Predicting body weight from body measurements of pre-pubertal Ayrshire heifers

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The relationship between heart girth, wither height, body length and body weight in 3- to 9.5-month-old pre-pubertal Finnish Ayrshire heifers gaining 600-650 g/d was analysed (experiment I). Regression analysis showed that heart girth was the trait most highly correlated to body weight ($R^2 = 0.969$). Including body length or wither height as a second term in the regression, increased $R^2$ values only slightly. When the relationship between heart girth and body weight was used to predict the body weight of heifers reared at two feeding levels (experiment II), the precision of prediction was affected by the plane of nutrition. Actual body weight for a given heart girth was slightly higher on the high than on the low feeding level. It is, nevertheless, concluded that the equations presented in the paper can be used to estimate accurately the body weight of pre-pubertal (95-140-cm heart girth) Ayrshire heifers gaining 550-700 g/d.

Key words: heart girth, wither height, body length, feeding level, replacement heifer

Introduction

Body weight (BW) measurements of replacement dairy heifers are important for monitoring the growth rate, optimizing nutrient allowance and determining a suitable size for breeding. Growth rate needs to be monitored, because the feeding level before puberty can affect mammary development (Sejrsen et al., 1982; Harrison et al., 1983; Niezen et al., 1992; Mäntysaari et al., 1995) and hence the subsequent milk-producing ability of heifers (Little and Kay, 1979; Foldager and Sejrsen, 1991). Since nutrient recommendations are based on BW and daily gain, it is necessary to know the live weight to optimize the nutrient intake of heifers.

Since most farmers do not have animal scales for measuring BW directly, an alternative method of estimating BW is needed. Among those used have been measurements such as heart girth, wither height, body length and hip width (Johansson and Hildeman, 1954; Kenttäemies et al., 1974; Kenttäemies and Vehmaan-Kreula, 1978; Verma and Hussain, 1985; Sørensen and Foldager, 1991; Heinrichs et al. 1992). In many cases, heart girth has been the trait most highly correlated to BW (Johansson and Hildeman, 1954; Nelson, et al., 1985; Heinrichs et al. 1992). However, the relationship between heart girth...
and BW may differ between breeds (Kenttämiest and Vehmaan-Kreula, 1978; Serensen and Fodager, 1991), animals of different age (Johansson and Hildeman, 1954) and animals on different feeding levels (Hvidsten, 1940; Johansson and Hildeman, 1954; Serensen and Fodager, 1991).

In Finland, the relationship used to estimate BW from the heart girth of heifers is based on investigations by Kenttämiest and Vehmaan-Kreula (1978). In their study they excluded heifers that were younger than 6 months. However, the critical rearing period, when feeding intensity may affect mammary development, begins at 3 months of age (Sejrsen and Foldager, 1991).

The purpose of this study was to investigate the value of heart girth, wither height and body length in predicting the BW of pre-pubertal Finnish Ayrshire heifers fed restricted diets.

Material and methods

Animals, diets and measurements

Experiment I

A group of 51 Finnish Ayrshire heifers were reared to gain 650 g/d from 3 months of age and 98 kg BW to 9.5 months of age and 225 kg BW. All heifers were fed the same diet, which included silage, hay, barley (when BW < 200 kg) and rapeseed meal (when BW < 130 kg). Average feed, energy and protein intakes are given in Table 1.

The body weight, heart girth, wither height and body length (from the point of the shoulders to the pinbone) of the heifers were measured every four weeks. All measurements were carried out by the same person. The total number of observations for each measurement was 408.

Experiment II

A 2x2 factorial experiment was conducted on 24 Finnish Ayrshire heifers. The factors were two feeding levels and two protein sources. The average age and weight of the heifers at the beginning were 3 months and 87 kg and at the end of the experiment 9 months and 221 kg. The average gain of the heifers on the low feeding level was 668 g/d and on the high feeding level 848 g/d.

The heifers were fed hay and barley supplemented with rapeseed meal or urea. Feed, energy and protein intakes by feeding level are given in Table 1.

During the experiment the body weight, heart girth and wither height were measured by the same person every four weeks. More detailed information about diets, feed intake, growth, slaughter weight and carcass quality of the heifers is given by Mäntysaari (1993). The mammary development of the heifers is presented by Mäntysaari et al. (1995).

Statistical analysis

The best prediction equation for BW from the body measurements was determined from the data of experiment I. After the fit of different functions had been tested, the best fit equation

\[ BW = e^{2.56M_i} \]  

where BW is body weight, \( M_i \) body measurement and \( b_i \) the corresponding parameter, was chosen to estimate BW from body measurements. Equation 1 was transformed to a linear statistical model

\[ \ln(BW) = \Sigma b_i M_i \]  

Regressions of the \( \ln(BW) \) on heart girth, wither height and body length using individual observations were performed. Models were fitted using the GLM procedure of SAS (1987). Linear and quadratic effects of the independent variables were considered. The base model was:

\[ \ln(BW)_{jk} = b_0 + b_1M_{jk} + b_2 M_{jk}^2 + S_j + e_{jk} \]  

where \( BW_{jk} \) is body weight, \( b_0 \) the intercept, \( M_{jk} \) the \( k^{th} \) body measurement (heart girth, wither height or body length) of the \( j^{th} \) heifer, \( S_j \) the effect of the heifer, \( b_1 \) and \( b_2 \) are regression coefficients, and \( e_{jk} \) is the residual associated with the \( k^{th} \) measurement of the \( j^{th} \) heifer.

