The measurement of chest girth as an alternative to weight determination in the performance recording of meat sheep

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ABSTRACT

The aim of this study was to assess, for two Italian meat sheep breeds (Appenninica and Merinizzata italiana), the relationship between an easily recorded measurement (girth of chest) and the character used for selection purposes (weight), and to define the most appropriate mathematical methods to infer the second from the first.

For the Appenninica 1392 lambs were measured, for the Merinizzata italiana 1559 lambs were measured. The possibility of estimating weight through chest girth (CG) measurement was evaluated, separately for each breed, by taking the most suitable model between those including different kinds of regression effect. The model was chosen in relation to the value of the determination coefficient and the sum of square residuals. The prediction accuracy of the model was assessed by comparing the expected values with the observed ones through a number of statistical tests.

A further prediction analysis was carried out using the mean values of the observed weights that fell in each 1 cm class of girth, in order to reduce the error derived by the varying numbers of observations per unit of chest girth.

The model including the square regression nested within the sex effect and the flock random effect nested within the sex effect was observed to be the most suitable one to predict the weight from the chest girth; the determination coefficients ranged between 0.944 (Appenninica) and 0.955 (Merinizzata). The prediction parameters were: -10.458 + 0.241 (CG) + 0.004 (CG²) for the Appenninica males; -6.121 + 0.093 (CG) + 0.005 (CG²) for the Appenninica females; -6.325 + 0.189 (CG) + 0.004 (CG²) for the Merinizzata males; -4.676 + 0.078 (CG) + 0.005 (CG²) for the Merinizzata females. The correlation between the observed and expected values was always higher than 0.97. The equations estimated using the mean weights for each girth showed extremely high determination coefficients (≈ 0.99) due to the reduction of variability implied by this method. Choosing between the equations calculated on the entire data set or on the mean weights will only be possible after a period of field tests.

Key words: Meat sheep, Performance recording, Chest girth, Weight.

RIASSUNTO

LA CIRCONFERENZA TORACICA COME MISURA ALTERNATIVA AL PESO NEI CONTROLLI FUNZIONALI DEGLI OVINI DA CARNE

I controlli funzionali previsti in Italia per la selezione degli ovini da carne si basano sul rilievo del peso ad età tipiche (nascita, 1 mese), tale attività trova però un serio ostacolo nell'elevato numero di pesi che gli addetti devono effettua-
Introduction

In Italy, the performance recording for meat sheep, should be carried out by weight measurements at typical ages: birth+15 days, 1 month±15 days (compulsory), at sale (optional for subject destined for slaughter).

There are, however, several obstacles for the correct implementation of the aforementioned selection protocols; only 10% of the controls are actually carried out due to a lack of suitable scales in all of the controlled farms, and for practical (availability of the farmer or the controller) or managerial (animals on pasture) impediments. Looking at this situation, it would therefore be beneficial to ask the farmer to perform the weight measurements, but their inclination for this kind of work is normally scarce.

These problems are not restricted to Italiansheep farming systems, but also many other countries where the environmental and managerial circumstances don’t allow easy weight control of lambs. From this point of view the problem has a general impact and the proposed hypothesis could be useful for any similar situation.

Estimation of weight through the measurement of other, easier to measure, morphological characters has been proposed in other species; amongst the tested biometric characters the girth of chest seems to be the most suitable. The determination coefficients reported by different authors for the regression models of the weights over this character are in fact equal to or higher than 0.9; the use of other characters has always been less successful (Sorensen and Foldager, 1991; Heinrichs et al., 1992; Pearson and Ouassat, 1996; Hile et al., 1997; Mohammed and Amin, 1997; Wilson et al., 1997; Panella et al., 1998; Alvarez et al., 1999; Gee et al., 2001). The use of this trait seems to be particularly suitable for large animals where the weight is hard to record by scale, but it is important to note how the use of a single measurement, easy and quick to carry out, represents
a huge advantage when in practical situations like that of meat sheep, where the number of subjects to measure is often quite high and the performance could be recorded by the farmer himself.

In some cases (Panella et al., 1998), in order to obtain a more accurate estimate of the weight, age has been considered together with the girth of chest. In the specific instance of meat lambs, such a variable seems to be trivial because the lambs are all measured in a very short age range (10 to 120 days). Moreover, age recording is quite inexact in normal farming practice.

