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# Estimating internal pelvic sizes using external body measurements in the double-muscled Belgian Blue beef breed

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## Abstract

*In the double-muscled (DM) Belgian Blue beef (BBB) breed, caesarean section (CS) is being applied systematically as a management tool to prevent dystocia. As a matter of fact, CS is the only possible way of calving in the breed. High birth weight and a relatively small pelvic area are the main causes of dystocia and, in the DM-BBB breed, the reasons for the systematically applied CS. Selection for lower birth weight and larger pelvic sizes might reduce dystocia and routine CS. Few data on inner pelvic sizes of pedigree animals are available. Using external measurements to estimate the inner pelvic sizes might be an option to resolve this problem. In this study, animals of the DM-BBB breed were measured and weighed on farms and in abattoirs. External and internal pelvic sizes increased with live weight and age of the animals. Gender had a significant influence on inner pelvic traits. Increased muscular conformation was associated with decreased inner pelvic dimensions. Models with weight, gender, age, withers height and outer pelvic width (TcTc) can be used to estimate inner pelvic sizes ($R^2$ between 0·35 and 0·77). The estimated inner pelvic sizes can then be used to genetically evaluate pelvic traits in the DM-BBB breed. Improving weight, withers height and TcTc width in combination with lowering muscular conformation may help to decrease the high rate of caesarean section in the DM-BBB.*

**Keywords:** *beef cattle, Belgian Blue, body measurements, pelvis.*

## Introduction

High birth weight of the calf in combination with a small size of the pelvic area of the dam are the main causes of dystocia and increase incidence of caesarean sections (Ménissier and Vissac, 1971; Laster, 1974; Meadows *et al.*, 1994; Murray *et al.*, 1999). The routine caesarean section has been criticized on animal welfare grounds (Grommers *et al.*, 1995). Decreasing the incidence of dystocia without using caesarean section as a preventive management tool can be done not only by selecting for lower birth weights, but also by selecting for higher pelvic height (PH), pelvic width (PW) and/or pelvic area (PA; Green *et al.*, 1988; Murray *et al.*, 1999). Genetic selection to change these traits requires routine measurement.

The PH, PW and PA of double-muscled (DM) animals are significantly smaller then those of non-DM animals (Ménissier and Vissac, 1971). The proportion of os coxa, being the combination of the pelvis, the sacrum and the first two coccygeale vertebrae, to the total bone weight is also smaller in DM cows than in non-DM cows (Shahin *et al.*, 1991). The differences between non-DM and DM animals are in the anterior pelvic plane. The narrowing of this anterior pelvic plane is accompanied by a deformation, i.e. convergence of the iliac branches of the hip–bone, and even an accentuation of the pelvic crest (Vissac *et al.,* 1973).

Measuring inner pelvic sizes on living animals can be done by using a pelvimeter (Rice and Wiltbank, 1972; Schwabe and Hall, 1989; Kriese, 1994). The most common measurements taken are : PH (the narrowest distance between sacrum and pelvic crest) and PW (broadest points between right and left iliac branches of the hip–bone) (Taylor *et al.,* 1975; Neville *et al.,* 1978; Brown *et al.,* 1982). The pelvic area is defined as the product of the measured PH and PW (Morrison *et al.,* 1986). Murray *et al.* (1999) measured not only PH and PW, but also the external distance between the most lateral points of the tuber coxae (TcTc) and the external distance between the tuber coxae and tuber ischii (TcTi). Rice and Wiltbank (1972) measured pelvic sizes of carcasses (non-DM Aberdeen Angus) before they were halved to see whether there was a meaningful correlation with the measurements of live animals. Except for Murray *et al.* (1999), most studies have examined non-DM beef cattle, and where DM cattle were investigated, breeds other than the DM Belgian Blue beef (BBB) breed were examined.

Because of the fact that natural calving is no longer present in the breed, selection for decreased caesarean section can, primarily, only be done indirectly, using internal pelvic sizes of the dam and birth traits of the calf as basic data.

