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# Evaluation of body weight prediction Equations in growing heifers

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**ABSTRACT.** This study was realized to evaluate prediction models for body weight (BW) using body measurements as heart girth (HG), wither height (WH), hip width (HW), body length (BL) and hip height (HH), and develop new Equations to predict the BW of Holstein and crossbred heifers. Prediction Equations (1, 2, 3, 4, 5 and 6) proposed in previous studies were tested, while body measurements, which were more significant in terms of predicting BW, were used to obtain new Equations. Heart girth was the body measurement with the greater correlation with BW. Equation 4 presented the best prediction results, showing a low average deviation, high accuracy and precision. Equations 1 and 2 predicted with a high presence of bias, while 2 had the lowest value of the concordance correlation coefficient and a great contribution made by systematic error. The 3 model presented a high variability in predicting BW. For both Holstein and crossbred heifers, the Equations evaluated are inadequate for predicting BW. Among the Equations evaluated, the model using HG presented the best adjustment and the greater adjusted coefficient of determination. Body measurements relating to HG and BL were the most significant variables in predicting the BW, resulting in the following Equation: BW = - 372.89 + 2.8072 × HG + 1.6087 × BL.

**Keywords:** body measurements, dairy heifers, heart girth, Holsteins.

## Avaliação de Equações de predição de peso corporal em novilhas em crescimento

**RESUMO.** Este estudo foi realizado para avaliar modelos de predição de peso corporal (PC), utilizando-se medidas corporais como perímetro torácico (PT), altura de cernelha (AC), largura de garupa (LG), comprimento corporal (CC) e altura de garupa (AG), e desenvolver novas Equações de estimação de PC para novilhas Holandesas e mestiças. Foram testadas Equações de predição (1, 2, 3, 4, 5 e 6) propostas em estudos anteriores e as medidas corporais mais relacionadas com PC foram utilizadas para gerar novas Equações. O perímetro torácico é a medida corporal mais correlacionada com PC. A Equação 4 apresentou os melhores resultados de predição com baixo desvio médio e alta precisão e exatidão. As Equações 1 e 2 apresentaram alto viés de estimação, enquanto 2 teve o menor valor de coeficiente de correlação e concordância, e grande contribuição de erro sistemático. O modelo 3 apresentou alta variabilidade na predição de PC. Tanto para novilhas Holandesas quanto mestiças, as Equações avaliadas não são eficientes em predizer PC. Entre as Equações avaliadas, o modelo usando PT apresentou o melhor ajuste e maior coeficiente de determinação ajustado. As medidas corporais de PT e CC foram as variáveis mais significativas na predição do PC, sendo utilizadas na obtenção da Equação: PC = - 372.89 + 2.8072 × PT + 1.6087 × CC.

**Palavras-chave:** medidas corporais, novilhas leiteiras, perímetro torácico, Holandesas.

## Introduction

Besides monitoring the nutritional quality of feeds, weight gain in animals should also be monitored in order to optimize dairy production. However, dairy producers have reported that weighing animals is time-consuming and costly (Heinrichs, Rogers, & Cooper, 1992). Thus, the estimation of body weight by using body measurements should help to solve such a problem, especially in production systems lacking weighing facilities.

Previous studies have investigated the correlation between body measures and weight prediction in dairy cattle (Heinrichs et al., 1992). The main body measurements used to predict the weight of dairy cattle are: heart girth, wither height, hip width, body length and hip height with Equations proposed by Heinrichs et al. (1992) and Reis et al. (2008). Although there are some differences regarding the measures, greater accuracy and precision are obtained when more than one variable is considered in the model (Reis et al., 2008). Additionally, regression procedures used to obtain relationships between body weight and body measurements may be affected by the breed, age, body condition and physiological state of the animal (Heinrichs et al., 1992), which justifies the use of different prediction Equations for each heifer class.

The objective of this study was to evaluate Equations to predict body weight of dairy heifers based on the following body measurements: heart girth, wither height, hip width, body length and hip height.

## Material and methods

The experiment was conducted at the dairy cattle research facility of the Universidade Federal de Viçosa, Brazil. The body weight (BW) and body measures of 12 Holstein and 12 crossbred (Holstein×Zebu) dairy heifers in feed lot were assessed. The weights and body measures were monitored four times in each animal and performed with a one-month interval, with 96 replications in total. All animal care procedures were approved by the Animal Ethics Committee of the Universidade Federal de Viçosa, which is registered under the protocol number 26/2013.

