Body Temperature and Endocrine Interactions Before and After Calving in Beef Cows[1]

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ABSTRACT: Multiparous beef cows (n = 7) were used to evaluate peripartum changes and interactions among body temperature (BT) and circulating progesterone (P_4), estradiol-17β (E_2), triiodothyronine (T_3), cortisol, thyroxine (T_4), and 13,14-dihydro-15-keto-prostaglandin $F_{2\alpha}$ (PGFM) concentrations. Electronic temperature monitors were placed under the obliquus abdominis internus muscle of the left flank, and BT was measured using radiotelemetry every 3 min for 10-s periods from 144 h before to 24 h after calving. Environmental temperatures (ET) were recorded hourly. Body and environmental temperatures were averaged, separately, within 8-h periods. Blood samples were collected every 8 h, and hormone concentrations were measured. Time of day affected BT ($P < .01$), at 0300 cows had the lowest BT, at 1900 the highest, and at 1100 values were intermediate. Body temperature remained relatively constant ($P > .10$) from 144 to 56 h before calving and from 8 to 24 h after calving but decreased ($P < .01$) from 48 to 8 h before calving. Precalving BT was affected ($P < .01$) by ET, but hour-before-calving (time) had the greatest effect on BT during the 48 to 8 h immediately preceding parturition ($b' = .41$, $P < .01$) and was independent of ET effects. Before the BT decrease, cows gestating heifers had lower ($P < .01$) BT than cows gestating bulls. Plasma E_2, PGFM, T_3, and T_4 concentrations before the precalving decrease in body temperature were greater ($P < .03$) in cows gestating bull rather than heifer calves. Approximately 30% of the variation (R^2) during the temperature decrease was explained by plasma hormone concentrations; PGFM ($b' = -.30$, $P < .05$) and T_3 ($b' = -.22$, $P < .10$) had the most significant effects. In conclusion, BT of the cow before the precalving decrease was affected by ET and sex of calf. However, the prepartum BT decrease was independent of these variables, and seemed partially endocrine-induced.

Key Words: Body Temperature, Calving, Hormones

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Introduction

Approximately 64% of the calf deaths that occur during the first 96 h after calving are caused by dystocia (Patterson et al., 1987), and approximately 50% of these losses could be prevented by giving timely, correct obstetrical assistance (Bellows et al., 1987). Weber (1910) reported that body temperature of the cow decreased 28 h before calving. Later studies indicated that body temperature before calving can decrease as much as 1°C (Vollman and Vollman, 1942). In addition, Ewbank (1963) suggested that a cow showing signs of parturition was unlikely to calve within 12 h if rectal temperature was 38.9°C or above. Birgel et al. (1994) determined correlations between serum progesterone concentrations and body temperature before calving and reported that changes in serum progesterone concentrations and body temperature could be used to predict time of calving within a 22-h period. Therefore, it may be possible that body temperature changes before calving could be used to predict an approximate time of calving and be useful in determining when to give obstetrical assistance to increase calf survival rate. Specific hormones and mechanisms involved in the decrease of body temperature before calving have not been identified. The objectives of this study were to evaluate peripartum

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Table 1. Effects of calf sex on birth weight, cow body temperature, and blood progesterone (P_4), estradiol-17β (E_2), triiodothyronine (T_3), cortisol, thyroxine (T_4), and 13,14-dihydro-15-keto-prostaglandin $F_{2\alpha}$ (PGFM) concentrations from 144 to 56 hours before calving (least squares means ± SE)

	Sex of calf			
Variable	Male (n = 3)	Female (n = 4)	Probability	SE
Birth weight, kg	41.2	42.5	NS[b]	2.42
BT, °C[a]	40.2	39.8	.01	.06
P_4, ng/mL	2.71	3.15	NS	.39
E_2, pg/mL	277.7	235.4	.05	43.4
PGFM, pg/mL	146.6	110.8	.01	27.8
Cortisol, ng/mL	6.5	5.6	NS	.6
T_3, ng/mL	1.33	1.42	.05	.03
T_4, ng/mL	51.2	63.6	.01	1.32

[a] BT = body temperature of the cow.
[b] NS = not statistically significant.

body temperature changes of cows and determine possible interactions among body temperature, sex of calf, environmental temperature, and circulating progesterone, estradiol-17β, triiodothyronine (**T_3**), cortisol, thyroxine (**T_4**), and 13,14-dihydro-15-keto-prostaglandin $F_{2\alpha}$ (**PGFM**) concentrations in the dam.

Materials and Methods

Seven crossbred, multiparous beef cows (3 to 6 yr of age) bred to a single Hereford sire, with known breeding dates, were used. Cows calved without difficulty during the summer of 1995 when the average environmental temperature was 22.5°C. Cows were maintained in drylots and received a diet of corn silage plus protein supplement fed to meet NRC (1984) requirements. Cows were weighed (715.2 ± 43.0 kg) and body condition scored (8.2 ± .75; 1 = emaciated and 10 = obese) approximately 15 d before the expected calving date. Electronic body temperature monitors[3], similar to those used by Bunch et al. (1989), were implanted surgically. Before starting surgical procedures, cows were tranquilized with an i.m. injection of 20 mg of xylazine and administered 2% lidocaine locally. Under aseptic procedures, a high lumbar incision was made in the left flank and monitors were placed under the obliquus abdominis internus muscle in direct contact with the peritoneum to ensure that body temperature and not skin temperature was measured. Monitors were implanted 15 to 18 d before the expected calving date and removed 48 to 96 h after calving. Body temperature was monitored via radiotelemetry for 10 s every 3 min using the Datacol 5.0 Data Acquisition System[3]. Hourly environmental temperatures were obtained from a weather station located 4.5 km from the drylots in which the cows were housed.