In the international literature there aren’t many citations on the indirect weight recording by chest girth in sheep (Ravikala et al., 1995); therefore the results obtained here suggest that this method could be used in other breeds that are managed in the same environmental conditions to the studied ones.

The aim of this study was to assess, for two Italian meat sheep breeds (Appenninica and Merinizzata italiana), the relationship between an easily recorded measurement (chest girth) and the character used for selection purposes (weight), and to define the most appropriate mathematical methods to infer the second from the first. This is in order to allow the performance recording process to be carried out rapidly and efficiently, due to both the ease of detection of the correct place to take the measurement itself (immediately behind the shoulder blade) and the simplicity of the required tool (measuring tape). The extreme ease of execution would enable the farmers involved in the selection programmes to perform the recording themselves.

**Material and methods**

The sample was composed of 2951 lambs between 3.2 and 29.3 kg in the Appenninica and 3.2 and 35.0 kg in Merinizzata italiana. The flock, sex, weight (accurate to the 100 g) and the girth of chest (accurate to 0.5 cm) were recorded for each subject.

For the first breed 1392 lambs were measured (702 males and 690 females) from 17 flocks, for the second breed 1559 lambs were measured (687 males and 872 females) from 21 flocks.

The possibility of estimating the weight through chest girth measurement (CG) was evaluated separately for the two breeds by testing the following model:

\[
\text{Weight}_{ijkl} = \mu + F(S)_{ij} + b_{1}CG(S)_{ijkl} + e_{ijkl}
\]

where:
- \(\text{Weight}_{ijkl}\) = dependent variable;
- \(\mu\) = overall mean;
- \(F(S)\) = random effect of the flock within sex;
- \(b_{1}\) = linear regression coefficient of the weight on the chest girth (CG) nested within sex (S);
- \(e_{ijkl}\) = experimental error.

Besides that, two other models were tested, one concerned with linear and quadratic regressions and one concerned with linear, quadratic and cubic regressions.

Because all the regression coefficients estimated in the several models where significant (\(P \leq 0.01\)) the choice of the most suitable model was made in relation to the value of the determination coefficients (\(R^2\)), to the sum of square residuals (SSR) estimated as a difference between the observed and expected values and to the standard deviation of the residual (RSD).

Once the model was chosen, the observations with a residual value greater than 2 times the standard deviation (SD) of the residuals themselves were eliminated (Draper and Smith, 1981). The percentage of discarded values was about 3% in Appenninica and about 6% in Merinizzata italiana.

The prediction accuracy of the model was then assessed by comparing the expected values (E) with the observed ones (O) through a number of statistical tests: correlation between E and O, correlation between O and the residual values (R), average percentage of residual standard deviation on the observed weights.

Moreover, a further prediction analysis was carried out using the mean values of the observed weights that fell in each 1 cm class of girth in order to reduce the error derived by the different number of observations per unit of chest girth. In this case the independent variable was the girth of
chest expressed in 1 cm classes within sex (both linear and quadratic effect), while the dependent value was the mean weight (accurate to the nearest 100 g) of all the individuals that were included in each girth class. The Flock effect within sex was not considered in the girth class model.

The Appenninica data set consisted of 73 girth classes with their correspondent mean weights (36 in the males and 37 in the females); in the Merinizzata data set there were 99 records (52 in the males and 47 in the females).

All the statistical elaboration of the data was carried out using the software SAS (S.A.S., 2000).

**Results and discussion**

The main statistical parameters (table 1) indicate a mean weight of 16.0±4.6 kg for the Appenninica males, 15.8±4.7 kg for the Appenninica females, 19.2±6.8 kg for the Merinizzata males and 16.3±5.4 kg for the Merinizzata females.

The difference in sexual dimorphism observed between the two breeds must be considered absolutely casual; the sample was, in fact, chosen at random in the controlled flocks.

A similar comment could be made for the chest girth, which is very similar in the two sexes for the Appenninica breed (57.1 and 57.6 cm for the males and the females respectively) and quite different for the Merinizzata (58.8 and 57.1 cm).

There was higher variability in the weights as opposed to the chest girth with variability coefficients around 30% and 15%.