Heifers were weighed on a mechanical scale, while tape measure was used for heart girth (HG) and body length (BL) measurements. Wither height (WH), hip width (HW) and hip height (HH) measurements were obtained with a metric measuring stick. The measurements were carried out on the animals in a 'forced station', with anterior and posterior members perpendicular on a flat floor, forming a rectangular parallelogram support base. For each biped, when seen in profile, each limb concealed the other and when seen from the front/back, the members were upright and equally supported on the floor (Hoffman, 1997).

Measurements were correlated with the respective animal weights by Pearson correlation and data were submitted to an analysis of linear and quadratic regressions. Prediction accuracy was assessed by the coefficient of determination adjusted for the degrees of freedom.

The prediction Equations of BW proposed by Heinrichs et al. (1992) were evaluated based on the variables HG, WH, HW and BL, described as Equations 1 to 4:

$$BW = 102.71 - 2.876 \times HG + 0.02655 \times HG^2 \quad (1)$$
$$BW = 632.13 - 16.837 \times WH + 0.11989 \times WH^2 \quad (2)$$
$$BW = 5.28 - 1.613 \times HW + 0.23436 \times HW^2 \quad (3)$$
$$BW = 96 - 3.324 \times BL + 0.03432 \times BL^2 \quad (4)$$

Two other Equations proposed by Reis et al. (2008), based on the variables of HG and HH were also evaluated, according Equations 5 and 6:

$$BW = 1717 - 35.167 \times HG + 0.23897 \times HG^2 - 0.0004626 \times HG^3 \quad (5)$$
$$BW = 7581 - 4.151 \times HG - 180.201 \times HH + 0.024932 \times HG^2 + 1.456103 \times HH^2 - 0.00383079 \times HH^3 \quad (6)$$

The prediction Equations were tested for all animals and then separately for crossbred and Holstein. They were all based on the correlation between the predicted values and the observed values by adjusting a simple linear regression for predicted values over observed values (Mayer, Stuart, & Swain, 1994), with estimates of the regression parameters tested by the joint hypothesis Ho: $\beta0 = 0$ and $\beta1 = 1$. The Model Evaluation System program was used in the statistical procedures in order to validate the Equations. The critical probability level for a type I error was 0.05. The adjusted coefficient of determination (R2) was used as a precision predictor, while Equation accuracy was estimated according to Liao (2003). The concordance correlation coefficient (CCC; Lin & Torbeck, 1998) was also estimated and used to combine measures of both accuracy and precision. Mean squared prediction error (MSPE) was split into squared bias (SB), systematic error (SE) and random error (RE), according to Bibby and Toutenburg (1977).

From the values obtained for body measurements and BW, prediction Equations were made in relation to body measurements. The BW prediction Equations were initially adjusted as a function of each body measurements (WH, HH, HG, BL and HW). They were then adjusted by a mixed model, considering breed (Holstein and crossbred) as a fixed effect and body measures as a fixed quantitative variable. The animals and the experimental periods were adjusted as random effects models (repeated measures). Both linear and quadratic effects of body measures were assessed with their respective interactions with the genetic group. When no significance was observed for these factors, they were removed from the model. All data with Student residual $> | 2 |$ were excluded as outliers.

A stepwise procedure was performed with variables WH, HH, HG, BL and HW (linear and quadratic effects) as heifers' BW predictors. The variables with a significance level $> 0.001$ were retained in the model. The same procedure was then used to obtain multiple regressions using the mixed models described above.

## Results and discussion

There was a high correlation between body measures and animal BW (Table 1). Among the variables studied, HG had the highest correlation (r = 0.9386; Table 1) with BW prediction (Heinrichs & Hargrove, 1987; Hoffman, 1997; Reis et al., 2008). This demonstrates that BW estimation using body measures is credible, especially when the HG measure is considered.