The routine collection of sufficient data of internal pelvic sizes *per rectum,* as done by Murray *et al.* (1999), on animals of known pedigree, for a genetic evaluation may pose a problem. Although risk can be minimized (Ménissier and Vissac, 1971), measuring internal pelvic sizes *per rectum* is both time-consuming and not without risk for the breeding animals and the technician. Internal measurements can also be done before (Rice and Wiltbank, 1972) or after slaughter. With this approach, one should be aware of the fact that many of the presented animals have no known pedigree, making these data useless for genetic evaluation. This means that an easier and more accessible method by which to collect sufficient data on internal pelvic sizes of animals of known pedigree for the DM-BBB breed is needed in order to start selection for wider internal pelvic sizes. Seeing that a regression model is available, it is possible to estimate inner pelvic sizes from external body sizes

The aim of this paper is to serve as a guideline for developing such a model (or models). Some models have been developed and presented as examples. There is a description of the way in which the necessary data to develop these models can be collected. The results obtained from this preliminary study can be of help when discussing the overall breeding policy in the DM-BBB breed.

**Table 1** *Number of observations (range of ages of animals in days is given in parentheses)*

| | | External body measurements | Internal pelvic measurements |
|---|---|---|---|
| Abattoirs† | 1 | 192 (228-3234) | 192 (228-3234) |
| | 2 | –- | 140 (609-4251) |
| | 3 | 200 (449-996) | –- |
| Farm‡ | 1 | 165 (1-2478) | –- |
| | 2 | 109 (unknown) | –- |

† Abattoir 1 = Melle; abattoir 2 = Zele; abattoir 3 = Verbiest (Izegem).
‡ Farm 1 = 2 DM-BBB farms near Ghent; farm 2 = clients of Ambulatory Clinic of Veterinary Faculty of Ghent University breeding DM-BBB.

## Material and methods

*Animals*

The number of observations are presented in Table 1. All animals were of the DM-BBB breed and data were gathered over a period of 6 years (1995-2001), either at abattoirs (three) or at farms (two). In total, external body measurements of 666 animals were available, of which 109 had no age information. Internal body measurements of 332 animals were available. Of these, 192 animals had both external and internal body measurements. Pedigree information was available on only a small number of the farm animals. The age ranged from 1 to 2478 days for animals on farms, and from 228 to 4251 days for animals at the abattoirs. The slaughter date minus the birth date mentioned on the identification card of the animals was used to calculate the ages of the animals. The 109 animals with no age information had either questionable birth dates or no accessible ID card. The abattoirs and farms mentioned were the only ones willing to co-operate. In abattoir 1, pre-mortem and post-mortem measurements were possible and allowed. In abattoir 2, accommodation was inadequate for pre-mortem measurements. Abattoir 3 did not provide access to the carcasses for reasons of hygiene.

*Measurements*

The external body measurements and weights, and external and internal pelvic sizes that were taken are described in Table 2. The internal pelvic measurements were done on halved carcasses. This means that PW could not be measured. All measurements were taken using a measuring-rod or measuring-tape. In total, 4 different inspectors helped to collect these weights and measurements. They had been well instructed by the chief inspector at the outset.

The visual appreciation of muscular conformation and fat percentage of the carcasses was done by the inspector of the abattoir according to the SEUROP classification method of the European Community (Anonymous (1991); S = extreme muscularity to P = dairy type; 1 = low fat content to 5 = extreme fat).

One inspector gathered external body measurements as well as internal pelvic sizes on 192 animals. The different pre-mortem and post-mortem measurements were done within a time lapse of 24 h. These 192 animals, 186 animals with an S (extreme muscular hypertrophy) or E (plain muscular hypertrophy) classification, were restricted to the so-called abattoir population. Measurements on the farms were done at the beginning of the winter season when animals were housed. Abattoir measurements were done on a weekly basis in November (winter).

*Statistics*
SPSS 9·0 for Windows was used to explore and analyse the data phenotypically. Correlations between the external measurements, as well as the internal measurements, and weights were determined both with and without adjustments for age or weight effects. The correlations between internal and external measurements were based on the data of the abattoir population. To see whether SEUROP classification (S and E animals) or gender influenced the internal traits, a general linear model was developed where the fixed effects were gender, SEUROP classification and the interaction between gender and SEUROP, and with the covariates age and weight (live weight or carcass weight).

