calvings from 1970 to 1974 were pooled, and the number of calvings in each of the 12 calendar months were tested for a seasonal pattern. The test was the \( \chi^2 \) test for goodness-of-fit of a uniform distribution. The expected value for each calendar month was set as 1/12 of the total calvings without adjustment for varying length of month. (The 39 calvings in 1975 were excluded because of a study design bias in favor of early calving months that year.)

Edwards (4) described a simple test for detecting unimodal cyclic patterns (hereafter referred to as the \( n/2 \) test). According to this test, if the \( n/2 \) largest of a group of \( n \) time-ordered observations are adjacent, then a unimodal temporal pattern is likely (\( n \) is the number of points in the graph, the number of areas in the histogram, the number of classes of the time variable, not the total sample size of
the observations summarized by the graph. The n/2 test was used to test for seasonal trends in the age-group-specific data relating number of calvings to month of calving.

A more formal Edwards test for cyclic trends in events (4) was used to test for seasonal patterns in disease incidence. Data from all years and all ages were pooled. No adjustments were made for length of month, leap year, or 1975. Observations are considered to have been placed by months around the circumference of a circle of unit radius. The d indicates the distance between the true geometric center of the circle and the center of gravity (average location) of the data points. The $\theta^*$ is the direction of the center of gravity ($\theta^* = 0^\circ$ corresponds to January 1). The $\chi^2$ tests the significance of the distance of the center of gravity of the data points from the center of the circle.

The Walter and Elwood (26) test is a modification of the Edwards test. The modification allows variation in the population at risk to be taken into consideration. The Walter and Elwood test is suitable for data on incidence rate, whereas the Edwards test is for incidence data. The Walter and Elwood test for seasonality of events was used to test for seasonal patterns in lactational risk (incidence rate) of disease according to month of calving. The test also was used to determine if cows in the age group 2 to less than 4 yr had a seasonal risk of AD. The tests took into account population at risk, leap year, and length of month.

**RESULTS**

The age-group-specific odds ratios of disease are in Table 1. The risks of all diseases except AD appeared to increase with age. All $\chi^2$ tests for homogeneity of odds ratios across age-groups (log odds method, 9) were significant, indicating that for each disease, cows in at least one age group had a significantly different risk from risks of cows in the other age groups. Therefore, summary odds ratios were inappropriate. The odds ratios are read as follows: for the age group 2 to less than 4 yr and disease AD, the odds ratio was 1.49 and was significantly different from 1.00. Therefore, compared to all other cows, the youngest cows were 1.49 times more likely to have had AD. In contrast, the age group 4 to less than 7 yr had only half the risk of AD (odds ratio = .50) compared to all other cows.

The monthly number of calvings peaked in the fall ($P<.001$). The n/2 test on the data in Figure 1 suggests that there was a fall peak in calvings in the youngest age group and no seasonal pattern for the other age groups. With n = 12, significance is $P<.004$.

Only AD and MET had significant seasonal patterns (Figure 2).

The results of the Edwards test of monthly

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**TABLE 1. Age-group-specific odds ratios of disease (2960 Holstein lactations; 20 ROP-herd health herds; 1970 to 1975).**

<table>
<thead>
<tr>
<th>Disease</th>
<th>2--&lt;4</th>
<th>4--&lt;7</th>
<th>7--&lt;10</th>
<th>$\geq$10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assisted delivery</td>
<td>1.49*</td>
<td>.50*</td>
<td>1.26</td>
<td>1.31</td>
</tr>
<tr>
<td>Retained placenta</td>
<td>.46*</td>
<td>.96</td>
<td>1.99*</td>
<td>2.87*</td>
</tr>
<tr>
<td>Metritis</td>
<td>.53*</td>
<td>1.08</td>
<td>1.58*</td>
<td>2.49*</td>
</tr>
<tr>
<td>Cystic follicle</td>
<td>.39*</td>
<td>1.22</td>
<td>2.05</td>
<td>2.27*</td>
</tr>
<tr>
<td>Luteal cyst</td>
<td>.32*</td>
<td>1.29</td>
<td>1.27</td>
<td>4.80*</td>
</tr>
</tbody>
</table>

*Different from 1.00 at $P<.05$.  

