Association of body condition with lameness in dairy cattle, a single-farm longitudinal study

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SUPPLEMENTARY FILE

Supplementary Material & Methods

Because all the assessments for the current data set were conducted as a standard procedure on the farm, this data collection is not considered an animal experimentation under German law and did not, therefore, need a special permit.

This project was conducted with the 288 German Holstein dairy cows kept on the LVAT – Institute for Animal Breeding and Husbandry (Groß Kreutz, Brandenburg, Germany) from February to October 2019. Cows were milked using a unit of an automatic milking system for each group (Lely Astronaut, Lely Holding S.à.r.l., Maassluis, The Netherlands). They were fed a maize-grass-silage-based total-mixed-ration dependent on the lactation stage, received individual performance-based quantities of concentrate feed at milking, and had ad-libitum access to water.

All barns provided a cubicle housing system. In a first barn, one of two high-yielding groups (approx. 55 cows) was kept on a grooved solid floor, with deep lime-straw cubicles and an animal-to-cubicle ration of 1:0.9. In a second barn, the second high-yielding group (approx. 55 cows) and the late-lactating cows (approx. 65 cows) were located on a slatted floor (partly covered with rubber for the high-yielding group) and elevated cubicles with a rubber cover at animal-to cubicle ratios of 1:1.2, and 1:1.1, respectively. Cows were moved to the late-lactating group with a performance of < 30 l/d, after at least day 100 into lactation and with a BCS of at least 3. A pen for cows due for calving, the calving pens, and a pen for freshly-lactating cows were also located in the second barn. All these pens had a grooved solid floor and deep-bedded group areas for lying. About 8 weeks before expected calving (and with a performance of < 30 l/d), the cows were dried-off. Manure was regularly scraped in the activity areas by fixed scraper, by hand, or by robot.

The claws of all lactating cows were routinely treated by a professional claw trimmer three times yearly. Around the time of the current observations, treatments took place in November 2018, on April 8-10 2019, August 8-9 2019, and November 2019. In addition, cows with claw problems were treated about once a month. In acute cases, specially trained personnel of the farm treated claws and, a veterinarian was consulted if medical treatment seemed necessary.

At the end of each month (except for March), all cows were scored for lameness and body condition by the first author (MK). At each of eight monthly scoring time-points 235 ± 8 (mean ± SD) cows were scored. A total of 1877 scorings were completed (6.5 ± 2.3 per cow). A preliminary visual inspection of the data revealed that dry cows had a clearly higher BCS than the cows in milk, as expected. To avoid collinearity between these two variables, the dry cows were dropped from the data for evaluation. Accordingly, a total of 1544 observations, (mean ± SD) 5.36 ± 1.89 observations/cow, were modelled.

To assess **lameness**, cows were marched on a straight route without obstacles across a distance of several meters. The assessment was based on the gait pattern of the cow, the homogeneity of the weight distribution on the claws, the regularity of the step lengths, and the body posture (curvature of the back and head position) according to the six-level score of Ebert et al. (2019, modified after Starke et al. 2007). The first author had been trained in two workshops to assess lameness (and BCS) taught by veterinarians. In addition, she could discuss and compare her scoring with two of the workshop teachers during the April and May assessment. For the evaluation of the risk for lameness, we only differentiated whether cows reached a score of three or higher rather than a score of 1-2 (non-lame or slightly "clammy"). As a check for intra-observer reliability, the first author scored 33 randomly selected cows on one day and five days later before the investigation started. 87 % of the cows were identically re-classified as lame or non-lame.

Whenever lameness of a cow was scored, her **body condition**, was assessed simultaneously. Cows were scored when they were standing either at the feed table, in the activity area or a lying cubicle. This was done visually and by palpation following the schemes of Ferguson et al. (1994) complemented by the procedure as visualised in Spengler Neff et al. (2015). Scores went from 1 (very lean) to 5 (very fat) in steps of a quarter score. At mean scores around 2.5, this procedure is inexact, and the scheme of Edmonson et al. (1989) as modified by Metzner et al. (1993) was additionally used. Eight body parts were scored according to his rule, averaged and eventually rounded to the nearest quarter score. Intra-observer agreement for BCS scoring was also checked. The same 33 randomly selected cows used for re-assessment of lameness were also scored for BCS. 94% of the cows did not differ in their assessment or differed only by a quarter score. The remaining 6% differed by half a score. In addition, pictures of 9-14 cows at each monthly scoring were taken and re-assessed after a month. Here, the assessments again differed by a maximum of 0.5 points.