Data of the abattoir population were used to develop multiple regression models that estimate inner pelvic sizes from easily accessible external measurements. The stepwise multiple regression method was used. The influence of the sex was incorporated in the model by implementing the gender as an independent dummy variable (0 for the male and 1 for the female). In the case of age, a hyperbolic function was found and a transformation (1/age) was therefore done. The trait 'shoulder width' was not implemented in the model because preliminary graphical examination showed no clear relationship with any of the six internal pelvic measurements. As the data of the abattoir population were collected by only one inspector, this effect was not included in the model. Different models were developed to estimate the inner pelvic sizes and the reliability of these estimations and the estimation errors were calculated.

**Table 2** *External body measurements and weights, and external and internal pelvic sizes of female (above) and male (below) double-muscled Belgian Blue beef cattle*†

| Trait | | No. | Min. | Max. | Mean | s.e. | Median |
|---|---|---|---|---|---|---|---|
| External | WH (cm) | 174 | 64 | 140 | 122 | 20 | 129 |
| | | 319 | 73 | 140 | 122 | 15 | 128 |
| | SW(cm) | 174 | 18 | 81 | 58 | 14 | 64 |
| | | 319 | 20 | 80 | 63 | 11 | 66 |
| | BcW (cm) | 158 | 19 | 76 | 61 | 12 | 66 |
| | | 304 | 18 | 76 | 60 | 8 | 63 |
| | HG (cm) | 174 | 78 | 272 | 205 | 50 | 226 |
| | | 319 | 78 | 254 | 198 | 34 | 204 |
| | LW (kg) | 174 | 38 | 986 | 583 | 258 | 677 |
| | | 319 | 38 | 1081 | 622 | 200 | 673 |
| | CW (kg) | 269 | 293 | 660 | 468 | 57 | 473 |
| | | 260 | 200 | 739 | 467 | 57 | 469 |
| | TcTc (cm) | 225 | 15 | 66 | 50 | 10 | 54 |
| | | 319 | 15 | 67 | 51 | 10 | 54 |
| | TiTi (cm) | 207 | 5 | 23 | 13 | 2·2 | 13 |
| | | 94 | 6 | 19 | 10 | 2·3 | 10 |
| Internal | PH (cm) | 269 | 17 | 29 | 23 | 2·4 | 23 |
| | | 58 | 16 | 25 | 21 | 1·5 | 21 |
| | Pusca (cm) | 269 | 21 | 31 | 25 | 1·8 | 25 |
| | | 60 | 19 | 27 | 24 | 1·6 | 23 |
| | Isscr (cm) | 269 | 31 | 42 | 37 | 2·1 | 37 |
| | | 60 | 26 | 42 | 34 | 2·4 | 33 |
| | Issca (cm) | 269 | 15 | 26 | 21 | 1·9 | 21 |
| | | 60 | 16 | 23 | 19 | 1·5 | 19 |
| | Sym (cm) | 269 | 17 | 29 | 19 | 1·0 | 19 |
| | | 60 | 16 | 23 | 19 | 1·2 | 19 |
| | Sac (cm) | 269 | 22 | 31 | 27 | 1·3 | 27 |
| | | 60 | 20 | 30 | 25 | 1·6 | 25 |

† WH = withers height; SW = shoulder width (distance between broadest points of the shoulder); BcW = back width (distance between the broadest points of the hindquarters); HG = heart girth (measuring half of the heart girth following the muscles on the thorax and then multiplying by two); LW = live weight; CW = carcass weight; TcTc = the external distance between the most lateral points of the tuber coxae; TiTi = the internal distance between the tuber ischii; PH or Puscra = pelvic height (pubis to sacrum cranialis); Pusca = pubis to sacrum caudalis; Isscr = ischium to sacrum cranialis; Issca = ischium to sacrum caudalis; Sym = length of the symphysis; Sac = length of the sacrum. No. = number of animals; s.e.= standard error.