**Table 1.** Means, standard deviations, coefficients of variation (CV%) and correlations of measures with weights.

| Item | Mean | Maximum | Minimum | Standard deviation | CV(%) | Correlation with weight |
|---|---|---|---|---|---|---|
| Weight | 283 | 345 | 212 | 39.8 | 14.1 | - |
| Heart girth | 156 | 168 | 138 | 8.9 | 5.7 | 0.9386 |
| Body length | 131 | 145 | 118 | 8.0 | 6.1 | 0.8164 |
| Wither height | 120.5 | 135 | 111 | 6.8 | 5.7 | 0.8246 |
| Hip height | 126 | 139 | 118 | 6.5 | 5.2 | 0.8400 |
| Hip width | 40.2 | 44.0 | 36.7 | 2.2 | 5.5 | 0.8809 |

The joint evaluation of the intercept and slope coefficient in the regression Equation for observed versus predicted values for BW (Table 2) rejects the null hypothesis ($p < 0.05$) for all Equations. This shows that the Equations are inadequate for BW prediction in growing dairy heifers, as well as indicating that the proposed Equations should be better evaluated. For BW prediction in growing dairy heifers, the main problem was found with Equation 2, in which weight prediction was based on WH. This Equation overestimated animal weight by 58.6 kg. The weak correlation with weight (0.8246) may explain the high bias observed in the model (Table 1). The 2 model also had the lowest CCC value and a great contribution in terms of SE. This was considered undesirable, since it represents the direction error (29%) in the MSPE decomposition.

Equations 1 and 2, using HG and WH, respectively, showed SB prediction. Equation 4 had the best prediction results. In the Equations proposed by Reis et al. (2008), lower bias was observed when compared to the Equation suggested by Heinrichs et al. (1992), which is associated with a higher RE in MSPE.

Empirically based regression Equations, as suggested by Heinrichs et al. (1992) and Reis et al. (2008), are population-dependent. These models are based exclusively on experimental data and not necessarily on theories or biological basis. Therefore, even when there is good data adjustment, the model should be considered specifically under the conditions of data collection. In this case, the prediction ability may be limited (Dijkstra, Forbes, & France, 2005).

The SB prediction constituted the main factor affecting prediction quality in Equations 1 and 2 for growing dairy heifers. Equation 4 had low average deviation, high accuracy and precision, with the greater error proportion of the model focusing on RE, which in turn demonstrated a well-controlled model. Therefore, the Equation using BL is the most recommended among those proposed by Heinrichs et al. (1992).

In the Equations proposed by Reis et al. (2008), although there is no accurate BW estimate, these models are the closest to the real values, with weight overestimations of 7.2 and 5.3 kg, respectively, for growing dairy heifers. It can be noticed that high SE values were obtained for these Equations: i.e., 20.5 and 40.2%, respectively (Table 2). These models, however, indicated higher REs: i.e., 64.3 and 52.2%, respectively.

Little dispersion in Equations 1, 5 and 6 occurred because they consider HG, which is a measure with a higher correlation when considering BW. Although this greater precision can also be observed in the high value for $R^2$, data are below the line of least squares, which can also be observed in the negative average deviation of these models (Table 2). Among all the assessed Equations, the 4 model is the most recommended for estimating BW in growing dairy heifers.

There was little data dispersion in Equations 1, 5 and 6 (Figures 1a, 1e and 1f). Equations 2, 3 and 4 predicted weight with greater variability (lower $R^2$), producing estimates with high bias proportions. Figure 1a also shows a high proportion of SE in the HR model (Figure 1b).

**Table 2.** Functional relationship of body weight values of dairy growth observed and those predicted by different Equations.

| Model | Y[1] | X[2] | $\beta_0$ | $\beta_1$ | $(R^2)$[3] | *P*-value[4] | CCC[5] | ACC[6] | Deviation | MSPE[7] | SA[8] | SE[9] | RE[10] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 244.5 | 262.5 | 20.906 | 0.852 | 0.898 | < 0.0001 | 0.898 | 0.930 | -18.0 | 324.3 | 54.1 | 9.7 | 36.2 |
| 2 | 244.5 | 303.2 | 92.878 | 0.500 | 0.755 | < 0.0001 | 0.575 | 0.563 | -58.6 | 3436.9 | 61.7 | 29.0 | 9.3 |
| 3 | 244.5 | 281.2 | 3.280 | 0.858 | 0.804 | < 0.0001 | 0.955 | 0.786 | -36.7 | 1347.5 | 74.5 | 2.6 | 22.9 |
| 4 | 244.5 | 230.1 | 51.418 | 0.839 | 0.755 | < 0.0001 | 0.964 | 0.960 | 14.4 | 207.3 | 26.4 | 7.6 | 66.0 |
| 5 | 244.5 | 251.7 | 33.326 | 0.839 | 0.895 | < 0.0001 | 0.886 | 0.976 | -7.2 | 52.4 | 15.2 | 20.5 | 64.3 |
| 6 | 244.5 | 249.8 | 48.697 | 0.784 | 0.909 | < 0.0001 | 0.822 | 0.959 | -5.3 | 27.9 | 7.6 | 40.2 | 52.2 |