Blood samples were collected via tail venipuncture every 8 h (0300, 1100, and 1900) during the study. Blood samples were placed on ice immediately after collection, processed within 20 min to yield plasma, and maintained at −20°C until assayed. Plasma progesterone concentrations were determined with a coated-tube RIA (Diagnostic Products, Los Angeles, CA) using procedures of Bellows et al. (1991). Intra- and interassay CV were 8.0 and 9.7%, respectively. Plasma estradiol-17β concentrations were quantified using procedures described by Perry et al. (1991), and the intra- and interassay CV were 8.6 and 11.6%, respectively. Plasma PGFM concentrations were determined with a direct single antibody technique (Velez et al., 1991), and the intra- and interassay CV were 11.7 and 14.1%, respectively. Plasma cortisol (kit 031, Pantex, Santa Monica, CA), T_3 (DPC, Los Angeles, CA), and T_4 (DPC) concentrations were determined using enzymatic reaction kits as validated by Godfrey et al. (1991), and the intra- and interassay CV were as follows: T_3, 4.5% and 12.5%; T_4, 8.3% and 9.8%; cortisol 4.6% and 11.2%, respectively[4].

For purposes of analyzing main effects and interactions of temperature and hormones, environmental and body temperature within 8-h periods from d 6 before calving until 24 h after calving were averaged. Body temperature and hormone data were analyzed using GLM procedures for analysis of variance (SAS, 1994), and calf birth weight was used as a covariate. Standard partial regressions (b′) based on residual correlations were calculated before, during, and after the prepartum decrease in body temperature (Wright, 1958; SAS, 1994). The Cusum plot method as described by Wohl (1977) was used to plot peripartum body temperature changes.

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Results and Discussion

The cows delivered four heifer and three bull calves without difficulty and with similar ($P > .10$) birth weights (Table 1). Body temperature of the cows was affected by three factors: 1) time of day (environmental temperature; $P < .01$), 2) sex of calf ($P < .01$), and 3) hour before calving (time; $P < .05$). Interactions were not significant ($P > .09$).

Body temperature changed ($P < .01$) during the day; it was lowest at 0300 (39.7 ± .06°C), highest at 1900 (40.2 ± .07°C), and intermediate at 1100 (39.9 ± .07°C; Figure 1). The observed diurnal variation in body temperature confirmed previous reports for cattle (Portfield and Olson, 1957) and sheep (Laburn et al., 1992). However, diurnal variation in body temperature was absent during the immediate prepartum period (48 to 8 h) and was only displayed from 144 to 56 h before calving and 8 to 24 h after calving (Figure 2). Standard partial regression coefficients indicated that the independent effect of environmental temperature had the greatest influence ($b' = .38$; $P < .01$) on

