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Short communication: Effect of maternal heat stress in late gestation on blood hormones and metabolites of newborn calves

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ABSTRACT

Maternal heat stress alters immune function of the offspring, as well as metabolism and future lactational performance, but its effect on the hormonal and metabolic responses of the neonate immediately after birth is still not clear. The objective of this study was to investigate the blood profiles of hormones and metabolites of calves born to cows that were cooled (CL) or heat-stressed (HS) during the dry period. Within 2 h after birth, but before colostrum feeding, blood samples were collected from calves [18 bulls (HS: n = 10; CL: n = 8) and 20 heifers (HS: n = 10; CL: n = 10)] born to CL or HS dry cows, and hematocrit and plasma concentrations of total protein, prolactin, insulin-like growth factor-I, insulin, glucose, nonesterified fatty acid, and β-hydroxybutyrate were measured. Compared with CL, HS calves had lower hematocrit and tended to have lower plasma concentrations of insulin, prolactin, and insulin-like growth factor-I. However, maternal heat stress had no effect on plasma levels of total protein, glucose, fatty acid, and β-hydroxybutyrate immediately after birth. These results suggest that maternal heat stress desensitizes a calf's stress response and alters the fetal development by reducing the secretion of insulin-like growth factor-I, prolactin, and insulin.
Key words: heat stress, hormones, dairy calves

Short Communication

Maternal heat stress during the dry period affects offspring. Compared with those from cooled (**CL**) cows, calves born to heat-stressed (**HS**) dry cows have impaired passive and cell-mediated immune function (Tao et al., 2012; Monteiro et al., 2014) and altered metabolism during the preweaning period (Tao et al., 2014; Monteiro et al., 2016). Moreover, Monteiro et al. (2013) reported that maternal heat stress during the dry period reduced heifer milk production during the first lactation. However, no studies have attempted to examine the fetal response to maternal heat stress during the late gestation in bovine, perhaps due to the technical difficulty of assessing the fetal metabolic and hormonal responses in utero. Although confounded with the stress responses related to parturition, the hormonal responses and blood metabolite profiles of the calves immediately after birth before milk ingestion could provide important information related to the fetal responses to maternal heat stress before the complications of postnatal nutrition and management. Indeed, Tao et al. (2012) observed that calves born to HS dry cows had a lower plasma concentration of cortisol immediately after birth compared with calves born to CL cows, indicating that maternal heat stress alters the fetal development of hypothalamus-pituitary-adrenal axis and related stress responses during the postnatal period. Thus, our hypothesis was that maternal heat stress during the dry period alters offspring metabolic and hormonal responses immediately after calving. The objective of the present study was to examine the blood hormone and metabolite profiles immediately after birth of calves born to CL and HS cows during the dry period.

The animal trial was conducted at the Dairy Unit of the University of Florida (Hague) during summer 2014, and the treatments and animal handling were approved by the University of Florida Institute of Food and Agricultural Sciences Animal Research Committee. Briefly, multiparous Holstein cows were dried off ~45 d before expected calving and randomly assigned to 1 of 2 treatments, HS or CL, based on parity and mature-equivalent milk production of the just completed lactation. All cows were housed in the same barn during the dry period, but CL cows were under shade and cooled by fans over the freestalls and feed bunks as well as soakers over the feed bunks, whereas HS cows were only

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Table 1. Hematocrit and plasma concentrations of total protein, glucose, fatty acids, BHB, insulin, prolactin and IGF-I of calves born to dams exposed to either heat stress (n = 20) or cooling (n = 18) during the dry period immediately after birth

Variable	Heat stress	Cooling	SEM	*P*-value TRT[1]	*P*-value Sex	*P*-value TRT × Sex
Hematocrit, %	32.00	34.94	1.57	0.05	0.85	0.62
Total protein, g/dL	5.22	5.19	0.08	0.74	0.58	0.18
Glucose, mg/dL	68.04	61.51	6.99	0.97	0.67	0.15
Fatty acids, μEq/L	798.8	627.6	97.5	0.42	0.26	0.89
BHB, mg/dL	0.75	1.06	0.28	0.14	0.64	0.76
Insulin, ng/mL	0.51	0.74	0.09	0.08	0.83	0.31
Prolactin, ng/mL	5.67	9.49	1.35	0.08	0.12	0.98
IGF-I, ng/mL	55.0	75.6	8.19	0.09	0.47	0.70