[1]Mean body weight observed (kg). [2]Mean body weight predict (kg). [3]$R^2$: coefficient of determination. [4]Ho: $\beta 0 = 0$ and $\beta 1 = 1$. [5]CCC: concordance coefficient of correlation. [6]ACC: accuracy. [7]MSPE: mean squared prediction error in%. [8]SA: square addiction of MSPE (%). [9]SE: systematic error of MSPE (%). [10]RE: random error of MSPE.

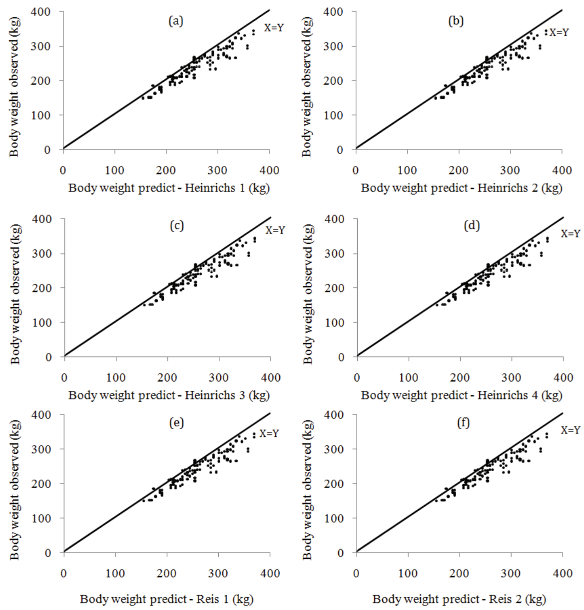


**Figure 1.** Curves of linear regression of body weights predicted by the Equations of Heinrichs et al. (1992) according to HG (a), WH (b), HW (c) BL (d), and Reis et al. (2008) according to PT (e) and HH (f) to growth dairy heifers.

A joint evaluation of the intercept and slope coefficient of the regression Equation (observed values versus predicted BW) for Holstein and crossbred animals separately (Table 3) shows the rejection of the null hypothesis ($p < 0.05$) for all Equations. This initially indicates that the evaluated Equations are inadequate for BW prediction in both genetic groups.

It was observed that the Equations proposed by Heinrichs et al. (1992), which were used for crossbred animals (Table 3), had a higher bias (SB) in prediction. Among the tested Equations, 2 and 3 had the best predictions, which can be observed in the CCC value being closer to 1. However, there was still great data dispersion, which can also be observed in the low $R^2$. The lowest dispersion was found for Equations 1, 5 and 6 (Figures 2a, 2e and 2f, respectively). In growing crossbred heifers, a higher bias in prediction was the main factor affecting the quality of BW prediction Equations by Heinrichs et al. (1992). Equations 1, 5 and 6 had the lowest dispersion, likely explained by the fact that HG was used as the body measure, which has the greater correlation with BW. Caution should be exercised when using Equations developed for Holstein animals in crossbred animals, as they can be associated with high prediction errors.

The Equations developed by Reis et al. (2008) presented a lower bias, which is associated with a greater contribution of RE in MSPE (Table 3). Equation 6 was more efficient in terms of BW prediction than Equation 5 in crossbred heifers. The Equations developed by Reis et al. (2008), although they did not accurately estimate BW, offered models that were the closest to real values (Equation 5 overestimated weight by 7.5 kg and Equation 6 underestimated weight by 4.1 kg in crossbred heifers). The high accuracy of Equations 5 and 6 may explain the low bias in the model. In Equation 5, an SE was observed, which contributed to the lower accuracy of this Equation compared to Equation 6. Considering the low number of repetitions (48), it can be inferred that Equation 6 has satisfactorily estimated the BW of crossbred heifers, demonstrating high precision, accuracy and a higher proportion of prediction errors concentrated within RE.

