Short communication: Verifying Holstein heifer heart girth to body weight prediction equations¹

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ABSTRACT

The estimation of Holstein heifer body weight (BW) from heart girth measurements is needed, as many farms do not have animal scales to make the management decisions that require BW. The correlation between heart girth and BW is known to vary with differing animal conformation. The previous equation to correlate the 2 measures for Holstein dairy heifers was done 25 yr ago. Data were derived from 6 US experiment stations that are part of Regional Research Project NC-2042: Management Systems to Improve the Economic and Environmental Sustainability of Dairy Enterprises. After deriving a new equation from a data set of observations and using a second validation data set, it was determined that the equation developed in 1992 was still valid and further equation development was not needed at this time.

Key words: dairy heifer, body weight, heart girth

Short Communication

Many management decisions, diet requirements, and health decisions for a dairy heifer are based on BW. The most widely accepted method of determining BW is a calibrated scale. Though this information is important for the farm manager for nutrition, health, and breeding events, animal scales are not often available and

alternative means of estimating BW are needed. Prediction of BW from heart girth (**HG**) has been shown to be more accurate than other structural measurements (Davis et al., 1961; Heinrichs et al., 2007). It has even been suggested that use of other body measures, such as HG, may be more reliable than a single weight due to short-term effects of gut fill, defecation, or urination (Russell, 1975). Whereas the BW to HG relationship has been reliable over time, the regression equations to estimate BW from HG have changed (Kendrick and Parker 1936; Davis et al., 1961; Heinrichs et al., 1992), most likely due to alterations in breeding and selection programs that have affected animal conformation, in addition to other traits, over time.

Heinrichs et al. (1992) developed the most recent equation to determine BW from HG for Holstein animals. A comparison of older equations (Kendrick and Parker, 1936) with the equation of Heinrichs et al. (1992) showed large differences in prediction of BW using an original data set and prompted a validation of that equation using a larger, more diverse set of data from across the United States, as reported (Heinrichs et al., 1992). It became clear that genetic selection had altered cattle conformation and necessitated a revised equation to calculate BW from HG. In addition, inter- and intraobserver variability associated with these measurements was examined (Heinrichs et al., 1992). Later, an independent data set (Heinrichs et al., 2007) showed that predictions of BW from HG were accurate compared with BW measured by a scale and were highly repeatable for multiple measurements by 1 person or measurements by many people, particularly for higher-weight animals.

Knowing that older prediction equations required changes over time, the objective of the present study was to determine if the equation developed in 1992 remains valid for Holstein dairy animals after 25 yr of genetic advancement. We also attempted to use newer

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Table 1. Description of Holstein heifer growth measurements that were compared with the equation used since 1992 for estimating BW from heart girth

Source	Measurements, no.	Animals, no.	BW, kg			Heart girth, cm		
			Mean	Minimum	Maximum	Mean	Minimum	Maximum
New Hampshire	477	40	149.5	85.3	226.3	123.7	103.0	148.0
Pennsylvania	177	177	291.4	38.6	725.7	144.6	76.20	212.1
South Dakota	69	35	262.6	145.6	442.3	145.5	119.1	177.8
Purdue (West Lafayette, IN)	1,009	177	192.1	113.9	310.2	133.7	114.5	156.8
Overall	1,732							

statistical methods to estimate BW from HG as part of our analysis.

The current data were collected from 4 NC-2042 experiment stations [Pennsylvania, New Hampshire, Purdue (West Lafayette, IN), and South Dakota] included Holstein heifer BW and HG measurements, and 1 or more of the following body measurements: age, withers height, hip height, hip width, and BCS (Ferguson et al., 1994). The initial data set had 1,742 observations of heifers before first lactation. Of the initial data set, 10 animals were removed due to obvious data errors, leaving 1,732 usable observations representing 429 individual animals (Table 1).

The new equation could have included additional information about the animal, such as other body measures or condition score; however, the measurements taken in this analysis were confounded by source, so that any results of multiple imputation to eliminate this problem would be in question. Therefore, a regression was planned to parallel what was done previously (Heinrichs et al., 1992). For linear regressions, all observations should be independent, but this requirement could not be met due to multiple measurements of some animals and clustering by experiment station.

In the more familiar experimental setting, where the goal is to make inferences among treatments, this nonindependence could be accommodated by using mixed models, which could adjust the error terms appropriately. Even though the goal of our study was to model and not infer, the nonindependence is still

an issue, especially for multiple measurements on the same animal. The possible idiosyncrasies from 1 animal should not be introduced more than once, and to include multiple measurements from 1 animal introduces age into the equation; including age on a weight tape would be confusing, as the measurements are repeated and cannot be considered nested. On the other hand, the nonindependence introduced by the clustering of station may or may not be a problem, as the relationship of HG to BW could be considered independent from source to source.

