PEER REVIEWED

Body Temperature and White Blood Cell Count in Postpartum Dairy Cows

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Abstract

The objectives of this study were to evaluate rectal temperature as a diagnostic tool in postpartum dairy cows and to compare body temperature and white blood cell counts in cows that remained healthy with those that became ill. Fifty Holstein dairy cows had complete physical examinations every four hours and a complete blood count once daily for the first 10 days after calving. Illness was defined as a rectal temperature of at least 104.5°F (40.3°C) in the absence of other clinical signs, or a clinical sign of illness other than increased temperature. Fifteen cows were diagnosed with illness and 35 remained healthy throughout the 10-day study period. No difference between mean rectal temperatures of cows that became ill and cows that remained healthy was found. Among cows that remained healthy, 23 (66%) had a rectal temperature of at least 103.1°F (39.5°C) at least once, 17 (49%) had a rectal temperature of at least 103.5°F (39.7°C) at least once and six (17%) had a rectal temperature of at least 104°F (40°C) at least once during the study period. Over the first three days after calving, mean total white blood cell counts and neutrophil counts were higher in healthy cows than in cows that became ill. Because rectal temperatures were frequently elevated in healthy postpartum cows, it was concluded that rectal temperature has low specificity for diagnosing illness in postpartum dairy cows in the absence of other clinical signs.

Keywords: bovine, dairy, postpartum, rectal temperature

Résumé

Les objectifs de cette étude étaient d'évaluer le rôle de la température rectale comme outil diagnostic chez les vaches laitières en postpartum et de comparer la température corporelle et le nombre de leucocytes chez des vaches qui restaient en bonne santé et chez celles qui devenaient malades. Un total de 50 vaches laitières Holstein étaient soumises à un examen physique complet à tous les quatre heures et à un hémogramme sanguin complet une fois par jour lors des premiers 10 jours suivant le vêlage. L'état de maladie était déclaré lorsque la température rectale dépassait 40.3°C (104.5°F) si aucun autre signe clinique n'était présent ou s'il y avait un signe clinique de maladie autre qu'une température élevée. L'état de maladie a été diagnostiqué chez 15 vaches alors que 35 vaches sont demeurées en santé pendant la période d'étude de 10 jours. Il n'y avait pas de différence au niveau de la température rectale moyenne chez les vaches qui sont devenues malades et chez celles qui sont restées en santé. Parmi les vaches qui sont restées en santé, 23 (66%) ont eu une température rectale de plus de 39.5°C (103.1°F) au moins une fois, 17 (49%) ont eu une température rectale de plus de 39.7°C (103.5°F) au moins une fois et six (17%) ont eu une température rectale de plus de 40°C (104°F) au moins une fois durant la durée de l'étude. Pendant les trois premiers jours suivant le vêlage, le nombre moyen de leucocytes et de neutrophiles était plus élevé chez les vaches saines que chez les vaches qui sont devenues malades. Parce que la température rectale était fréquemment élevée chez les vaches en santé après le vêlage, on en conclut que la température rectale a une spécificité faible pour diagnostiquer la maladie chez les vaches laitières en postpartum lorsque d'autres signes cliniques sont absents. Le nombre plus élevé de neutrophiles après le vêlage chez les vaches saines par rapport aux vaches qui sont devenues malades pourrait indiquer le déploiement d'une réponse immunitaire appropriée suivant les changements chez les vaches saines après le vêlage. Chez les vaches qui sont devenues malades, les neutrophiles ont peut être été mobilisés à des sites immunologiquement sollicités comme l'utérus et la glande mammaire.

Introduction

The first days to weeks after calving are a time of physiological change and adaptation for high-producing dairy cows. The postpartum period, also called the transition period, is the time of highest risk for development of disease in dairy cows as 75% of disease in dairy cows occurs in the first month after calving.[12] In addition to preventive measures, such as appropriate nutrition and excellent hygiene, close monitoring of recently calved cows has been recommended as a tool to enable the earliest possible intervention when illness develops in order to prevent more serious sequelae.[1,7] For such measures to be effective, accurate guidelines must be available to differentiate normal clinical findings from those which indicate probable illness. Little attention has been directed toward determining what temperature is normal in healthy cows in the immediate postpartum period. Without this information, it is impossible to determine what temperatures are abnormal. One objective of this study was to describe normal rectal temperatures in healthy postpartum cows, and compare rectal temperatures between postpartum cows that developed clinical disease and those that did not.

