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Short communication: Novel method to predict body weight of primiparous dairy cows throughout the lactation

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ABSTRACT

Body weight (BW) of dairy cows can be estimated using linear conformation traits (calculated BW; CBW), which are generally recorded only once during a lactation. However, predicted BW (PBW) throughout the lactation would be useful, e.g., at milk-recording dates allowing feed-intake prediction for advisory purposes. Therefore, a 2-step approach was developed to obtain PBW for each milk-recording date. In the first step, a random-regression test-day model was used with CBW as observations to predict PBW. The second step consisted in changing means and (co)variances of prior distributions for the additive genetic random effects of the test-day model by using priors derived from results of the first step to predict again PBW. A total of 25,061 CBW from 24,919 primiparous Holstein cows were computed using equations from literature. Using CBW as observations, PBW was then predicted over the whole lactation for 232,436 dates corresponding to 207,375 milk-recording dates and 25,061 classification dates. Results showed that using both steps (the 2-step approach) provided more accurate predictions than using only the first step (the one-step approach). Based on the results of this preliminary study, BW of dairy cows could be predicted throughout the lactation using this procedure. These predictions could be useful in milk-recording systems to compute traits of interest (e.g., feed-intake prediction). The developed novel method is also flexible because actual direct measurements of BW can also be used together with CBW, the prediction model being able to accommodate different levels of accuracies of used BW phenotypes.
Key words: dairy cattle, body weight, feed intake, Bayesian prediction model

Short Communication

Because milk-production costs are mainly influenced by feeding charges, interest is growing in improving feed efficiency of dairy cows. Dry matter intake appears to be an interesting trait for management purposes and could be included in breeding schemes (Pryce et al., 2014). However, direct DMI measurements are expensive and difficult. Several models were developed to estimate feed intake of dairy cows based on animal factors or diet characteristics (Huhtanen et al., 2011). Body weight of dairy cows influences their DMI through different ways. First, BW reflects the capacity of the digestive tract (Zom et al., 2012). Also, because of increased maintenance cost, heavier animals tend to eat more. For these reasons, BW is often used in predictive models of DMI. Hence, the NRC (2001) provided a model that estimates DMI only from variables related to the animal (i.e., fat- and protein-corrected milk yield, lactation stage, and BW). This model would be useful in milk-recording programs, but BW has to be routinely collected or, at least, reasonable estimates have to be available. However, in the Walloon Region of Belgium, as in many countries, BW is not routinely recorded on farms. Although it might be recorded in automatic milking systems, these data are not transferred to performance-recording databases. Nevertheless, it has been shown that BW can be estimated from linear conformation traits, hereafter called calculated BW (**CBW**; e.g., Koenen and Groen, 1998; Banos and Coffey, 2012; Haile-Mariam et al., 2014). Most of the equations developed to generate CBW take into account the lactation stage in addition to conformation traits. However, at least 3 issues exist related to CBW of classified cows: i) CBW are less precise than actual weightings of cows; ii) each CBW is associated with a classification date and therefore it is not directly available for the day when milk production is recorded; and iii) BW is highly variable inside a given lactation for a given cow, which has to be considered when estimating BW throughout the lactation. The first issue is difficult to address because modern production systems

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seldom measure or transfer animal weights, leading to a more widespread use of CBW (e.g., Haile-Mariam et al., 2014). The last 2 issues are currently overlooked, although they are extremely important for the practical use of BW, e.g., in computing DMI for every date of milk recording (test date). Therefore, because CBW is generally not related to a test date, the objective of this study was to develop a novel method to predict BW (**PBW**) throughout lactation of cows using initial CBW records based on conformation traits.

Linear conformation data (i.e., angularity, chest width, stature, body depth, and BCS) of cows were collected at the same day by the Walloon Breeding Association (Ciney, Belgium). A total of 25,061 linear conformation records from 24,919 first-lactation Holstein cows belonging to 622 herds in the Walloon Region of Belgium were available. Very few animals were classified more than once during their first lactation. Test-date records of studied cows provided by the Walloon Breeding Association from milk recording were then merged with the conformation-traits data set to identify dates when milk recording occurred. The final data set included DIM, birth date, calving date, and test or classification date, corresponding to the dates for which PBW had to be estimated. This data set was organized to estimate from 25,061 CBW a total of 232,436 PBW at 207,375 test dates and 25,061 classification dates. Pedigree data for these cows were extracted from the database used for the official Walloon genetic evaluation. The pedigree file contained 124,863 animals. Two existing equations developed by Laloux (2008), and currently used by the Walloon Breeding Association, were applied on linear conformation data and age of dairy cows to estimate CBW of cows at their classification date. The coefficient of determination (R^2) of the first equation, which was based on age, angularity, chest width, stature, body depth, and BCS, was 0.86. This equation was applied to cows at DIM ≤130 d. The second equation, applied to cows at DIM >130 d, was based on age, angularity, stature, body depth, and BCS and had a R^2 of 0.73 (Laloux, 2008). These 2 different lactation periods will be called hereafter early (**EL**) and mid-late (**ML**) lactation periods. Because developing improved CBW equations was not the objective of this study, precise R^2 of the equations were not revalidated. For this reason, an approximate average R^2 of 0.80 was used in this initial study, even if the presented method permitted a different weight for each CBW record.