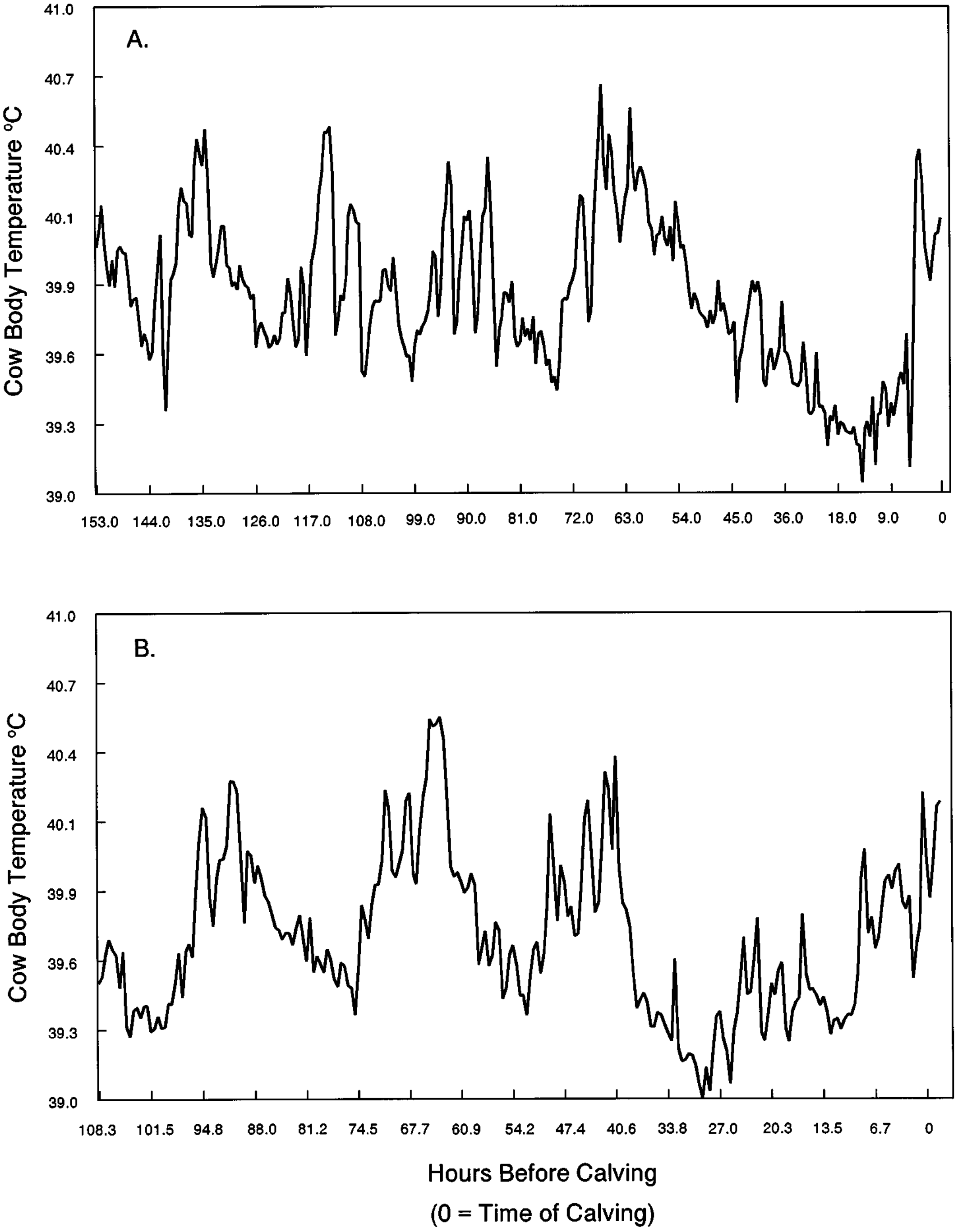

Figure 1. Effects of hour before parturition ($P < .01$) on cow body temperature. Panel A represents body temperature changes of a selected cow gestating a male calf and Panel B a cow gestating a female calf.

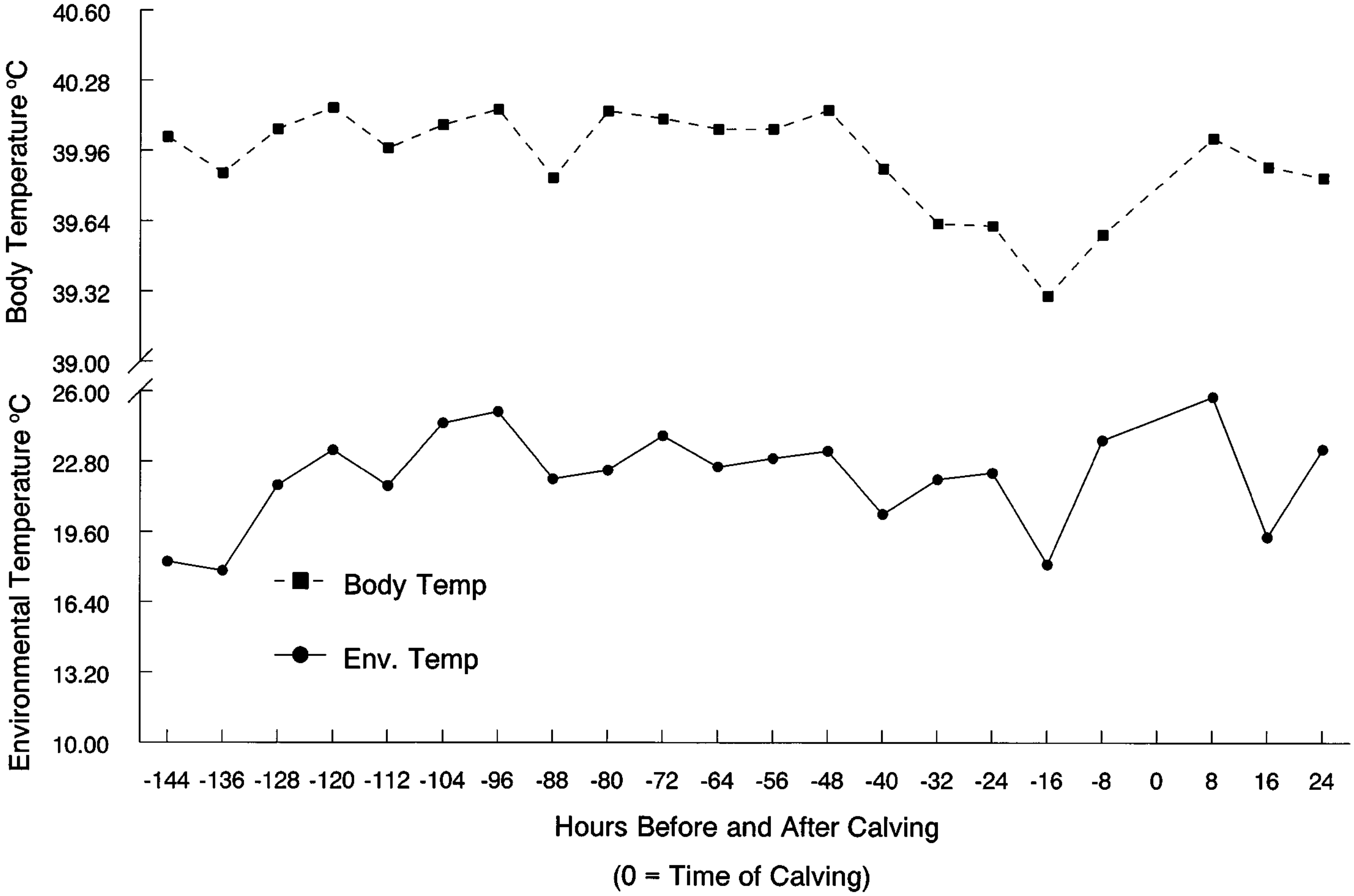

Figure 2. Least squares means (all cows) of cow body (SEM = .16; n = 7) and environmental temperature (SEM = 3.25) as affected (*P* < .01 and *P* < .10; respectively) by hour before and after calving.

precalving body temperature from 144 to 56 h prepartum, but the independent effect of hour-before-calving became highly significant during the 48 to 8 h immediately preceding parturition (b′ = .41; *P* < .01). This cause-and-effect change (Tables 2 and 3) indicated that the decrease in body temperature 48 to 8 h before calving was independent of an average 22.5°C environmental temperature and represented a shift in cause-and-effect relationships during this time period. In addition, our unpublished data from another study (S. E. Bellows) indicated that when environmental temperatures were below –20°C, body temperature of the cow 48 to 8 h before calving could decrease to as low as 31°C. The decrease in body temperature 48 to 8 h before calving may be independent of environmental temperature, but we suggest that the magnitude of the decrease may be influenced by environmental temperature (Figure 2).