## Results

*Descriptive statistics*
Table 2 shows descriptive statistics for all the external and internal measurements. Of the females with a known classification for carcass conformation, 55·4% were classified under 'S' and 42·4% were classified under 'E'. Of the males, 67·2% were classified under 'S' and 31·7% under 'E'. Females

**Table 3** *Simple correlations (diagonally above) and correlations adjusted for age and weight (diagonally below) between the external and internal pelvic sizes for the female (above) and the male (below) population considered*†

| Trait | | External | | Internal | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | TcTc | TiTi | PH | Issca | Pusca | Isscr | Sym | Sac |
| External | TcTc | | 0·62** | 0·47** | 0·25** | 0·37** | 0·48** | 0·28** | 0·44** |
| | | | 0·75** | 0·62** | 0·48** | 0·55** | 0·68** | 0·61** | 0·59** |
| | TiTi | 0·1 | | 0·13 | 0·22* | 0·33** | 0·12 | 0·19* | 0·20* |
| | | 0·1 | | 0·45** | 0·43** | 0·32* | 0·38** | 0·19 | 0·24 |
| Internal | PH | 0·18* | –0·07 | | 0·64** | 0·54** | 0·80** | 0·19** | 0·47** |
| | | 0·21 | 0·26* | | 0·68** | 0·60** | 0·86** | 0·58** | 0·68** |
| | Issca | –0·06 | 0·08 | 0·26** | | 0·73** | 0·60** | 0·29** | 0·36** |
| | | 0·03 | 0·25 | 0·33* | | 0·55** | 0·71** | 0·58** | 0·43** |
| | Pusca | 0·06 | 0·22* | 0·06 | 0·47** | | 0·36** | 0·35** | 0·58** |
| | | 0·08 | 0·09 | 0·14 | 0·16 | | 0·62** | 0·71** | 0·75** |
| | Isscr | 0·17* | –0·09 | 0·71** | 0·20* | –0·16 | | 0·55** | 0·55** |
| | | 0·25 | 0·10 | 0·60** | 0·35** | 0·05 | | 0·80** | 0·80** |
| | Sym | 0·02 | 0·04 | 0·05 | 0·09 | 0·24** | 0·40** | | 0·45** |
| | | 0·12 | –0·15 | –0·00 | 0·15 | –0·00 | 0·46** | | 0·72** |
| | Sac | 0·25** | 0·07 | 0·29** | 0·04 | 0·44** | 0·25** | 0·28** | |
| | | 0·14 | –0·05 | 0·26* | –0·14 | 0·48** | 0·49** | 0·32* | |

† TcTc = the external distance between the most lateral points of the tuber coxae; TiTi = the internal distance between the tuber ischii; PH or Puscra = pelvic height (pubis to sacrum cranialis); Issca = ischium to sacrum caudalis; Pusca = pubis to sacrum caudalis; Isscr = ischium to sacrum cranialis; Sym = length of the symphysis; Sac = length of the sacrum.

showed a higher level of fat deposition on the carcass (4·6% class 1; 53·8% class 2; 40·8% class 3) than males (5·1% class 1; 79·4% class 2; 15·2% class 3).

*Simple correlations*

Simple correlations between the external and internal pelvic sizes are illustrated in Table 3. It is clear that TcTc has a high correlation not only with pelvic height (male $rs = 0{\cdot}62$ and female $r = 0{\cdot}47$, both $P < 0{\cdot}01$), but also with other inner pelvic sizes in the male population ($r$ 0·48 to 0·68; $P < 0{\cdot}01$).

A highly significant simple correlation ($r > 0{\cdot}91$; $P < 0{\cdot}01$) was found between live weight and carcass weight in both the female and male population. Live weight showed a highly significant correlation ($r \geq 0{\cdot}89$; $P < 0{\cdot}01$) with the four external body measurements for males and females. For the two external pelvic sizes, there was a high correlation $r$ with live weight of at least 0·74 ($P < 0{\cdot}01$). There were differences between the correlations of LW with the internal pelvic sizes in the male population ($r > 0{\cdot}66$; $P < 0{\cdot}01$) and the female population ($r$ between 0·45 to 0·6; $P < 0{\cdot}01$). The significant correlations found between age and all the external traits ($r$ = 0·54 to 0·87; $P < 0{\cdot}01$) were higher than the ones found between age and the internal pelvic sizes ($r$ between 0·15 to 0·63 ; $P < 0{\cdot}01$).