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Figure 1. Number of calvings in each month by age group (2960 Holstein lactations; 20 ROP-herd health herds; 1970 to 1975).  

The significantly eccentric centers of gravity and the $\theta^*$ of AD and MET indicate winter and fall peaks in incidence, respectively.

The results of the Walter and Elwood tests are in Table 3 and are interpreted similarly to the Edwards test. These tests and the graphs indicate that cows which calved in the fall-winter and summer-fall were at increased risk of AD and MET, respectively, in their lactations.

The age-specific incidence rates of AD are in Figure 3. There was no seasonal pattern of AD in the youngest cows (Walter and Elwood test, $P>.10$). A fall peak in risk for cows at least 4 yr of age is suggested in the graph but cannot be verified by the n/2 test.

**DISCUSSION**

The tendency has been to report seasonal patterns on the strength of inspection of incidence or, at best, incidence rates. The $\chi^2$ test has an advantage over simple inspection in that it is a standard and formal test. However, the $\chi^2$ test ignores the ordering of the data, it tests using more degrees of freedom than is probably necessary to detect biologically meaningful trends (4), and it neither specifies the number of cycles nor points out their peaks. Thus, the $\chi^2$ test is conservative, and it is still necessary to inspect the data to detect the pattern.

The n/2 test offers advantages over the $\chi^2$ test in that the ordering of the time periods is critical, it is especially easy to use on graphs and histograms, and unimodal cyclic patterns are specified (if this is not appropriate, the test should not be used). As with the $\chi^2$ test, the peak period is determined by inspection.

The Edwards test and Walter and Elwood test are complicated to use, but they offer the advantage over the n/2 test of specifying the peak time, and the significance can be determined.

Risk of AD was increased significantly for the youngest age group (odds ratio = 1.49). These findings are consistent with (5, 16, 18, 23, 24).

**TABLE 2. Edwards' test for cyclic trends in events, for monthly disease incidence (2960 Holstein lactations; 20 ROP-herd health herds; 1970 to 1975).**

<table>
<thead>
<tr>
<th>Disease</th>
<th>$d$</th>
<th>$\chi^2$</th>
<th>$df$</th>
<th>$P$</th>
<th>$\theta^*$</th>
<th>(mo)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assisted delivery</td>
<td>.111</td>
<td>14.70</td>
<td>2</td>
<td>&lt;.001</td>
<td>333°</td>
<td>(Dec)</td>
</tr>
<tr>
<td>Retained placenta</td>
<td>.0540</td>
<td>4.89</td>
<td>2</td>
<td>&lt;.100</td>
<td>274°</td>
<td>(Oct)</td>
</tr>
<tr>
<td>Metritis</td>
<td>.0674</td>
<td>14.81</td>
<td>2</td>
<td>&lt;.001</td>
<td>271°</td>
<td>(Oct)</td>
</tr>
<tr>
<td>Cystic follicle</td>
<td>.0398</td>
<td>4.84</td>
<td>2</td>
<td>&lt;.100</td>
<td>328°</td>
<td>(Nov)</td>
</tr>
<tr>
<td>Luteal cyst</td>
<td>.0566</td>
<td>2.43</td>
<td>2</td>
<td>&gt;.100</td>
<td>10°</td>
<td>(Jan)</td>
</tr>
</tbody>
</table>

$^a$ $d =$ Distance between true center of unit radius circle and the center of gravity of the data, arranged by months around the circumference.

$^b$ $\theta^* =$ Direction of the center of gravity of the data ($0° =$ January 1).
Table 3. Walter and Elwood's test for seasonality of events with a varying population at risk applied to lactational incidence rates of disease according to month of calving (2960 Holstein lactations; 20 ROP-herd health herds; 1970 to 1975).