The increased risk of illness in postpartum dairy cows has been attributed to decreased immune function around the time of calving.[13,15] In order to obtain information about immune function in postpartum dairy cows, white blood cell (WBC) count was measured daily during the first 10 days postpartum, which is a more frequent measurement than in previous studies. The final objective of this study was to frequently measure WBC counts in the immediate postpartum period to define normal WBC counts in postpartum dairy cows and compare them with WBC counts in cows that developed clinical disease.

Materials and Methods

Study Animals

All Holstein cows that calved at the North Dakota State University Dairy Research Unit between September 10, 2005 and April 15, 2006 were scheduled to be enrolled in the study, which was approved by the Institutional Animal Care and Use Committee at North Dakota State University. Cows were housed in individual 10 ft x 10 ft (3 m x 3 m) pens constructed of portable fencing panels in an unheated barn, and had *ad libitum* access to water and a total mixed ration formulated to meet nutrient requirements for lactating dairy cows. Rolling herd average milk production during the study period ranged from 21,791 lb (9905 kg) to 23,013 lb (10,460 kg).

Study Procedures

Each cow had a complete physical examination performed every four hours, beginning within four hours after calving, until 60 examinations had been performed over a 10-day period. During examination, cows were either unrestrained or caught with a rope halter and tied to the side of the stall. At each physical examination, variables recorded included attitude (alert/quiet/depressed), eye position (normal/sunken), ear temperature by palpation (warm/moderate/cool), heart rate in beats per minute counted during auscultation of the left cranioventral chest wall for 15 seconds, lung sounds evaluated by auscultation of the left and right lung fields (increased/normal/decreased), rumen contractions per minute measured by auscultation of the left paralumber fossa for one minute, rectal temperature measured using an M525/550 electronic thermometer[a] inserted rectally for at least one minute, udder appearance/palpation (normal/abnormal), and vaginal discharge (no discharge/non-malodorous discharge/malodorous discharge). Examinations were performed at 12 am, 4 am, 8 am, 12 pm, 4 pm and 8 pm each day. Cows were milked twice daily, following 4 am and 4 pm examinations.

Beginning on the day of calving, a blood sample was collected each day at 4 am and 4 pm following completion of the physical examination. Blood was collected into a vacuum glass tube containing EDTA as an anticoagulant by venipuncture of the coccygeal artery or vein using a 21-gauge, 1-1/2-inch needle. This procedure produced significant bruising on the ventrum of the tail in the first study cow; thereafter, blood samples were collected only once daily from each cow at 4 pm, following completion of the physical examination. A complete blood count was performed on each blood sample within two hours of collection using a Hemavet 950 FS analyzer.[b] Proper calibration of the analyzer was confirmed each day prior to sample analyses using a control with known hematological values.[c]

Before beginning the study, it was determined that cows would be considered ill if they developed clinical signs of illness aside from increased rectal temperature, such as foul-smelling vaginal discharge (metritis), muscle weakness or recumbency without signs of injury or infectious disease (milk fever), abnormal gait (lameness), abnormal milk (mastitis), failure to expel the placenta within one day after calving (retained placenta) or auscultation of a gas-filled abomasum displaced from the ventral abdomen (displaced abomasum). All diagnosis of illness was made or confirmed by the herdsman at the farm, who was also one of the investigators. Any rectal temperature less than 104.5°F (40.3°C), in the absence of other abnormal clinical findings, was not considered a sign of illness. The investigators did not want to put the cows' health at risk by not treating those with a rectal temperature of 104.5°F or greater, so a temperature of 104.5°F or greater was considered a sign of illness, even in the absence of other clinical signs. Udder edema was not considered a sign of illness. Description of the clinical course of disease was not an objective of this study; consequently, cows that became ill during the study period were removed from further participation at the time of diagnosis.

Statistical Analyses

Data were analyzed using JMP and SAS 9.1 statistical software.[d] Statistical comparisons were made between the healthy-cow group (cows that did not develop clinical signs of illness during the study period) and the sick-cow group (cows that developed clinical signs of illness during the study period). Between-group comparisons of repeated measurements of continuous variables, such as temperature and WBC count, were performed using multivariate analysis of variance, which accounts for repeated measurements over time. Between-group comparisons of milk production at first test, days-in-milk (DIM) at first test, and days until pregnancy was done using analysis of variance, as were comparisons of temperatures among healthy cows by months and seasons of the year. Between-group comparisons involving the ordinal variables of lactation number and the number of cows culled from each group were done using the Chi-Square test or Fisher's exact test, depending on the number of levels of the variable.