Table 2. Correlation matrix for cow body temperature, environmental temperature, birth weight, hour, and circulating hormone concentrations[a]

Time related to precalving BT drop	ET	TD	BW	P_4	E_2	PGFM	Cortisol	T_3	T_4
Before	.50**	.51**	.45**	.09	–.09	.27*	.31**	–.05	–.03
During	.49**	.26	.37*	.34*	.08	–.44**	–.15	–.32*	–.23
After	.37*	.34[†]	.17	.24	–.15	.23	–.02	.004	.03

[a] BT = cow body temperature, ET = environmental temperature, TD = time of day, BW = birth weight, P_4 = progesterone, E_2 = estradiol-17β, PGFM = 13,14-dihydro-15-keto-prostaglandin $F_{2\alpha}$, T_3 = triiodothyronine, T_4 = thyroxine.

[†] *P* < .07.

**P* < .05.

***P* < .01.

The decrease in body temperature was most evident on a Cusum plot (Wohl, 1977), which is the accumulation of the difference between the reference value and each of the subsequent prepartum values (Figure 3). The decrease in body temperature before calving has been reported to be as much as 1°C immediately prepartum (Weber, 1910; Vollman and Vollman, 1942; Portfield and Olson, 1957). In vivo studies (Gilbert et al., 1985) and model predictions (Schroder et al., 1988) indicated that fetal lambs lost 80 to 85% of their heat via transfer to the placenta and the other 15 to 20% via transfer through the uterine wall. Blood flow to the placenta was directly affected by maternal temperature, and this effect would have influenced heat dissipation by the fetus (Schroder et al., 1988). In addition, fetal lamb temperature increased before lambing and decreased approximately 1.5°C within 20 min after lambing, even in a temperature-controlled environment (Laburn et al., 1994), indicating that newborn lambs may be protected from hyperthermia. We suggest that similar mechanisms may also occur in cattle. We also speculate that the biological importance of the decrease in maternal body temperature before parturition may be to decrease uterine blood flow and heat dissipation by the fetus, resulting in increased fetal temperature. Fetal temperature continues to increase through parturition because myometrial contractions also decreased uterine blood flow and heat dissipation by the fetus (Brar et al., 1988). We hypothesize that the increase in fetal temperature before parturition may be an important compensatory mechanism for the loss in body temperature that occurs in newborns after delivery.

Body temperature of cows was influenced ($P < .01$) by sex of calf before the immediate prepartum decline.

Table 3. Standard partial regression coefficients (b')[a] for body temperature as affected by environmental temperature, time of the day, hour, and circulating hormone concentrations before, during, and after the body temperature decreased[b]

	Body temperature (dependent variable)		
Independent variables	Before b′	During b′	After b′
Environmental T	.38**	.53**	.27†
Time of day	.18	−.17	.13
Hour before calving	.18	.41**	.003
R^2	.30	.39	.15
Including birth weight			
Birth weight	.39**	.34**	.36**
Progesterone	−.08	.15	−.32*
Estradiol-17β	−.16†	−.07	−.16
PGFM	.10	−.30*	.37**
Cortisol	.17*	−.04	−.09
T_3	−.09	−.22†	−.07
T_4	.02	.09	.31*
R^2	.27	.36	.27
Without birth weight			
Progesterone	.01	.18	−.15
Estradiol-17β	−.12	.06	−.23†
PGFM	.25*	−.27**	.38*
Cortisol	.28*	−.07	−.10
T_3	−.08	−.22†	−.10
T_4	.09	−.14	.18
R^2	.17	.30	.17

[a] b′ = Values calculated using residual correlations shown in Table 2.

[b] T = temperature, PGFM = 13, 14-dihydro-15-keto-prostaglandin $F_{2\alpha}$, T_3 = triidothyronine, T_4 = thyroxine.

†$P = .10$.

*$P < .05$.

**$P < .01$.

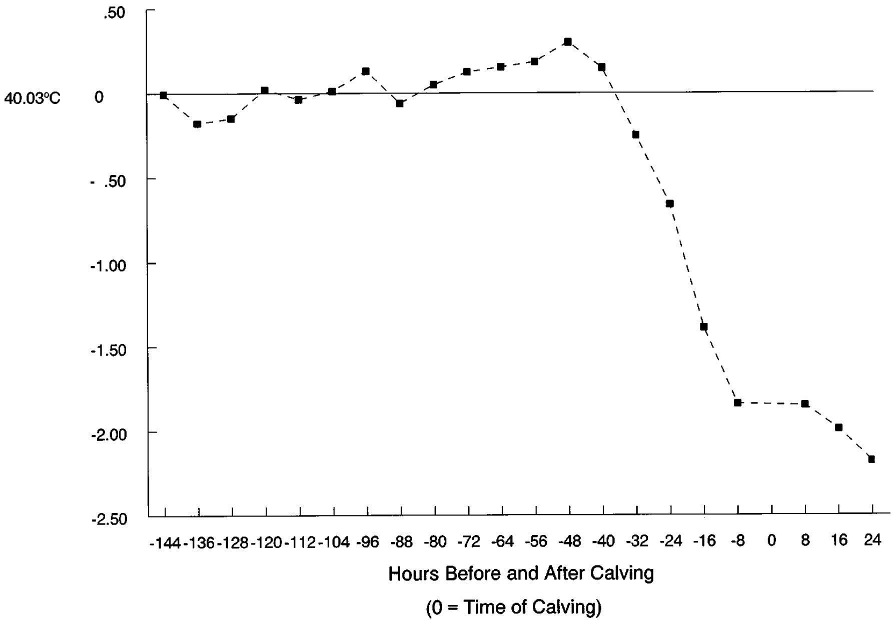

Figure 3. Cusum plot showing peripartum body temperature changes in cows (n = 7), using 40.03°C as a point of reference for temperature changes.