The joint evaluation of the intercept and slope coefficient in the regression Equation for observed versus predicted values for BW (Table 3) in Holstein heifers also rejects the null hypothesis ($p < 0.05$) for all Equations. This also indicated that evaluated Equations are inadequate for predicting BW in growing Holstein dairy heifers.

**Table 3.** Functional relationship of body weight values of dairy heifers in growth, crossbred and Holstein, observed and those predicted by different Equations.

| Model | Y[1] | X[2] | $\beta_0$ | $\beta_1$ | $(R^2)$[3] | *P*-value[4] | CCC[5] | ACC[6] | Deviation | MSPE[7] | SA[8] | SE[9] | RE[10] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Crossbred | | | | | | | |
| 1 | 233.9 | 252.5 | 36.089 | 0.783 | 0.831 | < 0.0001 | 0.857 | 0.896 | -18.8 | 351.6 | 51.1 | 13.7 | 35.2 |
| 2 | 233.9 | 262.7 | 22.101 | 0.807 | 0.746 | < 0.0001 | 0.931 | 0.813 | -28.7 | 821.8 | 65.7 | 5.1 | 29.2 |
| 3 | 233.9 | 264.7 | 30.984 | 0.766 | 0.676 | < 0.0001 | 0.927 | 0.796 | -30.9 | 953.3 | 63.1 | 6.2 | 30.7 |
| 4 | 233.9 | 208.0 | 27.316 | 0.993 | 0.571 | < 0.0001 | 1.303 | 0.771 | 25.8 | 664.1 | 51.9 | 0.0 | 48.1 |
| 5 | 233.9 | 241.3 | 48.986 | 0.766 | 0.830 | < 0.0001 | 0.839 | 0.958 | -7.5 | 56.9 | 13.7 | 27.5 | 58.8 |
| 6 | 233.9 | 229.7 | 30.363 | 0.886 | 0.890 | 0.006 | 0.938 | 0.991 | 4.1 | 17.0 | 8.7 | 11.1 | 80.2 |
| | | | | | | Holstein | | | | | | | |
| 1 | 255.2 | 272.4 | 14.905 | 0.882 | 0.934 | < 0.0001 | 0.912 | 0.944 | -17.3 | 298.3 | 58.5 | 8.5 | 33.0 |
| 2 | 255.2 | 343.8 | -61.383 | 1.487 | 0.860 | < 0.0001 | 1.601 | 0.571 | 71.3 | 5085.5 | 73.5 | 10.7 | 15.8 |
| 3 | 255.2 | 297.7 | -166.233 | 1.713 | 0.897 | < 0.0001 | 1.807 | 0.597 | 46.0 | 2119.8 | 50.9 | 29.7 | 19.4 |
| 4 | 255.2 | 252.2 | -50.263 | 1.563 | 0.846 | < 0.0001 | 1.696 | 0.450 | 91.6 | 8391.3 | 80.1 | 8.4 | 11.5 |
| 5 | 255.2 | 262.1 | -43.669 | 1.478 | 0.862 | < 0.0001 | 1.589 | 0.527 | 81.7 | 6666.0 | 78.8 | 8.5 | 12.7 |
| 6 | 255.2 | 269.8 | -29.577 | 1.383 | 0.927 | < 0.0001 | 1.435 | 0.613 | 73.9 | 5460.6 | 82.8 | 8.6 | 8.6 |

[1]Mean body weight observed (kg). [2]Mean body weight predict (kg). [3]$R^2$: coefficient of determination. [4]Ho: $\beta_0 = 0$ and $\beta_1 = 1$. [5]CCC: concordance coefficient of correlation. [6]ACC: accuracy. [7]MSPE: mean squared prediction error in%. [8]SA: square addiction of MSPE (%). [9]SE: systematic error of MSPE (%). [10]RE: random error of MSPE.