To evaluate rectal temperatures by time of day, the following linear mixed model was performed based on a normal theory linear model.

$$y_{ij} = \mu + b_{ij} + \tau_j + \varepsilon_{ij}$$

Note that y_{ij} is the observation of jth time of day on the response variable taken under the ith cow; μ is overall mean; b_{ij} is the random effect associated with the ith cow at the jth time of day; τ_j is the effect of the jth time of day; and ε_{ij} is a random error term. The between-cows error, b_{ij}, are assumed to be independent and identically distributed as $N(0,\sigma_B^2)$. The within-cows error, ε_{ij}, are also assumed to be independent and identically distributed as $N(0,\sigma_W^2)$. The covariance structure for the within-cows effect is assumed to be the first-order autoregressive. These assumptions were investigated by the examination of residuals. The fitted model was judged to be adequate. Tukey's test was used to investigate the differences among the means for each time point.

Statistical significance was designated as $P \leq 0.05$ for all tests. For comparisons of variables by number of DIM, the first DIM was considered to begin at the first midnight after calving.

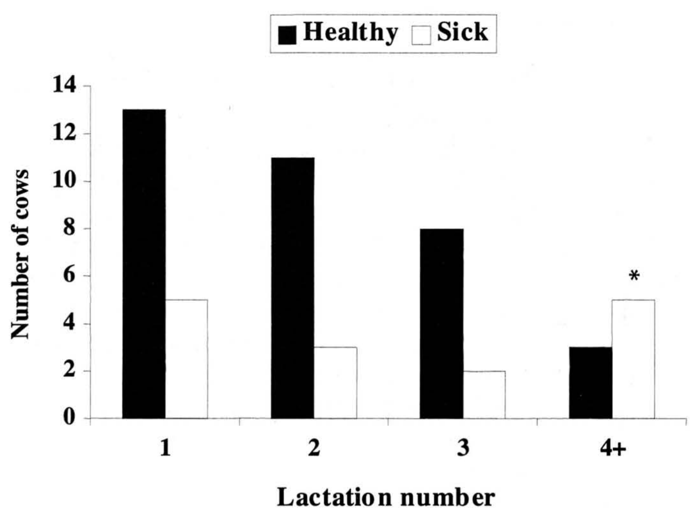
Results

Of the 53 cows that calved during the study period, 51 were enrolled in the study. One cow was not enrolled because she had mastitis at the time of calving, and one cow was not enrolled because she was temperamentally unsuitable for study procedures. One cow was initially enrolled in the study but removed after sustaining a serious injury within 24 hours of calving. Of the 50 cows retained for data analyses, 15 were diagnosed with an illness and 35 remained healthy throughout the 10-day study. Of the 35 cows that remained healthy during the study period, only one was treated for illness during the second 10 days-in-milk; she developed lameness on day 11 after calving and a displaced abomasum four days later. Illnesses diagnosed during the study period and the number of cows with each condition are given in Table 1. No cows reached a rectal temperature of 104.5°F in the absence of other clinical signs; all cows were diagnosed with illness based on clinical signs other than increased rectal temperature. The distribution of sick cows by lactation number is given in Figure 1. Cows in their fourth or greater lactation were more likely to be diagnosed with an illness than cows with fewer than four lactations (P=0.01).

Cows diagnosed with an illness during the study tended to have a higher rate of culling before the next lactation than healthy cows (28.6% vs. 11.4%, P=0.06).

Table 1. Primary diagnoses for cows that developed disease during the first 10 days-in-milk.

Condition	Number of cows affected
Displaced abomasum	2
Mastitis	2
Hypocalcemia	2
Retained placenta	4
Metritis	5
Total	15



* Cows in their fourth or greater lactation were significantly more likely to become sick than cows in their first through third lactations.

Figure 1. Numbers of cows that remained healthy (black bars) and cows that were diagnosed with an illness (white bars) during the first 10 days after calving, by lactation number.