\( \ln(BW) \) was also regressed on multiple independent variables. Since the \( R^2 \) values from the
Table 1. Age, body weight, growth and feed intake of the experimental heifers.

<table>
<thead>
<tr>
<th></th>
<th>Experiment I</th>
<th></th>
<th>Experiment II</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>x</td>
<td>std</td>
<td>x</td>
<td>std</td>
</tr>
<tr>
<td>N</td>
<td>51</td>
<td></td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Initial age, d</td>
<td>92</td>
<td>11.6</td>
<td>88</td>
<td>9.3</td>
</tr>
<tr>
<td>Final age, d</td>
<td>288</td>
<td>11.6</td>
<td>293</td>
<td>21.1</td>
</tr>
<tr>
<td>Initial BW, kg</td>
<td>98</td>
<td>12.6</td>
<td>86</td>
<td>10.7</td>
</tr>
<tr>
<td>Final BW, kg</td>
<td>225</td>
<td>16.2</td>
<td>220</td>
<td>3.9</td>
</tr>
<tr>
<td>Daily gain, g</td>
<td>647</td>
<td>52.6</td>
<td>668</td>
<td>45.7</td>
</tr>
<tr>
<td>Intake, kg/d</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry matter</td>
<td>3.59</td>
<td>0.190</td>
<td>3.73</td>
<td>0.088</td>
</tr>
<tr>
<td>Hay</td>
<td>0.56</td>
<td>0.124</td>
<td>2.33</td>
<td>0.093</td>
</tr>
<tr>
<td>Silage</td>
<td>2.13</td>
<td>0.178</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Concentrate</td>
<td>0.89</td>
<td>0.122</td>
<td>1.39</td>
<td>0.024</td>
</tr>
<tr>
<td>Nutrient</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NE, fu/d</td>
<td>3.28</td>
<td>0.157</td>
<td>2.73</td>
<td>0.055</td>
</tr>
<tr>
<td>CP, g/d</td>
<td>479</td>
<td>14.7</td>
<td>492</td>
<td>9.0</td>
</tr>
<tr>
<td>AAT g/d</td>
<td>321</td>
<td>13.7</td>
<td>327</td>
<td>14.8</td>
</tr>
</tbody>
</table>

BW, body weight; NE, net energy in fattening feed units; CP, crude protein; AAT, amino acids absorbed from the small intestine (Madsen, 1985).

Regression of body weight on different body measurements

The increase with age in the BW, heart girth, wither height and body length of the heifers in experiment I is presented in Figure 1. Correlations between BW and body measurements were high (r > 0.93). In agreement with previous studies (Johansson and Hildeman, 1954; Nelson et al., 1985; Heinrichs et al., 1992) heart girth was the trait most highly correlated to BW (r = 0.97).
Body weight is estimated from body measurements using the exponential function (Johansson and Hildeman, 1954; Kenttäemies et al. 1974; Kenttäemies and Vehman-Kreula, 1978, Sorensen and Foldager, 1991), although Verma and Hussain (1985) predicted the BW of calves using the linear relationship of heart girth to BW. Since the purpose of the present study was to establish the relationship of body measurements to the BW of pre-pubertal heifers, the ranges in BW and body measurements were relatively small. The linear regression of heart girth, wither height or body length, therefore, estimated the BW fairly accurately (R² > 0.914). The fit was, however, improved when equation 1 was used to predict BW from body measurements. The R² values for the linear regression of heart girth, wither height and body length to ln(BW) were 0.967, 0.929 and 0.945, respectively (Table 2). The additional quadratic terms were highly significant for heart girth and wither height although the increases in R² values were small. Including them in the regression would, however, improve the prediction.

Johansson and Hildeman (1954) concluded that BW can be estimated with about the same accuracy from heart girth only as with a combination of two or several measurements. Likewise Heinrichs et al. (1992) found that an additional linear term gave only little predictive benefit. Here, too, the addition of the linear effect of body length or wither height to the regression including the linear and quadratic effects of heart girth improved the fit only slightly (Table 3). The inclusion of all three independent variables in the equation increased the R² value by 0.014.

If a higher accuracy of the BW estimation is

Table 2. Regressions of ln(BW) on various body measurements.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Intercept</th>
<th>Linear</th>
<th>Quadratic</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart girth</td>
<td>-2.1183</td>
<td>0.02307*</td>
<td>-0.00007713***</td>
<td>0.967</td>
</tr>
<tr>
<td></td>
<td>1.0453</td>
<td>0.04196*</td>
<td>-0.00000154**</td>
<td>0.969</td>
</tr>
<tr>
<td>Body length</td>
<td>2.2654</td>
<td>0.02821*</td>
<td>-0.00000154**</td>
<td>0.945</td>
</tr>
<tr>
<td>Wither height</td>
<td>1.3685</td>
<td>0.03711*</td>
<td>-0.00020253**</td>
<td>0.929</td>
</tr>
</tbody>
</table>

*** P < 0.001
** P < 0.01
sought by adding another trait besides heart girth, the use of body length is more reasonable from the farmer’s point of view. This is because body length can be measured with the same tape measure as heart girth; a special measuring stick is needed to obtain a reliable estimate of wither height. From a statistical point of view, however, the addition of measurements other than heart girth provides little additional information.

