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Season of creation is associated with future survival, fertility, and milk yield of Holstein cows

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ABSTRACT

Environmental influences during different stages of pregnancy can induce lifelong changes in the structure, physiology, and metabolism of the offspring. Our hypothesis was that season of creation (when the female conceived), associated with heat stress conditions at conception and during the initial stages of embryonic development, affects the lifetime performance and survival of the female after birth. The objective was to analyze the association between month of creation and subsequent survival, fertility, and milk yield in cows maintained on dairy farms in Florida, where the climate during the summer is hot and humid but winters are mild. Initial data consisted of 667,104 Dairy Herd Improvement lactation records from cows calving between 2000 and 2012 in 152 herds. Dates of creation were estimated as birth date minus 280 d. The magnitude of heat stress in each herd was quantified by comparing milk yield during summer and winter. Wood's lactation curves were fitted to adjust milk yields for effects of days in milk, and residuals were obtained for each calendar month. A sine function was fitted on the 12 residuals per farm. The difference between the highest and lowest points on the sine function was termed the seasonality index, a measure of the direct effect of heat stress on milk production. Herds were categorized in 3 levels of seasonality [low (seasonality index values less than the 25th percentile value; <2.84), medium (values within the interquartile range), and high (values greater than the 75th percentile value; >5.22)]. Cows were grouped by their month of creation: summer (July–September) and winter (December–February), and comparisons were performed by parity using logistic regression, ANOVA, and survival analysis. Two models were developed. Model A included the complete population of cows (n = 337,529 lactation records) created in winter or summer. Model B included cows (n = 228,257 lactation records) that had parent-average genetic information available to be able to correct for farmer's use of lower genetic merit of sires in summer. Other variables included in the models were month and year of calving, age at first calving, and herd. Models were run per parity group (1, 2, and ≥3). In both models, age at first calving was lower for cows created during winter versus summer. The odds (95% confidence interval) of survival to a second calving for cows created in winter were 1.21 and 1.15 times the odds of survival for cows created in summer for models A and B, respectively. Numbers of days from calving to first breeding and from calving to conception were consistently smaller for winter versus summer months of creation across all parity categories. Milk yields (305 d and by 70 d in milk) were greater for winter versus summer. In conclusion, cows that were created in the winter had better subsequent survival and performance than cows that were created in the summer. There is evidence that season of creation may have lifelong negative consequences for the cow.
Key words: heat stress, conception, performance, survival

INTRODUCTION

Epidemiological studies in humans and experimental studies using animal models have shown that maternal manipulations, including nutrition and other transient environmental influences, during different stages of pregnancy can induce life-long changes in the structure, physiology, and metabolism of the offspring (Wu et al., 2006; Chmurzynska, 2010; Peñagaricano et al., 2013). Moreover, research has suggested that adult disease risk in humans is associated with adverse environmental conditions early in development. Although the mechanisms behind these relationships are unclear, an involvement of epigenetic deregulation has been hypothesized. Heijmans et al. (2008) suggested that individuals who were prenatally exposed to famine showed different levels of DNA methylation compared with unexposed, same-sex siblings.

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It has been suggested that the first stages of mammalian fetal development are determinant for the adult offspring, as dramatic changes in DNA methylation occur that are responsible of cell differentiation of the embryo, determining, in part, phenotype expression in adult life (González-Recio et al., 2012). Some evidence indicates that maternal diet during the different stages of pregnancy can induce physiological and epigenetic changes in fetal tissues in different species, which in turn could have serious implications after birth (Fleming et al., 2012; Lan et al., 2013). During late gestation, malnutrition is related to the lower birth weight of offspring, increased incidence of dystocia, and high mortality and morbidity of neonates (Wu et al., 2006); a link between impaired fetal growth, possibly caused by maternal malnutrition, and reproductive function, involving follicle development, has been also established (Sullivan et al., 2009; Bach, 2012; Dupont et al., 2012).

In dairy cows, other environmental conditions, such as heat stress during late gestation, have also been related to lower birth weight, decreased total plasma protein concentration and hematocrit, and compromised immune function of the newborn (Tao et al., 2012a, 2014; Monteiro et al., 2014). Some studies have reported the potential epigenetic effect on specific production and reproduction traits in dairy cows, with reduced yields for females born to mothers that were lactating while pregnant versus those born to heifers (González-Recio et al., 2012; Gudex et al., 2014). Moreover, 2 recent studies indicated that heat stress at the time of conception of their mothers had an effect on the subsequent milk production of Holstein cows (Brown et al., 2015; 2016).

Summer heat is a significant stressor affecting the dairy cows in many parts of the United States (St-Pierre et al., 2003). Direct negative effects on milk yield and reproduction are well documented (West, 2003; de Vries and Risco, 2005; Tao and Dahl, 2013).

Estimating the association between exposure to heat stress around time of creation and adult survival and performance of the female offspring is of interest, as summers in Florida easily lead to heat stress in dairy cattle, whereas winters are mild. Our hypothesis was that season of creation, associated with heat stress conditions at conception and during the initial stages of embryonic development, would have a life-long effect on performance and survival after birth. Consequently, the objective of our observational study was to analyze the association between calendar month of creation (associated with heat stress) and subsequent survival, fertility, and milk yield in cows maintained in dairy herds in Florida enrolled in the DHI program.

MATERIALS AND METHODS

Study Population

Florida has about 124,000 dairy cows, in herds ranging in size from about 100 to 6,000 cows, with an annual average milk yield per cow of 9,260 kg (Arriola and De Vries, 2016). Most common housing systems include open lot, freestall, grazing, and combinations of these systems. In addition to the use of shade structures, cooling systems for summer months include sprinkling combined with fans (Bucklin et al., 2015).

We analyzed DHI lactation records from 152 herds located in Florida ranging from 100 to 6,632 cows calving per year. A total of 667,104 lactation records of cows born between January 1988 and October 2010 and calving between January 2000 and December 2012 were available. Lactation records were provided by Dairy Records Management Systems (Raleigh, NC) and consisted of date of birth, calving date, parity, test-day milk yields, test-day dates, last reproductive status, date of conception, date of dry off, 305-d milk yield, herd code and state, breeding dates, and reported culling reason and date. Date of creation was estimated as date of birth minus 280 d.

In addition, a subpopulation of cows (n = 228,257 lactation records) had parent-average (**PA**) genetic data available for multiple traits. These PA were obtained from the August 2015 national genetic evaluation. The PA are estimates of the genetic merit underlying the survival, fertility, and milk yield of the cow based on her sire and dam, but are not affected by the cow's own performance.

Average temperature humidity indexes (**THI**) in Florida were calculated per calendar month from daily data provided by the National Oceanic and Atmospheric Administration for the years 2007 to 2013, according to the methodology reported by Ferreira et al., (2016). Calculations included the average of the highest and the lowest temperature for each day. The relative humidity was calculated considering average daily temperature and dew point. A THI >68 was considered an indication of heat stress (Zimbelman et al., 2009).

Data Edits

The analyses were restricted to Holstein cows. Lactation records missing parity number or birth or calving dates were removed from the data set. Dates of calving, conception, culling, and last known event were determined for each lactation record. Records that ended with the subsequent calving were considered completed.