Magnitude of the reduction in automatically scored body condition from calving to nadir body condition score affects the fertility of Holstein cows

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Abstract

Automatically generated body condition scores (BCS) through image technology enable daily assessments of body energy reserves of dairy cows. The availability of high frequency data allows for the analysis of specific patterns or points of interest, such as nadir BCS, and could result in quick interventions if necessary or tailored management adjustments. The objective of this study was to evaluate the effect of the decrease in BCS from calving to nadir BCS before first artificial insemination (AI1) on pregnancy per AI1 (PAI1) in Holstein cows. A retrospective observational study was completed using data collected from 6,100 lactations (primiparous = 3,683; multiparous = 2,417) starting between April 2019 and March 2021 in a commercial dairy operation located in Colorado, USA. Scores generated by BCS cameras (DeLaval International AB, Tumba, Sweden) at calving (BCScalv) and nadir (BCSnadir) were selected to calculate the ratio BCSnadir/BCScalv (BCSratio).

The BCSratio is a representation of the BCS change from calving to nadir, where greater BCS loss results in smaller values for the ratio. To facilitate the calculation of PAI1 probabilities, the resulting BCSratio values were categorized as low (≤ lower quartile, large BCS decreases), medium (interquartile range, moderate BCS decreases), and high (≥ upper quartile, small BCS decreases). Data were examined using logistic regression by univariable models that were followed by multivariable models considering calving season, occurrence of disease, and milk yield up to 60 DIM as covariables. All the analyses were performed separately for primiparous and multiparous cows. Median (range) for BCSratio were 0.91 (0.61-1.00) and 0.87 (0.53-1.00) for primiparous and multiparous cows, respectively. Predicted probabilities for PAI1 for low, medium, and high BCSratio categories were 34.1%, 38.2%, and 38.3% in primiparous and 18.2%, 24.3%, and 25.2% in multiparous cows, respectively. The logistic regression analyses identified significant associations between BCSratio and PAI1, where cows with greater BCSratio values were more likely to conceive at AI1. The analyses indicated that the odds (95% CI) of PAI1 increased by 2.47 (1.25-4.91; P = 0.009) and by 3.22 (1.48-7.06; P = 0.003) for each 0.5-unit increment in BCSratio in primiparous and multiparous cows, respectively. Overall, the magnitude of the reduction between BCS at calving and nadir BCS had a significant impact on pregnancy at first artificial insemination.

Keywords: Body condition, automated, nadir, fertility.

Introduction

The change from late gestation to early lactation is accompanied by remarkable metabolic and endocrine adjustments in the dairy cow (Gross *et al*., 2011). As this transition is characterized by a reduction in dry matter intake associated with an increased demand for nutrients to support the initiating lactation, cows experience a typical negative energy balance (NEB) during the peripartum period. Fat and labile protein mobilization from body energy reserves to match the increased energetic demands results in reductions in subcutaneous fat which can be assessed by body condition scoring (BCS) (Lean *et al*., 2013; Roche *et al*., 2009).

In practical terms, dairies watch for body condition to monitor cows' energy status and energy balance. Nonetheless, only one third of the US dairy farms implemented formal BCS into their management practices (Hady *et al*., 1994; Bewley *et al*., 2010), likely due to the time consuming and subjective nature of visual or tactile assessment (Edmondson *et al*., 1989; Leroy *et al*., 2005).

The advent of automated body condition scoring systems has allowed for the use of data originated at multiple and precise time points, with scores that are not affected by inter and intra evaluator variation (Borchers and Bewley, 2015).

Previous research has identified the impact of inadequate energy status and energy balance on cow fertility (Carvalho *et al*.; 2014; Roche *et al*., 2009; Barletta *et al*., 2017). Nonetheless, these studies were completed considering visual body condition evaluation at specific time points, which makes it difficult an evaluation of the magnitude and timing of the largest reduction in BCS during early lactation. Availability of daily scores originated from automated camera systems provides opportunity for precise assessment of the impact of BCS nadir on subsequent cow performance.

We hypothesized that the magnitude of the reduction between BCS at calving and nadir BCS would have a significant impact on< pregnancy at first artificial insemination. Therefore, the objective of this study was to evaluate the effect of the decrease in BCS from calving to nadir BCS before first artificial insemination (AI1) on pregnancy per AI1 (PAI1) in Holstein cows.