Table 3. Regressions of ln(BW) on the linear and quadratic effects of heart girth and the linear effect of body length and wither height.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Intercept</th>
<th>Linear</th>
<th>Quadratic</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart girth</td>
<td>1.6908</td>
<td>0.02313***</td>
<td>-0.00003154***</td>
<td>0.978</td>
</tr>
<tr>
<td>Body length</td>
<td>0.00993***</td>
<td>0.03138***</td>
<td>-0.00006131***</td>
<td>0.978</td>
</tr>
<tr>
<td>Wither height</td>
<td>0.01172***</td>
<td>0.01897***</td>
<td>-0.00002927*</td>
<td>0.978</td>
</tr>
</tbody>
</table>

Therefore, an equation based on the linear and quadratic effects of heart girth is recommended. The difference in predicted BW at 140-cm heart girth between the recommended equation and the table for older heifers given by Kenttämies and Vehmaan-Kreula (1978) is about 7 kg.

**Effect of feeding level on the relation of heart girth to body weight**

A number of investigators have shown that feeding level can affect the relationship between BW and heart girth (Hvidsten, 1940; Johansson and Hildeman, 1954; Sørensen and Foldager, 1991). In the present study, the usefulness of the prediction equation developed from the heifers in experiment I was evaluated for heifers on different feeding levels using the data of experiment II.

The mean differences between the estimated (BW = exp[b₀ + b₁HG + b₂(HG)^2]; see Table 2) and actual BW of the heifers on high and low feeding levels in experiment II is presented in Figure 2. The prediction estimating the BW of
the heifers on the low feeding level, which had similar daily live weight gains to those in experiment I, was satisfactory, but on the high feeding level the equation tended to underestimate the BW of the heifers. In the analysis of variance, feeding level had a significant effect on the goodness of fit of the prediction model ($P < 0.01$). The protein source of the diet in experiment II had no effect on fit.

In agreement with our results, Hvidsten (1940) and Johansson and Hildeman (1954) found that, at a certain heart girth, an increase in the condition score increased the BW. In contrast, the plane of nutrition did not affect the relationship between the heart girth and BW of Danish Black and White heifers (Sørensen and Foldager, 1991). For Red Danish heifers, the effect of feeding level was the opposite to our results, that is, the BW at a certain heart girth was greater on lower planes of nutrition (Sørensen and Foldager, 1991).

**Conclusions**

The regressions showed that, from the body measurements recorded, heart girth was the trait most highly related to BW. The linear relationship of heart girth to $\ln(BW)$ already gave relatively accurate predictions. However, the addition of a quadratic term improved the fit. Thus, the recommended equation for predicting BW from heart girth was:

$$BW = \exp(1.0453 + 0.04196(HG) - 0.0007713(HG)^2).$$

At a heart girth of around 100 cm, an increase of 1 cm increases the predicted BW by 2.3 kg, whereas the corresponding increase at 130 cm is 4.0 kg. This equation can be accurately used to predict the BW of pre-pubertal Finnish Ayrshire heifers with a heart girth of 95 to 140 cm. Since the feeding level affects the relationship between BW and heart girth, the best prediction of BW is achieved for heifers gaining 550–700 g/d.

**References**


SELOSTUS

Hiehojen elopainon määrittäminen mittauksin alkukasvatusvaiheessa

Päivi Mäntysaari

Maatalouden tutkimuskeskus

Tutkimuksen tavoitteena oli selvittää mittauten käyttökelpoisuutta 3–10 kuukauden ikäisten hiehojen elopainon määrittämisessä. Elopainon kehityksen seuraminen jo alkukasvatuskaudella on välttämätöntä, sillä utareen kehityksen kannalta kriittinen kasvuvaihe alkaa noin 3 kk iässä. Kokeessa mitattiin elopaino, rinnanympärys, pituus ja säkäkorkeus 3–9,5 kg ikäisiltä hiehoilta, joiden keskimääräinen päiväkasvu oli 650 g. Mittojen ja elopainon välisiä yhteyksiä pyrittiin selvittämään regressioanalyysillä. Rinnanympäryksen perusteella pystyttiin parhaiten ennustamaan elopainoa ($R^2 = 0,969$). Kun rinnanympäryksen lisäksi regressiomalliin lisättiin sekä pituus että säkäkorkeus, lisääntyi ennusteen varmuus vain vähän ($R^2 = 0,983$). Hiehojen elopainoa suositeltiin arvioitavan rinnanympäryksen perusteella kaavalla

$$EP = \exp[1,0453+0,04196(RY)-0,00007713(RY)^2],$$