For those cows that remained in the herd, the mean number of days until pregnancy was 156 for healthy cows and 165 for cows diagnosed with an illness; this difference was not statistically significant (P=0.72). Milk production at the first test of the lactation was significantly lower for sick cows than healthy cows (59.1 lb vs. 82.5 lb [26.9 vs 37.5 kg], P<0.01). Average DIM at the first test date for milk production was not different between sick cows and healthy cows (22.3 days vs. 23.6 days, P=0.74)

The number of cows in the sick-cow group for which data were recorded decreased as DIM increased due to cows being removed from the study as they were diagnosed. Consequently, there were not enough data to make meaningful statistical comparisons between the sick-cow and healthy-cow groups beyond the first five DIM. There was no significant difference (P=0.85) in mean rectal temperatures over the first five days after calving between healthy and sick cows. However, when compared with healthy cows, sick cows were significantly more likely to have at least one observed temperature greater than 103.1°F (39.5°C; P=0.04) or 103.5°F (39.7°C; P=0.04) in the first three DIM. Mean rectal temperature among healthy cows in this study did not vary significantly with month or season of the year (month: P=0.38, season: P=0.29). Mean rectal temperatures for sick cows and healthy cows at each daily observation time over the first five days after calving are shown in Table 2. Among healthy cows, mean rectal temperature was lower at 8 am than at 4 pm (P=0.04), but there were no significant differences between other time points. Mean rectal temperatures among healthy cows during the study period are shown in Figure 2. Differences in mean rectal temperature by time of day among sick cows did not achieve statistical significance (P=0.46). Among the cows that remained healthy during the study period, 23 (66%) had a rectal temperature of at least 103.1°F (39.5°C) at least once, 17 (49%) had a rectal temperature of at least 103.5°F (39.7°C) at least once, and six (17%) had a rectal temperature of at least 104.0°F (40°C) at least once. If only 4 am, 8 am and 12 pm observations are included, 12 cows (34%) had a rectal temperature of at least 103.1°F at least once, seven (20%) had a rectal temperature of at least 103.5°F at least once, and one had a rectal temperature of at least 104.0°F at least once. Table 3 shows the number and percentage of healthy cows with at least one measurement of rectal temperature of at least 103.1°F, 103.5°F and 104.0°F at each observation time during the study period. Figure 3 shows the number of healthy cows which had a rectal temperature of at least 103.1°F, 103.5°F and 104.0°F for each of the first ten DIM.

Table 2. Least square mean estimates of rectal temperature by observation time for healthy cows (n=35) and sick cows (n=15) measured each day for the first five days after calving.

Time	Temperature (°F)	
	Healthy cows	Sick cows[a]
12:00 am	101.68	101.93
4:00 am	101.73	101.66
8:00 am	101.61[b]	101.93
12:00 pm	101.64	101.77
4:00 pm	101.82[c]	102.00
8:00 pm	101.79	101.86

[a]There was no difference in mean temperature among times of day for sick cows.
[b,c]Mean temperature at 8 am was significantly lower than mean temperature at 4 pm among healthy cows.

The mean and range of values for WBC count, lymphocyte count and percentage, and neutrophil count and percentage in healthy and sick cows on days 1 through 5 after calving are given in Table 4. Mean WBC counts were compared for the first five days after calving and found to be lower in sick cows than healthy cows for the first three DIM (P=0.03). This difference was due to lower neutrophil counts in sick cows over the first three days after calving (P=0.03). Mean WBC counts in healthy cows for the first 10 days after calving are shown in Figure 4.

Discussion

The objective of this study was intensive measurement of rectal temperature and WBC counts in postpartum cows to determine normal levels and compare them with levels in cows that became ill. Previous studies examined rectal temperature in postpartum cows, although none monitored cows as frequently as this study. Previous studies measured temperature once daily, when the time of rectal temperature measurement was stated, it was between 5 am and 8 am.[11,21] Among healthy cows, although mean temperature at 4 pm was statistically higher than mean temperature at 8 am, the difference may not be clinically significant as the difference between the means was less than 0.3°F. This small difference in rectal temperature would be unlikely to affect diagnostic decision-making. Among sick cows, the range between the lowest and highest mean daily temperatures was greater than in healthy cows, but differences did not achieve statistical significance, probably due to the lower number of sick cows and/or higher variability in temperatures among sick cows.

