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Short communication: Changes in body temperature of calves up to 2 months of age as affected by time of day, age, and ambient temperature

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ABSTRACT

Extensive measurements of calf body temperature are limited in the literature. In this study, body temperatures were collected by taping a data logger to the skin over the tail vein opposing the rectum of Holstein calves between 4 and 60 d of age during 3 different periods of the summer and fall. The summer period was separated into moderate (21–33°C average low to high) and hot (25–37°C) periods, whereas the fall exhibited cool (11–19°C) ambient temperatures. Tail temperatures were compared in a mixed model ANOVA using ambient temperature, age of calf, and time of day (10-min increments) as fixed effects and calf as a random effect. Measures within calf were modeled as repeated effects of type autoregressive 1. Calf temperature increased 0.0325°C (±0.00035) per 1°C increase in ambient temperature. Body temperature varied in a distinct, diurnal pattern with time of day, with body temperatures being lowest around 0800 h and highest between 1700 and 2200 h. During periods of hot weather, the highest calf temperature was later in the day (~2200 h). Calf minimum, maximum, and average body temperatures were all higher in hot than in moderate periods and higher in moderate than in cool periods.
Key words: calves, body temperature, environment

Short Communication

Body temperature regulation in neonatal calves is metabolically immature (NRC, 2001). Additionally, calf performance is greatly affected by ambient temperature (Bateman et al., 2012), and extremes in ambient temperatures can negatively affect calf immunity (Carroll et al., 2012). Mature, healthy cattle maintain thermoneutrality through adjustments in behavior, heat production, heat transfer to and loss from their surface, and evaporation (Macauly et al., 1995). Metabolic and physiological changes and environmental stresses can change body temperature (Carroll et al., 2012). Body temperatures are also important for farm personnel and veterinarians to assess calf health.

Extensive measurements of calf body temperature are limited. Tympanic temperatures were extensively measured in young dairy calves and found to have a diurnal change over the 24-h day similar to adult dairy cows (Macauly et al., 1995). Whereas the rectum is the standard place to measure temperature, rectal temperatures are subject to errors, and if manually taken are laborious and disruptive to animal behavior (Burfeind et al., 2010). Errors with taking rectal temperatures include the procedure, the device, the depth of insertion into the rectum, and defecation, and errors can amount to as much as ± 0.5°C (Burfeind et al., 2010). A procedure for an indwelling rectal data logger allows temperatures to be recorded for a few days, as well as reduce labor and disruption of animal behavior (Reuter et al., 2010). A procedure for using a small data logger taped to the skin near the tail vein of the calf opposing the rectum has been reported to successfully measure body temperature, as tail temperature correlated (R^2 = 0.80) with rectal temperature (Nogami et al., 2013), and appears most useful for long-term, extensive measurements of body temperature (Esselburn et al., 2013; Nogami et al., 2013). Data loggers used by Esselburn et al. (2013) were attached directly to a calf's tail skin over the tail vein, and Dikmen et al. (2014) used vaginal indwelling loggers, both of which are precise to ±0.0625°C (Maxim Integrated Products Inc., Sunnyvale, CA). Therefore, the objective of the current research was to extensively measure the body temperature of calves between 4 and 60 d of age as affected by time of day, age, and ambient temperature.

Calves were cared for by acceptable practices as described in the *Guide for the Care and Use of Agricultural Animals in Research and Teaching* (FASS, 2010) and housed and managed under conventional farm procedures in the summer and fall. Four groups of 12 to 20 male Holstein calves (56 total), initially 2 to 4 d of age, from a single dairy farm were transported 3.5 h to

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the Nurture Research Center in southwest Ohio during summer and fall seasons. The first 3 groups of 12 calves each were received 35 d apart. The fourth group (20 calves) was received 70 d after the third group. Calves were housed in 1.2 × 2.4 m individual pens with a coarse rock, tile-drained floor bedded with straw in a curtain-sided, naturally ventilated barn with no added heat. Management practices including vaccinations and medical treatments during the trial were based on the recommendations of a veterinarian. Upon arrival, calves were fed 0.66 kg of DM daily from a 27% CP, 17% fat (DM basis) mixed ration for 39 d that was divided into 2 equal meals at 0630 and 1600 h. The mixed ration was fed at 0.33 kg of DM daily at 0630 h from 40 to 42 d to facilitate weaning. Starter (20% CP on DM basis) and water were fed ad libitum throughout.