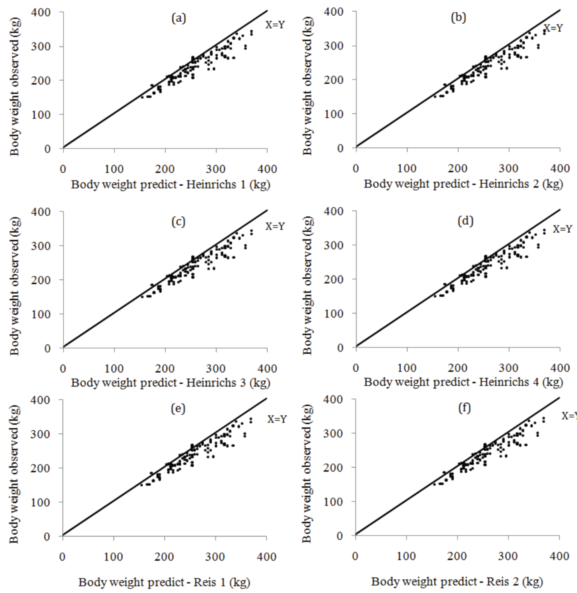


**Figure 2.** Curves of linear regression of body weights predicted by the Equations of Heinrichs et al. (1992) according to HG (a), WH (b), HW (c) BL (d), and Reis et al. (2008) according to PT (e) and HH (f) for crossbred dairy heifers growing.

It was observed that there is a high bias in the BW prediction in Holstein heifers (Table 3). Excepting Equation 1, all Equations showed low accuracy, even with high precision, which resulted in low CCC values. Equation 1 had the lowest bias and greater prediction of RE associated with the highest CCC. Equation 3 had the worst adjustment with both systematic and bias prediction errors, reflected in the distance between the points on the line (Figure 3). In the BW prediction in Holstein heifers, the high bias was the main factor of prediction error in both Equations by Heinrichs et al. (1992) (for Holstein animals) and Equations by Reis et al. (2008) (for crossbred animals). Equation 1 is recommended for BW prediction in Holstein heifers because it had the lowest bias, a greater prediction of RE and a greater CCC.

A lower dispersion (more accuracy) was observed in the Equations 1, 5 and 6 models (Figures 3a, 3e and 3f, respectively) using the variables most correlated with BW.

Due to a lack of reliable Equations to estimate BW from body measurements, prediction Equations were estimated from measurements obtained in the experiment (Table 4). The model developed in relation to HG showed better adjustment. Weight estimates based on BL (Table 4) are less accurate.

Weight prediction Equations from measurements of WH, HH and HW were affected by genotype ($p < 0.05$), demonstrating that these animals have different growth patterns. Specific Equations were then generated to estimate the weight of Holstein and crossbred animals based on these body measurements (Table 4). These results may partly explain the differences observed in the validation of prediction Equations for Holstein and crossbred animals (Table 3).

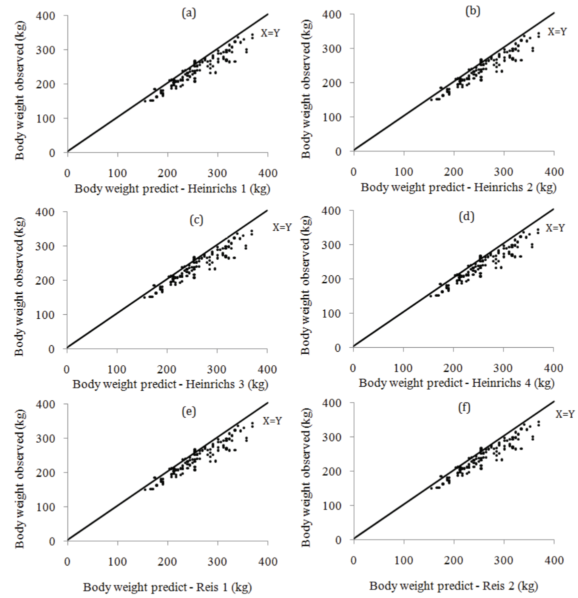


**Figure 3.** Curves of linear regression of body weights predicted by the Equations of Heinrichs et al. (1992) according to HG (a), WH (b), HW (c) BL (d), and Reis et al. (2008) according to PT (e) and HH (f) for Holstein dairy heifers growing.