The accuracy of classification of cows as sick or healthy is supported by the substantial difference in milk production between the two groups on the first test

Table 3. Number and percentage of healthy cows with at least one measurement of rectal temperature above 103.1°F, 103.5°F and 104.0°F at each observation time during the first 10 days after calving, and at any time during the study period.[a]

	12:00 am		4:00 am		8:00 am		12:00 pm		4:00 pm		8:00 pm		All Times	
Temperature (°F)	n	%	n	%	n	%	n	%	n	%	n	%	n	%
103.1	10	28	5	14	9	26	7	20	9	26	13	37	23	66
103.5	5	14	2	6	3	9	2	6	7	20	7	20	17	49
104.0	0	0	0	0	1	3	1	3	3	9	4	11	6	17

[a] A single cow may be included more than once in each column as events reported include all cows that achieved at least a certain temperature at each time (e.g. a cow that achieved a temperature of at least 104.0°F also achieved a temperature of at least 103.1°F and 103.5°F, and so is reported in all three rows within the column).

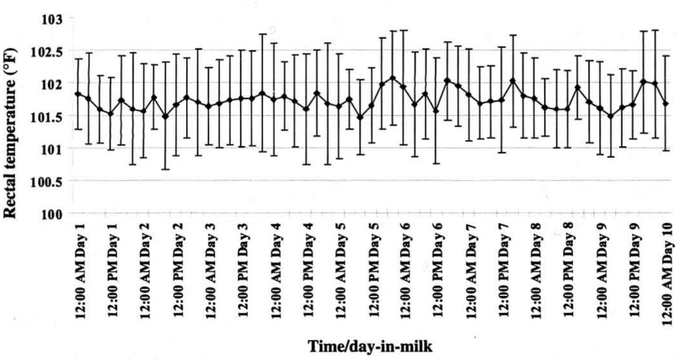


Figure 2. Mean rectal temperatures over time in healthy cows, beginning at the first 12 am measurement following calving. Bars indicate the standard deviation of each mean rectal temperature.

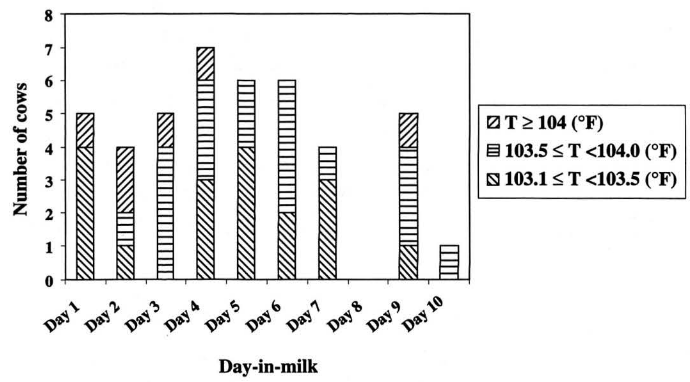


Figure 3. Number of healthy cows achieving certain rectal temperature (°F) levels at least once during each day-in-milk. Each day-in-milk is measured from 12 am to the following 12 am, with the first day-in-milk beginning at the 12 am following calving. Total number of cows is more than 35 as some cows had elevated temperatures on more than one day.

day after calving. Differences in culling rate between the two groups, although they did not quite achieve the a priori significance level of $P \leq 0.05$, also tended to support the study method of classifying cows as sick or healthy.

Several previous studies defined increased temperature in postpartum cows as 103.1°F.[3,4,21] In this study, mean temperatures between the sick and healthy cow groups were not found to be significantly different over the first five DIM. This finding should not be over-interpreted as the smaller number of sick cows and increased variability of temperatures in the sick-cow group may have contributed to the result. Additionally, four of 15 sick cows were diagnosed with metabolic or digestive diseases (milk fever or displaced abomasum) that would not be expected to have fever as a clinical sign, and four were diagnosed with retained placenta on the basis of physical appearance. On the other hand, sick cows were found to have a higher rate of occurrence of at least one temperature measurement greater than 103.1°F or 103.5°F in the first three days after calving, but healthy cows also regularly had temperatures above 103.1°F and 103.5°F, suggesting that temperature alone would not be a specific enough indicator of illness to be useful in a fresh-cow monitoring program. When measured at 8 am, nine of 35 (26%) of cows that did not become ill had at least one measured rectal temperature greater than or equal to 103.1°F, and three of 35 (9%) had at least one measured rectal temperature greater than or equal to 103.5°F during the first 10 DIM. These findings are consistent with those of a retrospective study in which rectal temperatures were measured once daily for the first 10 days after calving; 48% of normal cows were found to have at least one temperature measurement greater than 102.5°F.[11] Based on the results of the current study, reliance on a rectal temperature greater than 103.1°F or 103.5°F to diagnose illness in fresh dairy cows, in the absence of other clinical signs, will cause considerable over-diagnosis of illness.

