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In utero exposure to heat stress during late gestation has prolonged effects on the activity patterns and growth of dairy calves

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ABSTRACT

Exposure to heat stress during late gestation exerts negative carryover effects on the postnatal performance of the calf. In this study, we evaluated the health, growth, and activity patterns of calves born to cows exposed to heat stress (HT, provided only shade, n = 31) or cooling (CL, fans, soakers, and shade, n = 29) during late gestation (~46 d, maternal dry period). Calves' body weight, rectal temperature, suckling reflex, and movement scores were recorded at birth, and calves were fed 6.6 L of maternal colostrum in 2 meals. Blood samples were collected at birth (before feeding), 24 h after birth, and at d 10 and 28 of age. Calves were housed in individual pens, fed pasteurized milk (6 L/d), and had ad libitum access to grain and water until weaning (49 d). Activity was assessed during the first week of life (wk 1), at weaning (wk 7), and in the first week postweaning (wk 8) using electronic data loggers. Health and body weight were monitored weekly. At birth, calves born to CL cows were heavier (41.9 vs. 39.1 ± 0.8 kg), their temperature was lower (38.9 vs. 39.3 ± 0.08°C), and they were more efficient at absorbing IgG than HT calves. Suckling reflex and movement score at birth were not different between groups, but calves born to CL cows spent more time (50 min/d) standing in the first week of life as a result of longer standing bouts. In wk 7 and 8, calves born to CL cows had less frequent standing bouts than HT heifers, but CL heifers maintained greater total daily standing time (36 min/d) due to longer (7 min/bout) standing bouts. All calves were healthy, but HT heifers tended to have higher (looser) fecal scores on d 10. Heifers born from CL cows gained 0.2 kg/d more from birth to weaning, weighed 4 kg more at weaning, and had greater concentrations of IGF-1 than HT calves, particularly on d 28. In utero heat stress during late gestation had immediate and prolonged effects on passive immunity, growth, and activity patterns in dairy calves.
Key words: heat stress, immunity, activity, dairy calf

INTRODUCTION

Dairy cows exposed to heat stress during lactation have reduced feed intake, impaired systemic physiology, and decreased milk production (Collier et al., 2006; Baumgard and Rhoads, 2013). Exposing dairy cows to heat stress during the dry period, between 2 consecutive lactations, compromises mammary gland development prepartum (Tao et al., 2011), decreasing milk production in the subsequent lactation (do Amaral et al., 2009, 2011). Prenatal stressors, such as the plane of nutrition, environmental stress, and social stress, can also lead to impaired fetal development and compromised postnatal performance (Wu et al., 2006; Merlot et al., 2008; Reynolds et al., 2010). However, the effect of maternal heat stress on developing offspring during late gestation and the adverse short- and long-term consequences for their future performance, growth, and immunity are less studied and understood.

The in utero exposure of calves to heat stress has been shown to induce fetal growth retardation by decreasing uterine blood flow (Oakes et al., 1976), placental weight (Alexander and Williams, 1971), and the birth weight of the offspring (Collier et al., 1982; Tao et al., 2012a). Calves born to cows under heat stress during the dry period are lighter at birth and have lower passive immunity than calves born to cooled cows (do Amaral et al., 2011; Tao et al. 2012a; Monteiro et al., 2014). In addition to the in utero effects, recent studies have shown that heat stress also exerts carryover effects on the postnatal performance of the offspring during the preweaning period, including immune function (Tao et al., 2012a; Monteiro et al., 2014; Strong et al., 2015) and metabolic adaptations (Tao et al., 2014; Monteiro et al., 2016b). Understanding behavior is also a valuable tool when assessing animal welfare, and activity patterns are influenced by a range of factors, such as bedding material and comfort (Sutherland et

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al., 2014), and health (Proudfoot et al., 2014). Activity is also influenced by temperature: both calves and cows spend less time lying down in hot summer temperatures (Overton et al., 2002; Tripon et al., 2014). However, studies exploring the effect of in utero heat stress on the activity of dairy calves are lacking.

In this study, we set out to evaluate the physiological, behavioral, and immune responses induced by in utero heat stress during late gestation (i.e., the maternal dry period), and the effect on the growth and health of the calf before weaning. We hypothesized that in utero exposure to heat stress would negatively affect calf responsiveness at birth and patterns of activity, and would compromise postnatal health and growth compared with calves born to cows that were provided with active cooling during the dry period.