*Adjusted correlations*

Correlations between the external and internal pelvic sizes, adjusted for age and weight effects, are shown in Table 3. Only very few adjusted correlations remain significant, highlighting the high correlation between inner pelvic sizes and live weight. In males and females, the significant adjusted correlations show that SW (with PH, Isscr and Sym) and BcW (with PH) had significant negative correlations ($r$= –0·25; $P < 0{\cdot}01$). WH had positive low ($r$ between 0·17 to 0·26; $P < 0{\cdot}01$), but significant, adjusted correlations with inner pelvic sizes, indicating that taller animals, irrespective of their live weight, tended towards wider pelvic sizes. All the external body measurements had positive partial correlations with both the external pelvic measurements ($r$ between 0·28 to 0·59; $P < 0{\cdot}01$).

*General linear model*

Gender and muscular conformation, expressed as SEUROP classification, had significant ($P < 0{\cdot}01$) effects on internal pelvic sizes. It was only for Pusca and Issca that no significant effect of conformation was found.

*Multiple regression -models*

Table 4 shows different models to estimate inner pelvic sizes from external body sizes. For all the

**Table 4** *Models to predict inner pelvic sizes from easily accessible external body measurements*

| *Y* | Model | $R^2$ | s.e. |
|---|---|---|---|
| PH | $Y = 11{\cdot}863 + 1{\cdot}98 \times \text{gender} - 2024/\text{age} + 0{\cdot}07 \times \text{WH} + 0{\cdot}0047 \times \text{LW}$ | 0·77 | 1·16 |
| PH | $Y = 8{\cdot}08 + 1{\cdot}42 \times \text{gender} - 2379/\text{age} + 0{\cdot}103 \times \text{WH} + 0{\cdot}069 \times \text{TcTc}$ | 0·76 | 1·17 |
| PH | $Y = 9{\cdot}04 + 1{\cdot}49 \times \text{gender} - 2681/\text{age} + 0{\cdot}126 \times \text{WH}$ | 0·75 | 1·19 |
| Isscr | $Y = 13{\cdot}22 + 2{\cdot}11 \times \text{gender} - 1176/\text{age} + 0{\cdot}134 \times \text{WH} + 0{\cdot}008 \times \text{LW}$ | 0·72 | 1·41 |
| Isscr | $Y = 7{\cdot}12 + 1{\cdot}19 \times \text{gender} - 1898/\text{age} + 0{\cdot}197 \times \text{WH} + 0{\cdot}092 \times \text{TcTc}$ | 0·70 | 1·46 |
| Isscr | $Y = 8{\cdot}40 + 1{\cdot}29 \times \text{gender} - 2300/\text{age} + 0{\cdot}228 \times \text{WH}$ | 0·69 | 1·49 |
| Issca | $Y = 7{\cdot}219 + 1{\cdot}66 \times \text{gender} -1134/\text{age} + 0{\cdot}07 \times \text{WH} + 0{\cdot}14 \times \text{TcTc} + 0{\cdot}004 \times \text{LW}$ | 0·66 | 1·25 |
| Issca | $Y = 5{\cdot}92 + 1{\cdot}46 \times \text{gender} - 1816/\text{age} + 0{\cdot}128 \times \text{WH}$ | 0·64 | 1·28 |
| Pusca | $Y = 10{\cdot}53 + 1{\cdot}3 \times \text{gender} - 894/\text{age} + 0{\cdot}079 \times \text{WH} + 0{\cdot}16 \times \text{TcTc} + 0{\cdot}004 \times \text{LW}$ | 0·59 | 1·30 |
| Pusca | $Y = 9{\cdot}22 + 1{\cdot}10 \times \text{gender} -1625/\text{age} + 0{\cdot}134 \times \text{WH}$ | 0·56 | 1·34 |
| Sac | $Y = 10{\cdot}58 - 1034/\text{age} + 0{\cdot}102 \times \text{WH} + 0{\cdot}071 \times \text{TcTc}$ | 0·46 | 1·15 |
| Sym | $Y = 7{\cdot}51 + 0{\cdot}070 \times \text{WH} + 0{\cdot}0038 \times \text{LW}$ | 0·40 | 0·82 |
| Sym | $Y = 3{\cdot}25 + 0{\cdot}125 \times \text{WH}$ | 0·35 | 0·86 |

PH or Puscra = pelvic height (pubis to sacrum cranialis); Isscr = ischium to sacrum cranialis; Issca = ischium to sacrum caudalis; Pusca = pubis to sacrum caudalis; Sac = length of the sacrum; Sym = length of the symphysis. Gender: male = 0; female = 1; WH = withers height; LW = live weight; TcTc = the external distance between the most lateral points of the tuber coxae; $R^2$ = adjusted *R* square; s.e.= standard error of the estimate (cm).

models shown, the assumptions of normal distribution and homoscedascity of the dependent variable were fulfilled. It is clear from these models that especially the external traits LW, TcTc and WH are good estimators of internal pelvic sizes, confirming the simple and adjusted correlations.