These lameness and BCS scores were complemented with information on lactation stage, lactation number, medical treatment, season, and time since the last claw trimming event. Based on bi-variate plots, we ensured that our predictor variables were not strongly collinear. All variables varied within-cows except for lactation number that was kept constant within cows. Each observation of a cow was as assigned to a **lactation stage** based on the number of days since her last calving: 0 to 80, 81 to 160, 161 to 300, ≥ 301 DIM as well as dry cows. Observations ≥ 301 DIM were relatively rare such that they were pooled with the category of 161 to 300 DIM (resulting in a four-level factor). Only a minority of the cows changed between **lactation numbers** in the course of the observations. Therefore, we assigned a value of "low" for all cows that were observed in their first lactation and that have moved to the second during the current investigation. All cows in lactation number two or three that may have moved to the next higher lactation number were assigned a value of "intermediate". All the other cows that were at least in lactation 4 (and up to lactation number 9) at the beginning of the investigation were assigned a value of "high" for their lactation number (resulting in a three-level factor). If a cow had a **medical treatment** in the interval from the 15^{th} of the previous to the 14^{th} of the month following the current scoring, with a diagnose other than the locomotor system, and based on the recordings in the herd management software, she was considered "treated" (two-level factor). To investigate a **season**al effect, the monthly scorings were summarised. February, April and May were assigned to "winter-spring", June, July, and August to "summer", as well as September and October to "fall" (resulting in a three-level factor). The **time since the last claw trimming event** was determined (as a continuous variable). Young cows that had never been trimmed were assigned a value of 250 d, a value which was slightly higher than the highest value observed otherwise (244 d).

We evaluated the data using a Bayesian generalised linear mixed-effects model in R Version 4.0.2 (R Core Team 2020) using the package blme (Chung et al. 2013, which is based on package lme4, Bates et al. 2015). We considered lameness as the dichotomous outcome variable and used the other variables as fixed predictors. The continuous fixed effects (BCS and time since the last claw trimming event) were normalized and sum-contrasts were used for all factor variables (lactation stage, lactation number, medical treatment, season) such that p-values of main effects remain meaningful even in the presence of interactions. We aimed at a maximum model including up to all three-way interactions, but this model resulted in too many cases of full separation and could not be estimated even with the Bayesian approach. This indicates an over-specification of the model. Therefore, we modelled all main effects plus all their two-way interactions. Cow identity was used as a random effect to account for the repeated measurements of each cow. We set up a full model, compared this with a minimal model including an intercept only on the one hand and with models that each omitted one of the fixed effects on the other. To do so, one would ideally use parametric bootstrap (package pbkrtest, Halekoh & Højsgaard 2014). Given the sample size and the complexity of the model here, the parametric bootstrap would have needed an enormous amount of time (the calculation of the p-value for the full model ran longer than 24 h). Because all (except one) fixed effects were on the lowest hierarchical level of the random effect (the model error), pseudoreplication issues do not seem to be of high risk and we, therefore, used a likelihood-ratio test to compare models instead. Model assumptions were checked using a graphical analysis of the residuals (package DHARMa, Hartig 2020). This analysis suggested that the relationship of the risk of lameness and BCS was non-linear. We therefore included the square of BCS as an additional fixed effect (including all interactions of this quadratic effect with the other fixed effects). We focus here on the effects found that included BCS as our main focus of the study and those effects with a low p-value. We are fully aware that a high p-value alone does not indicate no relationship of those effects with lameness. Still, the effects with a low p-value are those that can be more strongly substantiated statistically in this data set with a given between- and within-cow variability.

Supplementary References

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