Material and methods

Study design and study population

This retrospective observational study included information collected from 6,100 lactations (primiparous = 3,683; multiparous = 2,417) starting between April 2019 and March 2021 in a commercial dairy operation located in Colorado, USA. Cows were maintained in a cross ventilated barn, milked 3X in a 90 units rotary parlor, and subject to first AI at about 80 DIM (primiparous) and 60 DIM (multiparous), following a Double OvSynch protocol. Pregnancy diagnosis was performed via transrectal ultrasonography on d 32±3 after AI and reconfirmed at d 80±3 of gestation. Cows determined non pregnant were administered prostaglandin F2α if a corpus luteum was visible and were submitted for AI based on estrus detection using the DeLaval activity meter system (DelPro Farm Manager software DeLaval International AB, Tumba, Sweden).

Data collection started at dry-off (multiparous) or at calving (primiparous) and continued until the AI resulting in pregnancy or culling. Cow demographic, reproductive, and health data were extracted from on-farm software (Dairy Comp 305; Valley Ag Software, Tulare, CA). Daily milk yield and BCS were extracted from DelPro Farm Manager software. The dataset included cow ID, date of calving, lactation number, calving-related and disease events, breeding dates, pregnancy diagnosis outcomes, daily milk yield for the first 60 DIM, and daily BCS.

Body condition scoring and BCS categorization

Scores were generated by an automatic BCS system using DeLaval BCS cameras (DeLaval International AB, Tumba, Sweden) previously validated by Mullins *et al*. (2019) that were mounted on the sorting-gate at each exit (n = 2) of the milking parlor. As the cow passed under the mounted camera, a continuous video (30 FPS, 32,000 captured reference points) was taken and a 3D image from the video was automatically created and saved by the BCS camera software (Mullins *et al*., 2019; Pinedo *et al*., 2022). In a secondary step, the saved 3D images were processed through an algorithm and analyzed to locate the key physical characteristics (pins, tail head ligaments, sacral ligaments, short ribs, and hooks) of the cow to calculate the automated BCS, viewable in DelPro Farm Manager. The proprietary algorithm used the BCS scoring scale proposed by earlier studies, modified to report BCS in 0.1-point increments (Ferguson *et al*., 1994).

All automated BCS data were recorded in and downloaded from DelPro Farm Manager and scores generated by BCS cameras at calving (BCScalv) and nadir (BCSnadir) were selected to calculate the ratio BCS at nadir/BCS at calving (BCSratio). The BCSratio is a representation of the BCS change from calving to nadir, where greater BCS loss results in smaller values for the ratio.

Calving-related events and disease events were obtained from farm records stored in on-farm software. Only health events diagnosed before or at the day of AI1 were considered in the analyses. Parity was created as a binary variable including primiparous (lactation number =1) and multiparous (lactation number $\geq$2) cows. Calvings were grouped by season (spring, summer, fall, or winter). Finally, a milk yield category was added as a covariable in the models using the quartile distribution of the average daily milk yield in the first 60 DIM (**M60**) obtained from DelPro Farm Manager.

Statistical analyses

All the analyses were performed separately for primiparous and multiparous cows. Descriptive time-to-event analysis for pregnancy was performed using PROC LIFETEST in SAS 9.4 (SAS institute Inc., Cary, NC).

Initial univariable models using only BCSratio as explanatory variable were followed by multivariable models that considered calving season, occurrence of disease up to AI1, and milk yield up to 60 DIM as covariables. Descriptive statistics were calculated using the PROC UNIVARIATE. Least square means for BCS and for days to AI1 by parity category were calculated and compared using ANOVA (PROC GLM).

Odds ratios (**OR**) and predicted probabilities for pregnancy at AI1 were estimated for the explanatory variables of interest using PROC GLIMMIX. For all outcome variables, significant predictors were selected at *P*-value <0.05; interaction terms and controlling variables remained in the models at *P*-value $\leq$0.10.

Results and discussion

The analysis included 6,100 lactations (primiparous = 3,683; multiparous = 2,417). Overall, distribution of calvings across seasons were spring 15.9%, summer 36.2 %, fall 27.8%, and winter 20.1%. Average milk yield for the first 60 DIM was 30.4 (0.07) kg and 45.3 (0.06) kg for primiparous and multiparous cows, respectively.