Data loggers (Thermocron model DS1922L-F5#, Maxim Integrated Products Inc.; precise to ±0.0625°C) were taped to the skin over the tail vein opposing the rectum using flexible tape (Vetrap, 3M, St. Paul, MN). Temperatures were captured every 10 min and stored on the data logger beginning at 4 d of age to up to 60 d of age. Data loggers were on each calf for >53 d/calf. All data loggers were removed twice through the trial for <24 h total to download the data to a personal computer (and import it into a spreadsheet) and replace the tape. Data loggers were also removed and replaced on the tail if tape appeared to be loose. A macro was written to remove any measurements less than 37.8°C, and then any measurement more or less than 0.25°C from the previous measurement was removed in an attempt to eliminate any erroneous values. The temperature thresholds of 37.8°C and the 0.25°C change were based on findings from casual observations of behavior, noted times of the behavior in specific calves, and temperature recordings at noted times during the first 4 d in the first set of calves. Behaviors that lead to erroneous values were extreme tail movements in excited calves consuming milk, calves sleeping on their sides where the tail was somewhat separated from the body, loose tape that secured the data loggers to the tail, and excited calves playing with their tails raised during pen maintenance and bedding by technicians. These behaviors frequently resulted in temperatures <37.8°C. Removed measurements ranged from <2% of total per calf to <7% of total per calf. Additionally, a data logger was taped to a room temperature sensor and recording device (TP125 temperature and humidity recorder, Dickson, Addison, IL) suspended on a wire 1.5 m above the floor of the nursery to record ambient temperature.

Statistical analyses of the data were conducted using Proc MIXED in SAS (version 8, SAS Institute Inc., Cary, NC). Rectal and tail temperatures were compared in a mixed model regression using time of day, day, and calf as random effects. Measures within calf were modeled as repeated effects. Day and time of day were not significant ($P > 0.1$) and removed from the model. To evaluate what affected calf temperatures, tail temperatures were compared in a mixed model ANOVA using ambient temperature, age of calf, and time of the day (10-min increments) as fixed effects and calf as a random effect. Measures within calf were modeled as repeated effects. Groups of days where ambient temperatures were distinctly different (hot, moderate, and cool) were compared in a completely randomized design with repeated measures of day using the mixed model ANOVA where minimum, maximum, and average temperatures of each day were used in the ANOVA. Means were separated with a protected LSD test. An auto-regressive type 1 covariance matrix was employed in each analyses as determined using Akaike's information criteria.

The functionality of the data loggers were evaluated and compared with other temperature measuring devices in various ways. One hundred readings from the data logger that was taped to the room temperature sensor and the room temperature sensor were randomly selected during the first 4 d of the first group of calves to compare ambient temperature readings. Readings were rounded to 1 decimal place, compared, and no paired readings were different. When data loggers were first removed from the calves, they were immediately tested in a hot water bath with a temperature taken using a rectal temperature probe to 1 decimal place (M700 digital thermometer, GLA Agricultural Electronics, San Luis Obispo, CA). A hot water bath was constructed using a large flat-bottomed Pyrex (World Kitchen LLC, Rosemont, IL) pie plate on a hot plate set to a low temperature (approximately 38.5°C) and subsequently a higher temperature (approximately 39.3°C). Each data logger was placed in smaller Pyrex pie plate set on 0.5-cm steel spacers within the hot water bath. After 30 min at each temperature, the data loggers were removed. The water bath temperature was checked before and after data logger immersion with the rectal temperature probe. Two readings from each data logger and the 2 readings from the rectal probe were compared at each water bath temperature after rounding to 1 decimal place. No paired readings differed. Comparisons of the rectal temperature probe, room temperature sensor, and data loggers agreed suggesting the data loggers were functioning properly.

Calf tail temperatures from the data loggers were compared with a paired rectal temperature taken with the rectal temperature probe. Rectal temperatures were taken on 25 different days, 3 times daily at approximately 0600, 1100, and 1700 h, with the exact time and calf recorded in the first group of 12 calves (900 paired