MATERIALS AND METHODS

Animals and Experimental Design

Maternal Treatments and Management. We conducted a trial at the Dairy and Calf Units of University of Florida (Hague) during the summer and fall of 2015 (June to December). Treatments and animal handling were approved by the University of Florida Institutional Animal Care and Use Committee. Pregnant multiparous Holstein cows were dried off approximately 46 d before expected calving and randomly assigned to 1 of 2 treatments: heat stress (**HT**, n = 31) or cooling (**CL**, n = 29). Groups were balanced by parity (average 2.8 ± 0.86) and mature equivalent milk production from their previous lactation. Cow sample size per treatment was calculated based on milk production data (27.7 vs. 34.0 kg/d, respectively, SD = 6.2 kg/d) for the heat stressed or cooled dry cows in the next lactation (Tao et al., 2012b), using a level of significance of 0.05 and 85% power. All cows were housed in the same freestall barn in 2 pens during the dry period. In the CL pen, cows were actively cooled using fans (J&D Manufacturing, Eau Claire, WI) and soakers (Rain Bird Manufacturing, Glendale, CA) over the feed bunks, whereas in the HT pen cows were provided with only shade (roof with open sides). When the ambient temperature exceeded 21.1°C, fans automatically turned on, and soakers were activated for 1.5 min at 5 min intervals. The treatments assigned to calves, HT or CL in utero, reflected the treatments assigned to their dams during the dry period (late gestation). All cows were fed a common close-up TMR throughout the dry period (15.4% CP, 34.5% NDF, 0.62% Ca, 0.37% P, 036% Na, 0.4% Cl, 0.3% Mg, 0.2% S).

The air temperature and relative humidity of each pen in the barn were recorded every 15 min using Hobo Pro series temperature probes (Onset Computer Corp., Pocasset, MA). The temperature-humidity index (**THI**) was calculated based on the equation reported by Dikmen et al. (2008). The average THI during the experimental period was similar for the HT and CL pens, and was ≥72 (average 77.6 and 77.9 for CL and HT, respectively) during the day and night for the entire period, but cows in the CL group had access to fans and soakers to ameliorate the adverse effects of the THI. Rectal temperature was measured twice daily (0730 and 1430 h) using a GLA M700 digital thermometer (GLA Agricultural Electronics, San Luis Obispo, CA), and respiration rate was monitored 3 times per week (1400 h, by counting the flank movements for 1 min) for all cows during the dry period to confirm the heat burden.

Calf Management. A total of 60 calves were born to cows exposed to HT (n = 15 heifers, n = 16 bulls) and CL (n = 15 heifers, n = 14 bulls) environmental conditions during the entire dry period (47.6 ± 1.5 and 43.9 ± 1.4 d for CL and HT cows, respectively). All calves were born between July 14 and October 6, 2015. Measurements at birth were performed for heifers and bull calves, but only heifers (n = 13 born to CL dry cows, n = 9 born to HT dry cows) were kept and followed until weaning. At birth, all calves were separated from their dams and had their navel dipped with 2% iodine to prevent infection. Day of birth was considered study d 0. Within 4 h of calving, dams were milked in the parlor using a portable milking unit to collect colostrum according to dairy unit standard operating procedures. A colostrum sample was collected and stored at −20°C. Calves were fed 6.6 L of fresh colostrum from their dam in 2 separate meals (3.8 L within 4 h and 2.8 L within 12 h after birth) by bottle or by esophageal feeder when needed (5 calves were tube-fed due to lack of interest in drinking the colostrum offered). Depending on colostrum availability, some calves were fed frozen colostrum collected from a different dam, as long as it belonged to the same treatment group. Eight heifer calves, 6 from the HT group and 2 from the CL group, were removed from the experiment because they received insufficient colostrum. After 1 d of age, heifer calves were transported to the calf unit, housed in individual pens, and provided with 6 L/d of pasteurized milk for 21 d and 8 L/d after that until weaning at 49 d. All calves had ad libitum access to grain and water from birth to weaning. Grain intake was not recorded. Calves were weaned by reducing their milk allotment to 3 L/d for 1 wk. All calves were exposed to the same