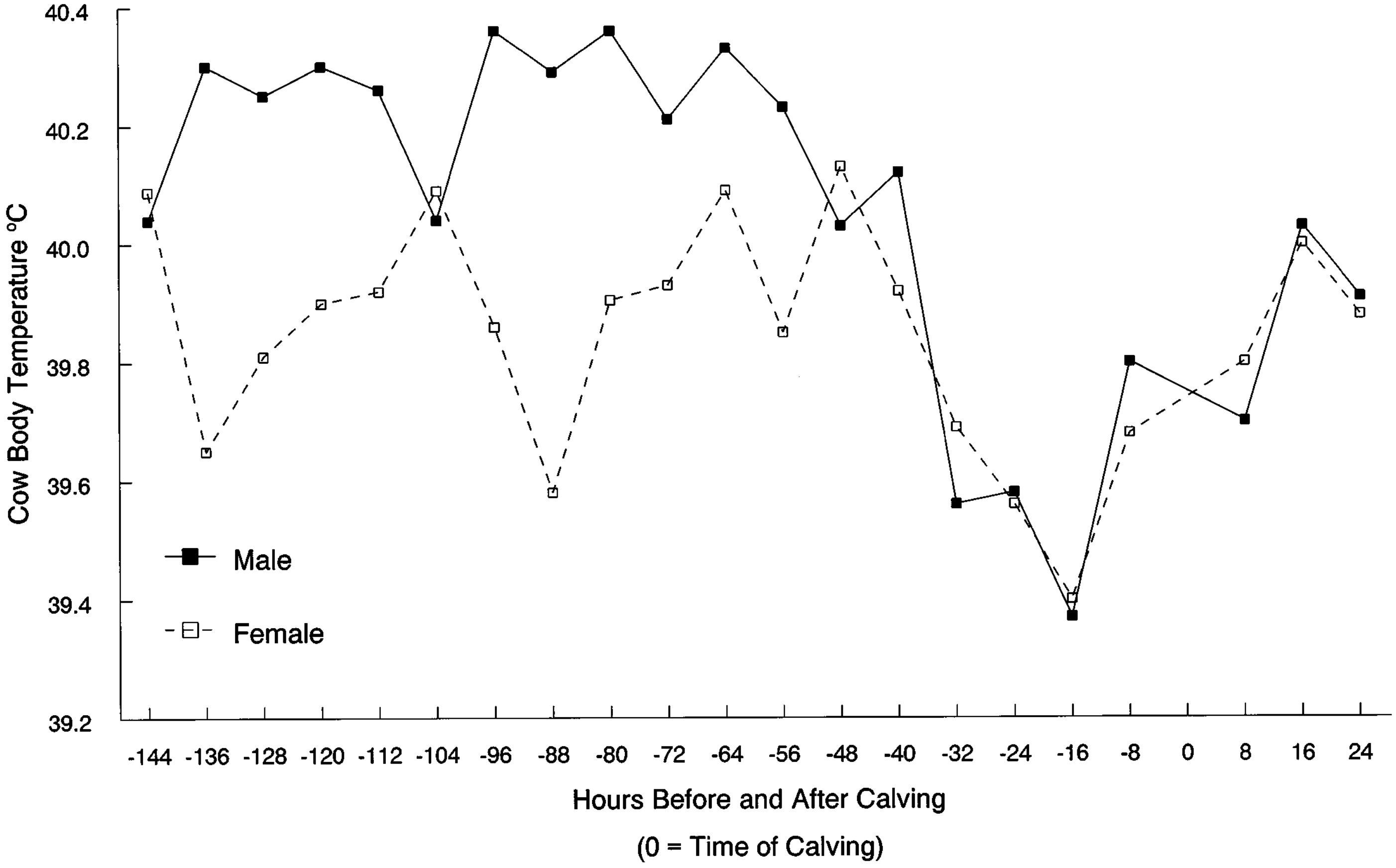

Figure 4. Least squares means of body temperature before calving (SEM = .21) as affected ($P < .01$) by sex of calf from 144 to 56 h before calving (females, n = 4; males, n = 3).

Cows gestating heifer calves had lower body temperatures than cows gestating bull calves (Figure 4). In contrast, there was no influence ($P > .10$) of sex of calf on body temperature during the immediate 40 to 8 h prepartum temperature decline or after calving. Sex of calf also affected estradiol-17β and PGFM concentrations. Cows bearing bull calves had higher estradiol-17β ($P < .05$) and PGFM ($P < .01$) concentrations (Table 1) than cows bearing heifer calves from 144 to 56 h before calving. Sex of calf did not influence ($P > .10$) peripartum progesterone or cortisol concentrations. Differences in estradiol-17β concentrations between sexes could be caused by differences in placental size and(or) function (Echternkamp, 1984). Positive correlations between calf size and serum estrogen concentrations have been reported (Terqui et al., 1975; Echternkamp, 1984). In this study there were no sex differences in birth weight, but there could have been differences in placental size that influenced plasma estradiol-17β and PGFM concentrations. Cows gestating heifer calves had higher plasma T_3 ($P < .03$) and T_4 ($P < .01$) concentrations than cows gestating bull calves (Table 1). Gopinath and Kitts (1981) reported that growing beef steers with Synovex-S (progesterone and estradiol-17β) implants had greater plasma T_3 and T_4 concentrations than steers without implants, suggesting that sex differences in circulating steroid and PGFM concentrations may account for the sex of calf differences in plasma T_3 and T_4 concentrations.