To address multiple measurements from the same animals, 10 different data subsets were created from the current data set by randomly selecting 1 observation for each animal, thus creating independent measurements. Candidate equations were regressed utilizing both linear regressions (BWsimple) and mixed (BWmixed) models (with station as a random effect) for each of these data sets, and the coefficients obtained were averaged to create unbiased estimates. Coefficients from the 10 analyses were used to create new predicted values:

$$\text{BW}_{1992} = 277.3812486 - 7.1637099 \times \text{HG} + 0.0610770 \times \text{HG}^2;$$

$$\text{BW}_{\text{simple}} = 407.8921916 - 9.2239388 \times \text{HG} + 0.0699841 \times \text{HG}^2;$$

$$\text{BW}_{\text{mixed}} = 318 - 7.8648 \times \text{HG} + 0.06497 \times \text{HG}^2.$$

Table 2. Description of Holstein heifer growth measurements that were used in the validation data set to validate the equation used since 1992 for estimating BW from heart girth

Source	Measurements, no.	Animals, no.	BW, kg			Heart girth, cm		
			Mean	Minimum	Maximum	Mean	Minimum	Maximum
Illinois	115	115	366.2	188.4	690.1	168.8	134.6	215.9
Minnesota	350	201	281.5	74.5	726.4	147.6	89.4	213.4
South Dakota	95	58	262.6	145.6	442.3	131.5	97.5	163.8
Purdue (West Lafayette, IN)	938	212	191.4	101.2	290.1	133.4	107.0	154.5
Overall	1,498

Figure 1. Relationship between BW and heart girth. Solid line shows the BW predicted by the current Holstein weight tape (Heinrichs et al., 1992). Individual data points (marked by $\times$) indicate actual heart girth and BW measurements of heifers in the comparison data set. Body weight predicted by the 1992 equation was highly correlated with actual BW ($r = 0.98$; $P < 0.0001$).

In spite of all efforts to obtain nonbiased estimates for these newest equations, the possibility that the results could be sample-specific were reasonably high. Therefore, these 2 newest equations were compared with the 1992 version utilizing an independent validation data set of 1,498 animals that was again from 4 NC-2042 experiment stations (Minnesota, South Dakota, Illinois, and Purdue).

The data set used to develop new prediction equations (Table 1) covered a wide range of BW and HG measurements across the 4 locations, as did the validation data set (Table 2). The results of the new linear regression and mixed model equations were nearly identical, and both deviated at higher BW (>450 kg) from the 1992 equation. To test the performance of the new equations, all 3 equations were used to get predicted values for the validation data set and to obtain residuals for evaluation. Regressing the residuals created by the 1992 equations showed uniform residual patterns, indicating no bias for the 1992 equation. The 2 new equations developed here yielded residual plots that indicated substantial bias, especially at BW >450 kg. Mean squared prediction error for the BW1992 equation was 2,289.9, for BWsimple it was 2,539.4, and for BWmixed it was 2,414.9. The lower value for the 1992 equation confirms that it remains the better of the 3 options. Thus, we confirmed that the newer equations were indeed sample-specific, and the 1992 equation still performed well. The correlation between actual and predicted BW was 0.98 ($P < 0.0001$), allowing us to conclude that the existing equation remains accurate

in predicting BW from HG measurements (Figure 1). This is useful information considering that 25 yr have elapsed since the last equation was developed.

It has been shown that BW is more correlated with HG than any other body measure, primarily because it accounts for body size and body condition (Heinrichs et al., 2007; Lukuyu et al., 2016); however, all body measures are correlated to some degree (Heinrichs et al., 1992). Studies report that, with different breeds of cattle (Lukuyu et al., 2016) or after breed selection has occurred over a period of time (Heinrichs et al., 1992), prediction equations do differ and appropriate equations must be used for a given population of animals. As with previous equations, it is possible that given enough time, body confirmation will change enough to require a new equation; however, that is not the case at this time. Furthermore, although the mixed model prediction equation could be used to create tables that include age at a given HG (Brody, 1945), more complex tables would not be applicable for a weight tape.

Upon comparing the previously developed HG to BW equation with 2 independent data sets, we concluded that the previous equation converting HG to BW for Holstein dairy heifers (Heinrichs et al., 1992) remains valid for the current genetics and type of Holstein dairy heifers.

REFERENCES

- Brody, S. B. 1945. *Bioenergetics and Growth; with Special Reference to the Efficiency Complex in Domestic Animals*. Reinhold Pub. Co., New York, NY.

- Davis, H. P., W. W. Swett, and W. R. Harvey. 1961. Relation of heart girth to weight of Holstein and Jerseys. Nebraska, Agric. Exp. Stn. Bull. 194. Univ. Nebraska, Lincoln.
- Ferguson, J. D., D. T. Galligan, and N. Thomsen. 1994. Principal descriptors of body condition score in Holstein cows. *J. Dairy Sci.* 77:2695–2703.
- Heinrichs, A. J., H. N. Erb, G. W. Rogers, J. B. Cooper, and C. M. Jones. 2007. Variability in Holstein heifer heart girth measurements and comparison of prediction equations for live weight. *Prev. Vet. Med.* 78:333–338.
- Heinrichs, A. J., G. W. Rogers, and J. B. Cooper. 1992. Predicting body weight and withers height in Holstein heifers using body measurements. *J. Dairy Sci.* 75:3576–3581.
- Kendrick, J. F., and J. B. Parker. 1936. Estimating the weights of dairy cows from heart-girth measurements. BDIM No. 695. USDA Bureau of Dairy Industry, Washington, DC.
- Lukuyu, M. N., J. P. Gibson, D. B. Savage, A. J. Duncan, F. D. N. Mujibi, and A. M. Okeyo. 2016. Use of body linear measurements to estimate liveweight of crossbred dairy cattle in smallholder farms in Kenya. *Springerplus* 5:63. <https://doi.org/10.1186/s40064-016-1698-3>.
- Russell, W. S. 1975. The growth of Ayrshire cattle: An analysis of linear body measurements. *Anim. Prod.* 21:217–226.