This study provides new information about the mean rectal temperature of healthy lactating dairy cows

Table 4. Mean and range values for circulating white blood cells (WBC), neutrophils (NE) and lymphocytes (LY) for the first five days after calving in healthy and sick cows during the first 10 days-in-milk (DIM). NE% and LY% are cell type as a percentage of total WBC population.

		Days after calving				
Healthy cows		Day 1	Day 2	Day 3	Day 4	Day 5
WBC	mean	12.61[a]	10.71[a]	10.11[a]	9.08	8.54
cells x $10^3/\mu L$	range	3.58-22.10	3.86-22.60	4.04-18.68	3.00-17.04	3.30-18.10
NE	mean	7.37[c]	5.63[c]	5.13[c]	4.18	3.66
cells x $10^3/\mu L$	range	2.41-14.60	1.72-9.31	1.64-9.20	1.07-9.55	1.15-8.94
NE%	mean	59.25	54.08	51.47	46.16	44.57
	range	32.83-77.21	25.72-78.93	20.59-75.06	17.31-71.02	16.45-68.47
LY	mean	4.56	4.62	4.49	4.53	4.55
cells x $10^3/\mu L$	range	1.08-14.27	1.53-16.10	1.89-13.26	1.8-13.60	1.93-13.68
LY%	mean	35.06	41.51	43.78	48.40	51.50
	range	18.66-64.56	20.31-71.25	21.16-75.49	24.33-79.84	28.30-81.59
Sick cows						
WBC	mean	10.84[b]	7.04[b]	7.65[b]	5.90	5.95
cells x $10^3/\mu L$	range	4.70-15.22	4.44-12.32	3.94-12.92	4.18-7.66	4.04-8.14
NE	mean	6.98[d]	3.19[d]	3.30[d]	2.72	2.60
cells x $10^3/\mu L$	range	1.91-10.84	1.10-5.55	0.92-5.91	1.63-4.19	1.42-3.82
NE%	mean	62.22	44.64	42.51	45.45	42.71
	range	40.74-77.37	23.73-63.79	19.63-60.89	32.57-54.72	35.17-53.53
LY	mean	3.24	3.52	3.99	2.82	2.88
cells x $10^3/\mu L$	range	2.30-5.38	2.14-8.71	2.45-8.90	1.87-3.51	2.35-3.46
LY%	mean	32.34	50.59	51.88	48.49	49.78
	range	17.28-53.81	30.67-72.10	34.79-77.33	38.84-56.67	41.81-58.10

[a,b] WBC counts were significantly different between sick cows and healthy cows for the first three DIM
[c,d] NE counts were significantly different between sick cows and healthy cows for the first three DIM
Normal values[9]: WBC 4.0-12.0 cells x 10^3; NE 0.6-4.1 cells x 10^3; NE% 15.0-47.0;
LY 2.5-7.5 cells x 10^3; LY% 45.0-75.0

in the postpartum period. Mean rectal temperatures among the healthy fresh cows in this study were higher than those found in cycling heifers in a warm climate.[18] This difference is consistent with the earlier observation that lactating cows have higher mean temperatures than cows that are not lactating.[2] Results of this study suggest, however, that fresh cows may have higher mean temperatures than cows in mid-lactation. A study done in Manitoba, which is near North Dakota and has similar climate, found that eight mid-lactation cows (mean DIM 132±14.4) at ambient temperatures between 68.0°F (20.0°C) and 75.2°F (24.0°C) had mean vaginal temperatures of 100.2°F (37.9°C) or 100.4°F (38.6°C), depending on the time of feeding.[17] These temperatures are more than a full degree (F) lower than the means found at all times in healthy cows in this study (101.6-101.8°F; 38.7-38.8°C), despite the considerably cooler ambient temperatures in the current study, which was conducted during the cool months in an unheated barn. These differences are unlikely to result from variation due to measuring the temperature in the vagina versus the rectum as a recent study measuring rectal and vaginal temperatures simultaneously in 276 dairy cows found little difference in the two methods.[9] In addition,