<table>
<thead>
<tr>
<th>Disease</th>
<th>(d^a)</th>
<th>(\chi^2)</th>
<th>df</th>
<th>(p)</th>
<th>(\theta^b) (mo)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assisted delivery</td>
<td>.0834</td>
<td>8.19</td>
<td>2</td>
<td>&lt;.025</td>
<td>342° (Dec)</td>
</tr>
<tr>
<td>Retained placenta</td>
<td>.0362</td>
<td>2.19</td>
<td>2</td>
<td>&gt;.100</td>
<td>240° (Aug)</td>
</tr>
<tr>
<td>Metritis</td>
<td>.0439</td>
<td>6.23</td>
<td>2</td>
<td>&lt;.050</td>
<td>245° (Sept)</td>
</tr>
<tr>
<td>Cystic follicle</td>
<td>.0162</td>
<td>.794</td>
<td>2</td>
<td>&gt;.100</td>
<td>23° (Jan)</td>
</tr>
<tr>
<td>Luteal cyst</td>
<td>.0522</td>
<td>2.06</td>
<td>2</td>
<td>&gt;.100</td>
<td>45° (Feb)</td>
</tr>
</tbody>
</table>

\(d^a\) = Distance between the true center of a unit radius circle and the center of gravity of the data, arranged by months around the circumference.

\(\theta^b\) = Direction of the center of gravity of the data (\(\theta^b\) = January 1).

Calving age was significantly related to occurrence of RP; the risk increased steadily across the age groups from an odds ratio of .46 in the youngest to 2.87 in the oldest cows. These findings are in contrast to (6) in which the control group was hospital-based rather than based on the hospital service area, and to (5). However, the rising risk of RP with age agrees with (3, 8, 14).

The occurrence of MET in a lactation was significantly related to calving age. The odds ratios rose steadily with age from .53 in the youngest to 2.49 in the oldest age group. This is in contrast to (6).

Age was also a significant factor in occurrence of CF in a lactation. The odds ratios increased steadily with increasing age group. These findings agree with (15) but are in contrast to (6).

There was also a significant relationship between calving age and LC; the risk tended to increase with age.

In general, the risk of disease increased with advancing age; the only exception was the high risk of AD in the youngest group. The disparate age risk pattern for AD compared to the other diseases is an argument against AD having been a major risk factor in the development of the other diseases.

We reported different age and seasonal patterns for RP, MET, and CF in (6), and we point out several differences between the two studies. The earlier study was based on 5,990 Ontario Veterinary College Medical Case Abstract cases of 10 diseases (RP, endometritis, metritis, pyometra, and CF, and abomasal displacement, mastitis, ketosis, milk fever, and ovarian hypofunction). All data records were cases of disease. In contrast, in the current study 70% of the data records were free of all five of the diseases. In the earlier study the cases were from approximately the same time as the current study, but the cows were from a
The age distributions of Holstein records in the earlier and current study, respectively, were: 2 to less than 4 yr, 21% vs. 43%; 4 to less than 7 yr, 45% vs. 35%; 7 to less than 10 yr, 24% vs. 16%; at least 10 yr, 10% vs. 6%. Thus, the former odds ratios were calculated for an older population of cows, each cow had at least one disease, and there was much greater variability in herd of origin (including programs for disease prevention). Finally, the seasonal patterns in the earlier study were reported on the basis of visual inspection of plots of proportional monthly incidence (monthly incidence disease A ÷ monthly incidence all diseases), and the data set included 577 (9.6%) non-Holstein cases. In contrast, the current study used formal statistical methods with consideration of the true population at risk.

The youngest age group was the largest and the only age group with a significant calving season. Thus, the overall fall calving peak was apparently due to the influence of the 2 to less than 4 yr old cows.

Calving and AD are concurrent events, and both the number of calvings and the incidence of AD peaked in the fall or early winter. Also, there was an overall fall-winter peak in the risk of AD. To interpret the increase in risk of AD by season, consideration of the effects of age simultaneously on calving and the risk of AD is necessary. The youngest age group included the most cows and was the only age group with a seasonal (fall peak) calving pattern and with an increased risk of AD (odds ratio = 1.49). The Walter and Elwood test for this age group, however, showed that it had no significant seasonal risk pattern. Therefore, the seasonal risk for AD occurred in the older cows and was strong enough to be detected in the full data set in spite of the dampening effect of the calving season pattern in the age group with the highest age-specific risk. In the youngest cows there was a nonseasonal age-specific risk of AD (shown by the generally higher incidence rate for the youngest cows in each month, compared to the older cows; Figure 3). In contrast, in cows at least 4 yr of age there was a sparing effect due to age but a seasonal pattern of AD risk.