To predict PBW of cows across DIM using empirical Bayes predictions, the following weighted univariate random-regression test-day model was developed based on preliminary studies (results not shown):

$$\mathbf{y} = \mathbf{X}\mathbf{b} + \mathbf{d}_{\mathrm{l}}\alpha_{\mathrm{l}} + \mathbf{d}_{\mathrm{q}}\alpha_{\mathrm{q}} + \mathbf{Z}_{\mathrm{el}}\mathbf{h}_{\mathrm{el}} + \mathbf{Z}_{\mathrm{ml}}\mathbf{h}_{\mathrm{ml}} + \mathbf{Z}_{\mathrm{el}}\mathbf{a}_{\mathrm{el}} + \mathbf{Z}_{\mathrm{ml}}\mathbf{a}_{\mathrm{ml}} + \mathbf{e}, \quad [1]$$

where $\mathbf{y}$ was the vector of observations (i.e., CBW); $\mathbf{b}$ was the vector of fixed effects including year of milk-recording date or classification date, season of milk-recording date or classification date (4 seasons defined as winter for December, January, and February; spring for March, April, and May; summer for June, July, and August; and autumn for September, October, and November), classes of gestation stage (4 classes including nongestating cows, early-gestating cows, late-gestating cows, and no information about gestation status of cows), and age at calving × lactation stage (6 classes of age at calving defined as lower than 25 mo, between 25 and 27 mo, between 28 and 30 mo, between 31 and 33 mo, between 34 and 36 mo, and higher than 36 mo and 3 classes of 122 DIM); $\mathbf{d}_{\mathrm{l}}$ and $\mathbf{d}_{\mathrm{q}}$ were linear and quadratic regression variables expressed as linearized evolutions of average smoothed weight across DIM; and α_{l} and α_{q} were associated fixed regression coefficients. The model contained 2 correlated random-regression herd effects ($\mathbf{h}_{\mathrm{el}}$ and $\mathbf{h}_{\mathrm{ml}}$) and 2 random-regression animal genetic effects ($\mathbf{a}_{\mathrm{el}}$ and $\mathbf{a}_{\mathrm{ml}}$), for EL and ML lactation periods. Finally, $\mathbf{e}$ was the vector of residuals, and $\mathbf{X}$, $\mathbf{Z}_{\mathrm{el}}$, and $\mathbf{Z}_{\mathrm{ml}}$ were incidence matrices assigning observations to fixed and random effects. Model [1] was equivalent to a bi-period (EL vs. ML lactation) test-day model sharing fixed effects.

Because preliminary studies showed heterogeneity of residual variances (data not shown) reflecting also different R^2 of equations from Laloux (2008), observations were weighted with their respective residual variances according to the fact that they were obtained in EL or ML lactation periods. It was assumed that $\mathbf{h}_{\mathrm{el}}$ and $\mathbf{h}_{\mathrm{ml}}$ followed a multivariate normal (**MVN**) distribution, $\mathrm{MVN}\left(\begin{bmatrix}\mathbf{0}\\\mathbf{0}\end{bmatrix}, \mathbf{I}\otimes\mathbf{H}_0\right)$, where $\mathbf{I}$ was an identity matrix and $\mathbf{H}_0$ was a (co)variance matrix among EL and ML lactation periods. It was also assumed that $\mathbf{a}_{\mathrm{el}}$ and $\mathbf{a}_{\mathrm{ml}}$ followed a MVN distribution, $\mathrm{MVN}\left(\begin{bmatrix}\mathbf{0}\\\mathbf{0}\end{bmatrix}, \mathbf{A}\otimes\mathbf{G}_0\right)$, where $\mathbf{G}_0$ was the (co)variance matrix among EL and ML lactation periods and $\mathbf{A}$ was the numerator relationships matrix.

Following the model [1] and the previous assumptions, variance components were estimated using EM-REML implemented in the REMLF90 software (Misztal, 2012). Estimated relative herd variances were 0.26 kg^2 for EL and ML, and correlation across herd effects was 0.88. Estimated heritabilities for CBW were 0.14 in EL and ML lactation periods. A very high genetic