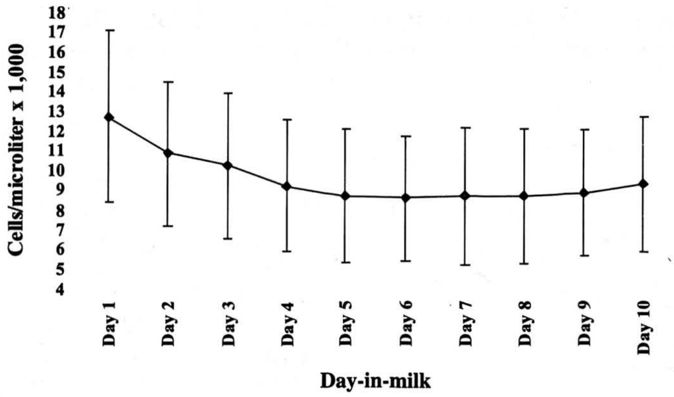


Figure 4. Mean white blood cell counts in healthy cows for the first 10 days-in-milk. Bars indicate the standard deviation of each mean white blood cell count.

cows in both studies consumed a total mixed ration formulated according to National Research Council standards for lactating dairy cows; the rations differed little in protein, energy and fiber levels, although the ration fed during the current study did have a higher forage-to-concentrate ratio. Increased dietary fiber and increased dry-matter intake have been associated with increased heat production in lactating dairy cows. Variations in dry-matter intake have the greatest effect on heat production of any dietary factor.[20] Total dry-matter intake was not measured in the current study, but was unlikely to be greater than the 46.2-48.4 lb (21.0-22 kg)/day mean consumption reported by Ominski *et al* due to the depression of feed intake commonly seen around the time of parturition in dairy cows.[19] In addition, it is not known whether increased heat production due to dietary differences would result in higher rectal temperatures when environmental temperatures are cool. Dietary variability is unlikely to account for most of the difference in mean temperatures observed between the two studies. Other explanations for the higher rectal temperatures observed in healthy postpartum cows in this study compared to the temperature of healthy mid-lactation cows reported by Ominski *et al* may be normal inflammation from calving-related tissue trauma, possible bacterial contamination of the uterus and/or udder, or the physiological adjustment to increased metabolic demands postpartum.

Body temperatures observed in the fresh cows in this study may actually be cooler than those observed in the general population of fresh cows in the United States for several reasons. First, as stated previously, cows in this study were maintained in an unheated environment during cold months in a northern climate where the environmental temperature rarely rose above 50°F (10°C). In addition, many cows in commercial production systems are unaccustomed to handling and move about when restrained and examined, which is likely to raise their body temperature. Cows in this study were all calm enough to be examined with no restraint or restrained with a rope halter tied in a box stall. Finally, when cows are caught in headlock rows as often done to facilitate examination on commercial dairies, most cows are touching other cows on one or both sides, and they may become warmer due to the radiating body heat of the cows on either side. Cows in this study were in box stalls with no other cows close by. It is therefore expected that "elevated" rectal temperatures in healthy fresh cows may be even more common in large commercial dairies than in this study, particularly in warmer months or climates.

The frequent elevations in rectal temperature among fresh cows in this study suggest that rectal temperature alone is not a sensitive screening tool for diagnosis of illness in postpartum dairy cows. The most pronounced difference between sick and healthy cows was the difference in mean first-test-day milk production, which was more than 20 lb (9.1 kg). Previous work has suggested that milk yields in cows with ketosis, displaced abomasum and digestive disorders begin to decrease five to seven days prior to the observation of clinical signs.[5] The combined results of these two studies suggest that some combination of temperature and milk production data might enhance sensitivity and specificity when screening postpartum cows for metabolic and infectious disease.

Increased rectal temperature in a healthy postpartum cow may indicate that the cow is staging an effective immune response to the physiological insults encountered at calving. Investigators at the Free University of Berlin found that cows with rectal temperatures greater than 103.1°F in the first 10 DIM have increased first service conception rates compared with cows that do not achieve those temperatures,[3] suggesting some degree of inflammatory response may be beneficial to the postpartum cow, which is in agreement with findings of this study regarding WBC counts in postpartum cows.