The reasons for the seasonal effect on risk of AD are unknown but might have to do with the onset of the stabling period and winter. Stabling and winter can mean at least no grazing, less exercise, different feed, greater energy expenditure for maintenance, less sunlight, and more crowding.

No seasonal incidence rate pattern for AD was in a Swedish study (5), but a midwestern US study (16) reported more AD from October to March (in agreement with these findings).

Calving and RP are essentially concurrent events. However, in spite of the seasonal calving pattern, there was no seasonal incidence pattern for RP. This might suggest the possibility of a seasonal risk pattern with a decreased risk during the months of increased calvings. However, no seasonal risk pattern was detected. This may be explained in part in that while the patterns were statistically nonsignificant, the highest monthly incidences of RP were in the fall months and the centers of gravity in the Edwards and Walter and Elwood tests were in the fall quadrant. Perhaps, though, age effects are a more important explanation. The age group that had a seasonal calving pattern was the youngest, and this was the age group that had significantly decreased risk of RP (odds ratio = .46). Therefore, failure to detect a seasonal risk pattern for RP is reasonable.

The lack of a seasonal pattern for RP agrees with (5, 6) but disagrees with other papers, among which there is disagreement regarding the identity of the peak season (3, 8, 14, 20, 25, 27).

Of all MET diagnoses, 64% were in the same or next calendar month as calving, and 15% more were in the month after that. Therefore, most MET diagnoses were less than 3 mo after calving. There was a seasonal calving pattern, so a seasonal MET incidence pattern (with incidence peaking around or just after the calving peak) would at first have seemed a reasonable finding. However, the age group responsible for the calving season had a decreased risk of MET (odds ratio = .53, 2 to less than 4 yr), and the high-risk oldest two groups (odds ratio = 1.58, 7 to less than 10 yr; odds ratio = 2.49, ≥10 yr) had no seasonal calving pattern. Age effects should have worked against a seasonal incidence pattern. Also, 95% of the 141 MET cases that were also RP cases were diagnosed less than 3 mo after calving, so the RP-MET cases were even more closely time-linked to calving. Since there was no seasonal RP pattern, the RP link
also would have worked against the expression of a MET incidence pattern. In spite of the effects of age, RP, and calving season, there was a seasonal MET incidence with the peak season being the fall-winter. This implies that there must have been a strong pattern of increased risk of MET in lactations begun with summer-fall calvings.

Most cases of MET were diagnosed within a few months of calving, but most were not diagnosed in the same month. The shift in seasons for MET incidence compared to calving month-risk is evidence of this. It is difficult to explain why lactations begun with summer or fall calvings would be at increased risk of uterine infection. It may be that it is not the summer and fall calvings that are important but rather the following fall and winter open, service periods. If this is correct, then it is possible that, as with AD, the seasonal risk is referable to the winter and stabling. It is also possible that a study specifically designed to distinguish between postpartum MET and MET occurring later in the lactation could assist in clarifying the seasonal patterns (there is a tendency for later diagnoses to be "endometritis" — apparently implying a less severe condition).

The seasonal MET patterns agree with (6, 19, 21).

Both CF and LC were time-linked poorly to calving. Significant seasonal patterns in incidence or risk were not detected in either disease. This lack of seasonal patterns contrasts with repeated statements that the incidence or risk of cystic ovary is greatest in the winter months (1, 2, 6, 10, 11, 12, 13, 17, 19, 21, 28). We have no explanation for these differences.

CONCLUSIONS

Age at calving influenced the risk of disease in the lactation. The youngest cows had an increased risk of AD, whereas the risks of RP, MET, CF, and LC increased with advancing age. The RP, CF, and LC diagnoses had no seasonal patterns. Calvings in the late fall and early winter had increased risk of AD. Lactations begun in the late summer to early fall had increased risk of MET, and the MET case numbers peaked in the fall-winter season.

REFERENCES