## Discussion

The purpose of this investigation was to draw up a guideline to develop a model that can help estimate inner pelvic sizes from external body measurements and to describe a method to collect the data needed for the development of such a model. Because correlations exist between external body traits (LW, TcTc and WH) and internal pelvic sizes, models can be developed as shown. Repeating the measurements on abattoir animals on a much larger scale can help create a model which is representative of the total DM-BBB breed. This model can then be used to estimate inner pelvic sizes from external body traits taken from numerous pedigree animals. These estimated inner pelvic sizes can be genetically evaluated and finally result in estimated breeding values to be used in selection. Using male data as well increases the total amount of available data, and therefore the reliability of a genetic evaluation.

When repeating the research to create a representative model for the DM-BBB breed, one should remember that it will be breed-specific. Breed is known to influence pelvic traits (Bellows *et al.*, 1971; Laster, 1974; Brown *et al.*, 1982 and Morrison *et al.*, 1986). Focusing on females between 24 months (first parity) and 48 months (third parity and mature) and males between 18 and 24 months (slaughtering age) the development of separate models for males and females should be considered. Gender significantly influences pelvic sizes (this study) and age influences variation of the pelvic size (this study; Glaze *et al.*, 1994). When measuring TcTc, a clear distinction must be made. TcTc can be measured not only on the ventro-lateral (Murray *et al.*, 1999; this investigation) but also on the dorso-medial point of the tuber coxae. Measuring before the carcass is halved may result in an additional important inner pelvic trait (pelvic width).

The fact that the results of Murray *et al.* (1999) have been confirmed by the results of this study, increases the possibility that the results of both studies are very likely to be representative of the breed.

Once a representative model confirming the best estimators of inner pelvic sizes, namely LW, WH and TcTc has been created, collecting weight and TcTc on a routine basis, as is already being done for WH (Hanset *et al.*, 1990; Gengler *et al.*, 1995; Leroy and Michaux, 1999), should be encouraged. Tuber coxae measurements should not be done on DM–BBB animals around calving time, because there are pelvic changes that can bias the results (Ménissier and Vissac, 1971; Murray *et al.*, 1999).

The method described to obtain a large quantity of data on pelvic traits indirectly is much more accessible than the direct method of pelvimetry as presented by Murray *et al.* (1999). The inspector needs no veterinary skills and there is a limited risk for the animals. What is more, internal pelvic height and pelvic width measurements have a lower repeatability (0·61 and 0·49, respectively) than external measurements (0·78 to 0·96; Ménissier and Vissac, 1971).

The negative-adjusted correlations of SW and BcW, both muscular conformation traits, with inner pelvic sizes, and the result of the general linear model, indicate that increased muscular conformation within the DM-BBB is related to decreased inner pelvic dimensions. However, it must be made clear that in DM-BBB, animals having the same SW (and therefore comparable muscular conformation), show a great variety of pelvic height.

Recent research by Hanset *et al*. (2001) shows that average weight in the DM–BBB breed keeps decreasing but conformation is still rising. This negatively influences PH and other inner pelvic traits, thereby increasing the degree of dystocia in the DM-BBB breed even more. To improve the rate of natural calving in the DM-BBB cattle, selection must be adapted. A possible adaptation would be the creation of a line of suckler breeding cows, with a strong emphasis on maternal calving ease, high weight, wide TcTc, acceptable muscular conformation and good height. From an economic point of view, it is worthwhile considering the creation of a line with a strong emphasis on beef characteristics (extreme muscular conformation) and direct calving ease (low weight and muscular conformation at birth) to breed with this breeding suckler line.

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