[1]TRT = treatment.

provided with shade. The temperature-humidity index during the dry period between stall areas for both groups of cows were similar and averaged 78 ± 4 (mean ± SD). Rectal temperature was measured daily at 1430 h and the least squares means were 39.3 versus 39.0°C for HS and CL cows, respectively (SEM = 0.02°C, $P < 0.01$); the respiratory rate was counted at 1500 h once a day and the least squares means were 66.7 versus 49.1 breaths/min for HS and CL cows, respectively (SEM = 3.3 breaths/min, $P < 0.01$) during the entire dry period. Thirty-eight calves were delivered during the experiment, including 18 bulls (HS: n = 10; CL: n = 8) and 20 heifers (HS: n = 10; CL: n = 10). No treatment effect was noted for birth weight of the bulls (LSM = 42.6 vs. 39.8 kg for CL and HS, respectively; SEM = 1.8 kg; $P = 0.28$; B. M. Ahmed and G. E. Dahl, unpublished data) and heifers (LSM = 36.3 vs. 35.7 kg for CL and HS, respectively; SEM = 1.5 kg; $P = 0.79$, Monteiro et al., 2016). Within 2 h after birth and before colostrum feeding, a blood sample was collected via jugular venipuncture into sodium-heparinized vacuum tubes (Becton Dickinson, Franklin Lakes, NJ) and immediately placed in ice. The hematocrit and total plasma protein were assessed using a microcapillary centrifuge and refractometer, respectively, and then the plasma samples were harvested after centrifugation at 2,619 × *g* at 4°C for 30 min. The concentrations of glucose (Autokit Glucose; Wako Chemicals USA Inc., Richmond, VA), fatty acids [HR Series NEFA-HR(2), Wako Chemicals USA Inc.], and BHB (Autokit 3-HB, Wako Chemicals USA Inc.) in plasma were measured by colorimetric methods (Monteiro, et al., 2016). The insulin and prolactin (**PRL**) concentrations of plasma were determined by RIA (Malven et al., 1987; Miller et al., 2000). The IGF-I concentration of plasma was determined by chemiluminescent enzyme immunoassay according to the instruction provided by manufacturer (Immulite 1000, Siemens Medical Solutions Diagnostics, Los Angeles, CA), and the monoclonal murine anti-IGF-I antibody (Immulite 1000 IGF-I, Cat#: LKGF1, Siemens Medical Solutions Diagnostics) was used; the assay was validated for bovine serum previously (Brandão et al., 2016). The plasma concentrations of metabolites and hormones were analyzed using the MIXED procedure of SAS 9.4 (SAS Institute, Cary, NC). The statistical model included fixed effects of treatment, sex, and treatment by sex with calf (treatment × sex) as a random effect; the least squares means ± standard error of the mean are reported. No treatment effects were observed for concentrations of total protein, glucose, fatty acids, and BHB in plasma, but HS calves had lower ($P = 0.05$) hematocrit and tended ($P \leq 0.09$) to have lower plasma concentrations of insulin, PRL, and IGF-I compared with CL calves (Table 1).

During the dry period, the stall areas for both CL and HS cows had similar temperature-humidity index, indicating all cows were exposed to a similar degree of heat stress; however, the cooling system effectively reduced the heat strain of CL cows evidenced by the lower rectal temperature and respiration rate compared with HS cows. Thus, the effectiveness of the cooling treatment in this experiment is confirmed. The lower hematocrit of HS calves compared with CL is consistent with Tao et al. (2012), and may indicate a carryover effect from in utero hypoxia due to the impaired placental oxygen diffusion caused by maternal HS (Regnault et al., 2007). Compared with CL, the lower plasma concentration of PRL immediately after birth of HS calves is of interest and indicates that maternal stress alters calf PRL release in response to parturition. It is well known that PRL is a robust stress hormone in cattle (Tucker, 1971), and the lower concentration of PRL in HS calves relative to CL after parturition may suggest that maternal heat stress attenuates the calf stress responses postnatally. Consistent with this theory, using a similar experimental design, Tao et al. (2012) reported that HS calves had lower serum cor-