Early work measuring WBC populations in postpartum cows found that healthy cows have increased white blood cell counts on days 1, 2, 5 and 10 after calving when compared with pre-calving cell concentrations.[6] When twice-weekly WBC counts were performed on cows with naturally-occurring endometritis, post-calving concentrations of neutrophils were found to be decreased compared with pre-calving levels for 1.5 weeks following calving.[14] The decreased levels of circulating neutrophils were attributed to migration of those cells out of the circulation and into the mammary gland and uterus in postpartum cows facing an immune challenge.

Direct comparisons of postpartum dairy cows that developed disease with those that remained healthy have had mixed results. Ohtsuka *et al* measured blood cell populations on the day of calving; at one week; and one, three and six months postpartum in nine cows that developed mastitis or metritis in the first two weeks after calving, and 11 cows that did not become ill.[16] WBC and neutrophil numbers were lower in cows that became ill than in healthy cows from the day of calving through the end of the first month in lactation. When Kim *et al* compared WBC counts in 11 cows that developed endometritis and 19 healthy cows at one week prepartum, on the day of calving and once weekly for four weeks after calving, cows with endometritis had higher WBC and neutrophil counts at all measured time points.[10] This contrasts with results of the current study and the study reported by Ohtsuka *et al*. The reason for this disparity is not readily evident, but may be due to the later diagnosis of endometritis in the study by Kim *et al*, where cows were not evaluated for presence of metritis until four weeks after calving. This late diagnosis may have affected results by selecting for affected cows with inflammatory responses of longer duration, and perhaps by misclassifying as unaffected those cows which experienced effective neutrophil recruitment to the uterus and subsequent resolution of the inflammatory response and clinical signs of endometritis prior to four weeks postpartum.

No report was found that measured WBC counts daily in postpartum dairy cows. Cows in the current study that developed disease had lower mean WBC counts and neutrophil counts for the first three days after calving when compared with cows that remained healthy. Because of the frequency of monitoring in this study, it was also established that the decreased neutrophil counts in cows that became ill occurred very early in lactation (and may have existed prepartum).

Results of this study suggest that "normal" leukocyte counts for cows in the immediate postpartum period may be higher than previously described. The normal range of peripheral WBC concentrations in cattle has been given as 4,000 to 12,000 cells/µL, and normal neutrophil counts are 600 to 4,120 cells/µL.[8] Cows that remained healthy had mean WBC counts above the normal range on day one after calving and mean neutrophil counts above the reference range on the first four days after calving, while cows that became ill had mean WBC counts in the normal range throughout the first five days after calving and neutrophil counts in the normal range starting on the second day after calving. Cows with an adequate immune response the first few days after calving, as indicated by an absence of clinical signs of illness, had mean peripheral neutrophil concentrations that are higher than what might be considered normal in mid-lactation cows. The increase in neutrophil numbers may compensate for decreased neutrophil function in cows during the postpartum period. Cows that have WBC counts in the reference range during the immediate postpartum period may actually be at increased risk of developing disease.

Conclusions

Results of this study provide evidence that healthy dairy cows in the postpartum period have higher rectal temperatures and WBC counts than would be considered normal for cows in mid-lactation. Cows that remained healthy in the first 10 days after calving frequently had rectal temperatures greater than 103.1°F and 103.5°F, values which had previously been described as indicative of illness. The use of rectal temperature alone to diagnose illness in postpartum dairy cows, in the absence of other clinical signs, will result in significant overdiagnosis of illness in cows that are healthy. Increased rectal temperature may be most useful in combination with daily milk production as a tool to indicate which postpartum cows should be given a full physical examination for the presence of other clinical signs. Future investigation may focus on the sensitivity and specificity of these combined factors for early diagnosis of sick postpartum dairy cows.

Cows that remained healthy had significantly higher neutrophil counts in the first three days after calving when compared with cows that became ill, and their neutrophil counts exceeded normal reference ranges for several days after calving. WBC counts in cows that became ill remained within reference ranges and neutrophil counts in such cows dropped into normal range by the second day after calving. This finding suggests that "normal" hematologic values in postpartum dairy cows are higher than what is considered normal in other cattle. The explanation for this phenomenon may be that an increase in the number of circulating neutrophils enables cows that remain healthy to meet the immune challenges encountered around the time of parturition.

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Endnotes

[a]GLA Agricultural Electronics, San Luis Obispo, CA
[b]Drew Scientific, Oxford, CT
[c]Multi-Trol™, Drew Scientific, Oxford, CT
[d]SAS Institute Inc., Cary, NC

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