Among the Equations, the models based on WH had the worst adjustment (AIC = 711.3). Observing the intercept and slope values for the crossbred and Holstein models, the effect is more evident on crossbreds, indicating a high-modulus linear effect. Holstein, however, showed higher weight gain in relation to WH because it has a negative linear effect of lower value. For HH (Table 4), Holsteins had a concave down curve, which is biologically unexplained. However, the main fact is that the effect was manifested by crossbred heifers with a positive intercept value.

Among the Equations estimated, the model developed from HG indicated better adjustment because it had a lower AIC and a high determination coefficient ($R^2$ 0.90), corroborating several results published previously (Heinrichs & Hargrove, 1987; Hoffman, 1997; Reis et al., 2008).

Weight estimates based on BL (Table 4) are less accurate due to a low determination coefficient ($R^2$ 0.76) and a lower correlation with BW (Table 1). This may be due to the difficulty in obtaining animal measurements on live animals, which may lead to a high variability in the results.

**Table 4.** Equations for estimating the body weight from body measurements for dairy heifers in growth, Holstein and crossbred.

| Item | Equation | CV%[1] | $(R^2)^2$ | $S_{xy}$[3] | AIC[4] | n[5] |
|---|---|---|---|---|---|---|
| Heart girth | BW = – 286.50 + 3.5808 × X | 5.9 | 0.90 | 14.3 | 653.3 | 91 |
| Body length | BW = –36.7443 + 2.2506 × X | 9.4 | 0.76 | 22.8 | 677.8 | 90 |
| Wither height – Crossbred | BW = 197.84 – 4.9706 × X + 0.04679 × $X^2$ | 7.4 | 0.86 | 18.1 | 711.3 | 90 |
| Wither height – Holstein | BW = 197.84 – 3.0623 × X + 0.02947 × $X^2$ | 7.4 | 0.86 | 18.1 | 711.3 | 90 |
| Hip height – Crossbred | BW = 2570.22 – 45.8572 × X + 0.2203 × $X^2$ | 6.5 | 0.89 | 15.7 | 662.3 | 89 |
| Hip height – Holstein | BW = – 394.19 + 6.3993 × X – 0.0097 × $X^2$ | 6.5 | 0.89 | 15.7 | 662.3 | 89 |
| Hip width – Crossbred | BW = 569.97 – 23.1701 × X + 0.3801 × $X^2$ | 8.0 | 0.83 | 19.4 | 659.0 | 89 |
| Hip width – Holstein | BW = 192.13 + 2.6075 × X + 0.1075 × $X^2$ | 8.0 | 0.83 | 19.4 | 659.0 | 89 |

[1]CV: coefficient of variation. [2]$R^2$: coefficient of determination. [3]$S_{xy}$: standard deviation. [4]AIC: precision. [5]n: number of data to generate the Equation

The worst adjustment in Equations based on WH likely occurred due to a lower correlation with BW (Table 1) compared to other measures (Table 4). Moreover, there are different growth patterns between the genetic groups for this measure.

Although HW was highly correlated with BW (Table 1), it showed a low determination coefficient associated with a high coefficient of variation (Table 4) when compared to other variables. This leads to an inaccuracy in the predicted weights based on this body measure indicator. The intercept and slope values (Table 4) shows that crossbred heifers have more effect on this measure.

The joint assessment of all body measurements using the stepwise procedure produced higher significance in the HG and BL measures. These measures were, therefore, kept in the prediction model, obtaining the final Equation: BW = - 372.89 + 2.8072 × HG + 1.6087 × BL.

A lower AIC value was obtained for this Equation (AIC = 633.1), with a correlation coefficient of 0.95 and a variation coefficient of 4.38%, with no breed effect ($p > 0.05$). The above Equation is the most suitable for BW estimation when compared to other Equations in Table 4. These data also show that, even though there are discrepancies in the literature concerning which body measure should be considered in the model, accuracy and precision tend to be higher when more than one variable is considered (Reis et al., 2008).

## Conclusion

Equations for body weight estimation proposed by Heinrichs et al. (1992) and Reis et al. (2008) are initially not efficient in terms of weight prediction in growing dairy heifers. Precision was always low in Holstein heifers, with the most appropriate Equation being 1. The most suitable models for crossbred heifers are those proposed by Reis et al. (2008).

We recommend the use of the following Equation to estimate weight in Holstein and crossbred heifers: BW= - 372.89 + 2.8072 × HG + 1.6087 × BL.

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