Estradiol-17β has a hypothermic effect in postmenopausal women, and this influence may be mediated through endogenous opioids at the hypothalamic level, but progesterone has a hyperthermic effect on body temperature that seems to be independent of endogenous opioids (Cagnacci et al., 1992). Therefore, prepartum differences in body temperature of cows bearing female or male calves might result from differences in sex hormone concentrations influencing the hypothalamus (Table 1), but this remains unclear and further research is needed.

Plasma concentrations of P_4, E_2, and PGFM changed ($P < .01$) over time; prepartum P_4 decreased and concentrations of E_2 and PFGM increased as parturition approached (Figure 5A). Plasma concentrations of PGFM continued to increase up to 8 h after calving. Plasma cortisol concentrations did not increase ($P > .10$) before parturition, perhaps because of the variation in time of cortisol increase before calving within the seven cows (Figure 5B). Peripartum hormonal changes in this study are similar to those summarized in a review by Bazer and First (1983).

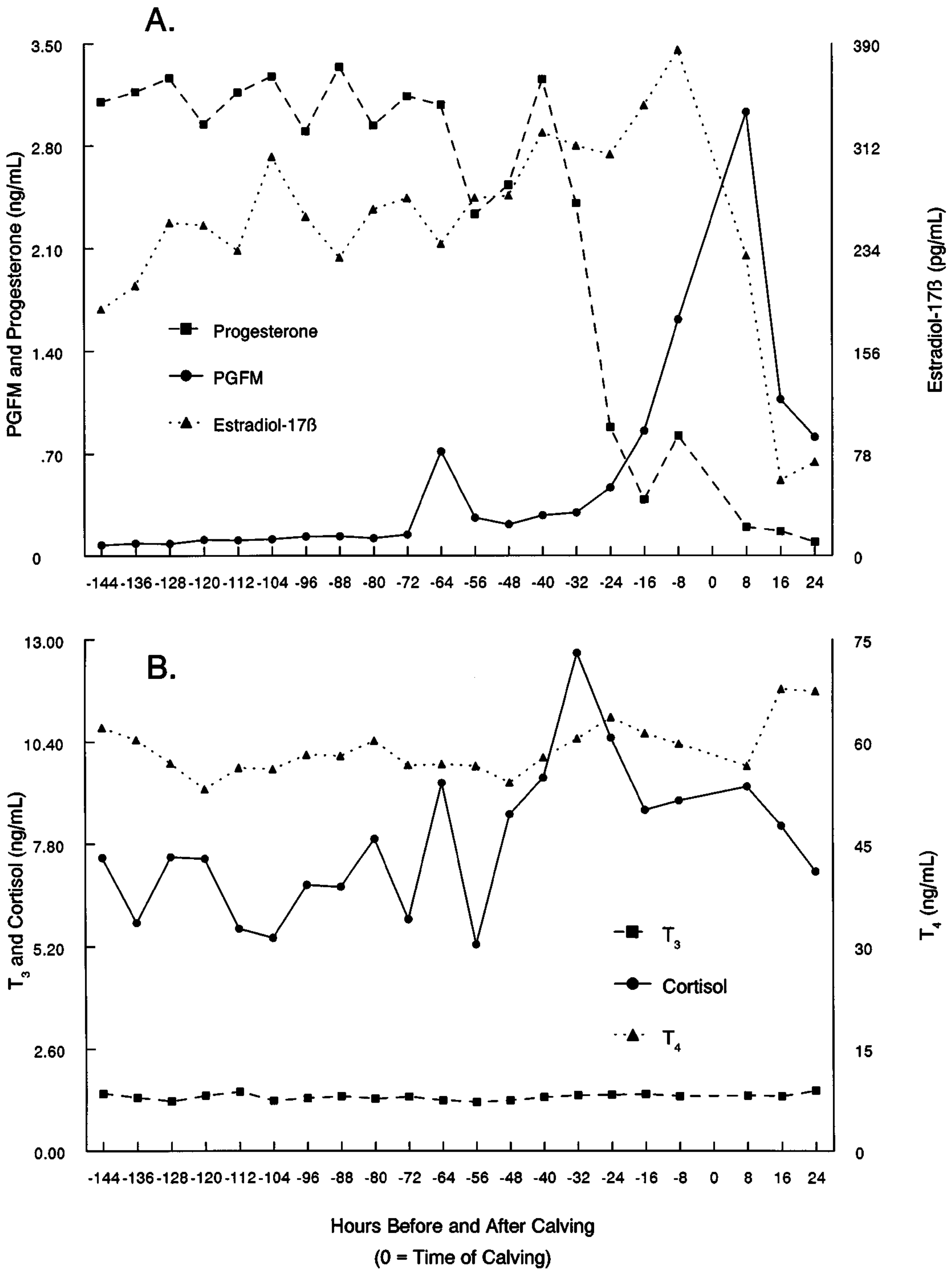

Figure 5. Least squares means of circulating progesterone (SEM = .32; $P < .01$), estradiol-17β (SEM = 41.17; $P < .01$), 13,14-dihydro-15-keto-prostaglandin $F_{2\alpha}$ (PGFM; SEM = 222.5; $P < .01$), cortisol (SEM = 2.10; $P > .10$), triiodothyronine (T_3; SEM = .08; $P > .10$), and thyroxine (T_4; SEM = 3.6; $P > .10$) concentrations before, during, and after calving as affected by time (sex and time interactions were not significant).