Median time from calving to nadir were 51 d and 59 d for primiparous and multiparous cows, respectively, while average BCS change from calving to nadir in primiparous and multiparous cows were -0.22 and -0.35 (Table 1). Median (range) for BCSratio were 0.91 (0.61-1.00) and 0.87 (0.53-1.00) for primiparous and multiparous cows, respectively. These values agree with a recent report that indicated that days to nadir were 38 d and 54 d in primiparous and multiparous cows housed in a large commercial dairy farm in Indiana (Truman *et al*., 2022). In the same study, primiparous cows lost 0.14 BCS points, while multiparous cows lost 0.30 points from calving to nadir BCS.

Mean (SD) DIM to AI1 for primiparous and multiparous cows were 83.3 (11.5) d and 63.4 (11.5) d (*P* <0.001) and pregnancy per AI1 was 33.9% (primiparous = 42.2%; multiparous = 28.1%; *P* <0.001). Predicted probabilities for PAI1 for low, medium, and high BCSratio categories were 34.1%, 38.2%, and 38.3% in primiparous and 18.2%, 24.3%, and 25.2% in multiparous cows, respectively.

Data for this study originated from an automated BCS system, which allowed for the identification of the BCS nadir through daily measurements. Thus, the system provides the exact magnitude of the BCS reduction during early lactation. The nadir calving ratio is a representation of this BCS change, where smaller values indicate more severe BCS loss.

The logistic regression analyses identified significant associations between BCSratio and PAI1. As expected, cows with greater BCSratio values were more likely to conceive at AI1. The analyses indicated that the odds (95% CI) of PAI1 increased by 2.47 (1.25-4.91; *P* = 0.009) and by 3.22 (1.48-7.06; *P* = 0.003) for each 0.5-unit increment in BCSratio in primiparous and multiparous cows, respectively.

Previous studies have reported the associations among BCS variables and multiple reproductive variables (Roche *et al*., 2007; Carvalho *et al*., 2014; Chebel *et al*., 2018). As reviewed by Roche *et al*. (2009), most of the reports studying the physiological effects of energy status and energy balance on fertility suggest a positive association between an earlier achievement of pregnancy and increased BCS and reduced BCS loss during early lactation. The results from the current study align with those reported recently by our group in a similar analysis where cows with large loss in BCS between calving to 21 DIM, 56 DIM, and AI1 had lesser odds of P/AI1 compared with other categories of ÄBCS within the same time period (Pinedo *et al*., 2022). The strength of our study is the availability of daily BCS for a detailed description of the BCS drop from calving to nadir. To our knowledge, this is the first study testing the effects of BCS nadir on pregnancy outcomes in a large population of dairy cows. In primiparous cows, insemination started on average 30 days after nadir, at a time where we expect their energy level to be more in balance. In contrast, inseminations for multiparous cows started on average at the same time as they reached nadir. This could be an important factor to explain the lower achieved P/AI1 in multiparous cows. Further studies should investigate cow and parity specific best breeding windows based on BCS profiles.

The reasons for the reduced fertility in cows losing BCS are not fully understood. Nonetheless, the follicular/oocyte quality could be affected by suboptimal energy status during the early postpartum, impairing subsequent fertility in lactating dairy cows (Britt,

Table 1. Descriptive statistics for body condition scores, days in milk at nadir, and average milk yield in the first 60 DIM. Unless stated, least square means (SE) are presented.

Parameter	Primiparous	Multiparous
BCS at calving	3.38 (0.009)	3.34 (0.009)
BCS at nadir	3.15 (0.009)	2.99 (0.009)
BCS change	-0.22	-0.35
DIM at nadir (d)	51 (0.18)	59 (0.21)
BCSratio (median [range])[1]	0.91 (0.61-1.00)	0.87 (0.53-1.00)
Milk yield (average 60 DIM; kg)	30.4 (0.07)	45.3 (0.06)

[1] BCSratio = Calculated as BCS at nadir/BCS at calving.

1992). In addition, changes in hormone levels that regulate gene expression and the secretion of proteins by the endometrium, could affect implantation or pregnancy recognition (Beam and Butler, 1999).

Conclusion

Overall, the magnitude of the reduction between BCS at calving and nadir BCS, analysed here as BCSratio, had a significant impact on pregnancy at first artificial insemination. Larger reductions in BCS were associated with lower likelihood of pregnancy, with a more pronounced effect in multiparous than primiparous cows.

Automatic BCS is a useful tool to monitor and manage energy balance. Individual cow or group BCS profiles should be considered to determine the onset of breeding windows. The implications for fertility management deserve further exploration.

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