Birgel et al. (1994) used circulating progesterone concentrations and body temperature to predict that calving would occur within the next 22 h. Results from the present study confirm that changes in plasma hormone concentrations and body temperature can be used to predict calving. However, practical application of this technology is limited.

The correlation matrix shown in Table 2 was further analyzed to detect cause-and-effect relationships between peripartum maternal body temperature and hormone concentrations by calculating standard partial regression coefficients (b′) with and without birth weight (Table 3). Birth weight had the greatest effect on body temperature before (.39), during (.34), and after (.36; $P < .01$) calving. Heavier calves and placenta (conceptus) may generate more heat in utero and increase cow body temperature. Furthermore, calf and placental size influence circulating hormone concentrations (Terqui et al., 1975; Echternkamp, 1984), which may also affect cow body temperature. Before and after the precalving decline in body temperature, changes in plasma hormone concentrations accounted for 17% of the body temperature variation (R^2) when birth weight was not included in the model. However, when birth weight was included, the R^2 value increased to 27%. When birth weight was not included during the prepartum body temperature decrease, changes in plasma hormone concentrations accounted for 30% of this variation, and PGFM (–.27; $P < .01$) and T_3 (–.22; $P < .10$) had the greatest effect on body temperature (Table 3). In contrast, when birth weight was included in the model during the body temperature decrease, the R^2 value increased to only 36%, and PGFM (–.30; $P < .05$) and T_3 (–.22; $P < .10$) still had the greatest effect on body temperature (Table 3). Triiodothyronine has been reported to enhance oxygen consumption and heat production (Norman and Litwack, 1987). However, in the present study T_3 had a negative effect on body temperature during the prepartum decrease in body temperature, and we offer no explanation for this phenomenon. Prostaglandins are widely distributed in the brain, and PGE_2 has been reported to induce hyperthermia by acting at the hypothalamic level (Oka and Hori, 1994). Because $PGF_{2\alpha}$ is an antagonist of PGE_2, $PGF_{2\alpha}$ may act at the hypothalamic level to decrease body temperature. Further research is needed to clarify this relationship.

Plasma T_3 and T_4 concentrations did not change ($P > .10$) as parturition approached (Figure 5). However, circulating T_3 concentrations were affected by time of day ($P < .01$); they were lowest at 0300 (1.29 ± .03 ng/mL) and greatest at 1100 (1.44 ± .03 ng/mL) and 1900 (1.39 ± .03 ng/mL). Furthermore, plasma T_4 concentrations tended ($P < .08$) to be affected by time of day; cows had the lowest concentrations (55.5 ± 1.4 ng/mL) at 0300, intermediate values at 1100 (57.0 ± 1.4 ng/mL), and highest values at 1900 (60.0 ± 1.4 ng/mL). Similar results were reported for dairy cows by Bitman et al. (1984), who found higher plasma T_3 and T_4 concentrations in the afternoon than in the morning, and by Refsal et al. (1980), who showed diurnal variation in T_3 and T_4. Furthermore, Holstein heifers had higher plasma thyroid-stimulating hormone concentrations in the afternoon than in the morning (Stewart et al., 1994).

Implications

Body temperature before the immediate precalving decrease in body temperature is influenced by sex of calf and environmental temperature. After calving, body temperature is influenced only by environmental temperature. In contrast, the immediate precalving (48 to 8 h) decline in body temperature is independent of either sex of calf or environmental temperature, but the magnitude of this decrease may be dependent on environmental temperature. We speculate that the precalving decrease in body temperature could increase fetal temperature and induce an important compensatory mechanism for body temperature loss that occurs after delivery in newborn calves. The precalving decline in body temperature and changes in blood hormone concentrations are factors to consider in predicting more accurately the time of onset of calving. However, because mechanisms controlling the precalving decline in body temperature in cows and their possible influences on parturition and calf survival are not understood, further research is needed before automated temperature measurement could be used to accurately predict start of parturition and determine when obstetrical assistance should begin.

Literature Cited

Bazer, F. W., and N. L. First. 1983. Pregnancy and parturition. J. Anim. Sci. 57(Suppl. 2):425.

Bellows, R. A., D. J. Patterson, P. J. Burfening, and D. A. Phelps. 1987. Occurrence of neonatal and postnatal mortality in range beef cattle. II. Factors contributing to calf death. Theriogenology 28:573.

Bellows, R. A., R. B. Staigmiller, J. M. Wilson, D. A. Phelps, and A. Darling. 1991. Use of bovine FSH for superovulation and embryo production in beef heifers. Theriogenology 35:1069.

Birgel, E. H., Jr., E. Grunert, and J.A.G. Soares. 1994. The preparatory phase of delivery in cattle, under consideration of the external signs of delivery and changes in progesterone to predicting the calving time. Dtsch. Tieraerztl. Wochenschr. 101: 355.

Bitman, J., H. Tao, and R. M. Akers. 1984. Triiodotyronine and thyroxine during gestation in dairy cattle selected for high and low milk production. J. Dairy Sci. 67:2614.

Brar, H. S., L. D. Platt, G. R. Devore, J. Horenstein, and A. L. Medearis. 1988. Qualitative assessment of maternal uterine and fetal umbilical artery blood flow and resistance in laboring patients by doppler velocimetry. Am. J. Obstet. Gynecol. 158: 952.

Bunch, T. D., G. W. Workman, and R. J. Gallan. 1989. Remote body temperature and heart rate monitoring in desert Bighorn sheep. Desert Bighorn Counc. Trans. 33:1.

Cagnacci, A., G. B. Melis, R. Soldani, A. M. Paoletti, and P. Fioretti. 1992. Effect of sex steroids on body temperature in postmenopausal women. Role of endogenous opioids. Life Sci. 50: 515.

Echternkamp, S. E. 1984. The relationship between prepartum systemic estrone sulfate concentrations and calf birth weight in beef cows. J. Anim. Sci. 59(Suppl. 1):368.

Ewbank, R. 1963. Predicting the time of parturition in the normal cow. Vet. Rec. 75:367.

Gilbert, R. D., H. Schroder, T. Kawamura, P. S. Dale, and G. G. Power. 1985. Heat transfer pathways between fetal lamb and ewe. J. Appl. Physiol. 59:634.

Godfrey, R. W., S. D. Smith, M. J. Guthrie, R. L. Stanko, D. A. Neuendorff, and R. D. Randel. 1991. Physiological responses of newborn *Bos indicus* and *Bos indicus* × *Bos taurus* calves after exposure to cold. J. Anim. Sci. 69:258.

Gopinath, R., and W. D. Kitts. 1981. Effect of anabolic compounds on plasma levels of thyroid hormones in growing beef steers. J. Anim. Sci. 53(Suppl. 1):321.

Laburn, H. P., D. Mitchell, and K. Goelst. 1992. Fetal and maternal body temperatures measured by radiotelemetry in near-term sheep during thermal stress. J. Appl. Physiol. 72:894.

Laburn, H. P., K. Goelst, and D. Mitchell. 1994. Body temperatures of lambs and their mothers measured by radio-telemetry during parturition. Experientia 50:708.

Lammoglia, M. A., J. W. Holloway, A. W. Lewis, D. A. Neuendorff, and R. D. Randel. 1995. Influence of maternal and service-sire breed on serum progesterone and estrogen before calving and plasma 13,14-dihydro-15-keto-prostaglandin $F_{2\alpha}$ after calving. J. Anim. Sci. 73:1167.

Norman, A. W., and G. Litwack. 1987. Hormones. Thyroid Hormones. Academic Press, Orlando, FL.

NRC. 1984. Nutrient Requirements of Beef Cattle (6th Ed.). National Academy Press, Washington, DC.

Oka, T., and T. Hori. 1994. EP1-receptor mediation of prostaglandin E2-induced hyperthermia in rats. Am. J. Physiol. 267:R289.

Patterson, D. J., R. A. Bellows, P. J. Burfening, and J. B. Carr. 1987. Occurrence of neonatal and postnatal mortality in range beef cattle. I. Calf loss incidence from birth to weaning backward and breech presentation and effects of calf loss on subsequent pregnancy rate of dams. Theriogenology 28:557.

Perry, R. C., L. R. Corah, G. H. Kiracofe, J. S. Stevenson, and W. E. Beal. 1991. Endocrine changes and ultrasonography of ovaries in suckled beef cows during resumption of postpartum estrous cycles. J. Anim. Sci. 69:2548.

Portfield, I. D., and N. O. Olson. 1957. Vaginal temperature of dairy cows before and after calving. J. Am. Vet. Med. Assoc. 131:381.

Refsal, K. R., J. J. Hasenau, R. F. Nachreiner, and E. M. Convey. 1980. Diurnal variation in serum triiodothyronine and thyroxine in lactating dairy cows. J. Anim. Sci. 51(Suppl. 1):320.

SAS. 1994. SAS User's Guide: Statistics (Version 6.10 Ed.). SAS Inst. Inc., Cary, NC.

Schroder, H., R. D. Gilbert, and G. G. Power. 1988. Computer model of fetal-maternal heat exchange in sheep. J. Appl. Physiol. 65: 460.

Stewart, R. E., J. S. Stevenson, and J. E. Minton. 1994. Serum hormones during the estrous cycle and estrous behavior in heifers after administration of propylthiouracil and thyroxine. Domest. Anim. Endocrinol. 11:1.

Terqui, M., C. Delouis, J. Thimonier, and R. M. Ortavant. 1975. Relations entre les oestrogenes au milieu de la gestation, le poids a la naisssance et la croissance ulterirure des veaux de race Charolaise. C. R. Acad. Sci., Parid D 280:2789.

Velez, J. S., R. D. Randel, and D. A. Neuendorff. 1991. Effect of uterine manipulation on postpartum fertility and plamsa 13,14-dihydro-15-keto-prostaglandin $F_{2\alpha}$ in Brahman cows and first calf heifers. Theriogenology 36:987.

Vollmann, R., and U. Vollmann. 1942. Vergleichende temperaturuntersuchugen zur reproduktionsphysiologie der frau und der kuh. Schweiz. Arch. Tierheilkd. 84:403.

Weber, E. 1910. Beobachtung uber die rektaltemperatur des gesunden rindes, zugleich ein beitrag zur frage der vorausbestimmung der zeit der geburt bel der kuh. Dtsch. Tieraerztl. Wochenschr. 18:143.

Wohl, H. 1977. The cusum plot: Its utility in the analysis of clinical data. The New Engl. J. Med. 296:1044.

Wright, S. 1958. The method of path coefficients. In: J. L. Lush (Ed.) Systems of Mating and Other Papers. 161. Iowa State University Press, Ames.