The adaptation indices of the data to the different models reported in table 2, show determination coefficients that are marginally higher

| Trait  | APPENNINICA | MERINIZZATA |
|--------|-------------|-------------|
| Weight | kg          |             |
| Male   | 16.0±4.8    | 19.2±6.8    |
| Female | 15.8±4.7    | 16.3±5.4    |
| Girth  | cm          |             |
| Male   | 57.4±6.9    | 59.8±9.3    |
| Female | 57.6±7.1    | 57.4±8.1    |

* M=male; F=female.

Table 1. The traits (X ± SD) in the sample.

| Model  | APPENNINICA | MERINIZZATA |
|--------|-------------|-------------|
| Linear | R²          | 0.942       | 0.952       |
|        | RSD         | 1.113       | 1.323       |
|        | SSR         | 1639.0      | 2579.8      |
| Quadratic | R²    | 0.944       | 0.955       |
|         | RSD        | 1.103       | 1.278       |
|         | SSR        | 1618.1      | 2406.4      |
| Cubic  | R²          | 0.945       | 0.956       |
|        | RSD        | 1.095       | 1.273       |
|        | SSR        | 1591.3      | 2389.1      |

Table 2. Determination coefficient (R²), residual standard deviation (RSD) and residual sum of square (SSR) of the models with different kinds of regression.
when moving from the linear to the square chest girth regression effect in the model, while the differences are negligible between the square and the cubic effects. A similar observation can be made looking at the RSD and at the SSR, in fact a reduction can be noted moving from the linear to the square regression model, while these parameters are virtually the same between the square and the cubic models.

Due to the above considerations, the quadratic model was considered the most suitable one to predict the weight from the chest girth.

The determination coefficients ranged between 0.944 (Appenninica) and 0.955 (Merinizzata) and were quite similar to that found by others in goat (Mohammed and Amid, 1997) and in Holstein heifers (Heinrichs et al., 1992) to predict weight from chest girth. The SSR value ranged from 1618.1 (Appenninica) to 2406.4 (Merinizzata) and the RSD from 1.103 and 1.278.

Also the statistics shown in table 3 lead us to hypothesise a good applicability of the squared equations. The correlations between the expected values and the residuals, used to assess a possible distortion of the prediction caused by the variation in the size of the lambs, were always low (< 0.25) and significant ($P \leq 0.01$). It is therefore possible to say that the prediction error in the studied interval is not affected by the size of the animal. Nevertheless the differences between the correlation coefficients were higher moving from linear to square model. The quality of the prediction is also confirmed by the percentage ratio of RSD over the observed values that is always lower than 10%.

The prediction curves (table 4) have always negative intercept values both in Appenninica (-10.58 and -6.121) and in Merinizzata italiana (-6.325 and -4.676), though some differences can be noted in the slope parameters. The linear coefficients (which are fairly homogeneous in the absolute values in the two breeds) are close to 0.2 in the males and to 0.1 in the females; these differences are significant at

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Table 3. Accuracy of weight prediction of the models with different kinds of regression.

| Model   | APPENNINICA | MERINIZZATA |
|---------|-------------|-------------|
| Linear  | Correlation O,R 0.245** | 0.219** |
|         | RSD/O*100 7.800±2.820 | 9.010±5.061 |
| Quadratic | Correlation O,R 0.237** | 0.212** |
|         | RSD/O*100 7.728±2.793 | 8.709±4.887 |
| Cubic   | Correlation O,R 0.234** | 0.209** |
|         | RSD/O*100 7.690±2.780 | 8.674±4.874 |

**: $P \leq 0.01$

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Table 4. Parameters (±SE) of the prediction curves of weight on chest girth.

|                      | M     | F     | M     | F     |
|----------------------|-------|-------|-------|-------|
| Intercept            | -10.458±1.912 | -6.121±1.532 | -6.325±1.504 | -4.676±1.025 |
| Coefficients:        |       |       |       |       |
| Linear               | 0.241±0.095 a | 0.093±0.085 b | 0.189±0.071 a | 0.078±0.076 b |
| Quadratic            | 0.004±0.0008 A | 0.005±0.0007 B | 0.004±0.0006 A | 0.005±0.0006 B |

The parameters with different lower or capital letters are different for $P \leq 0.05$ and $P \leq 0.01$ respectively.
the 5% level in both breeds. The square coefficients are the same for the Appenninica and for the Merinizzata, but are significantly different (P≤0.01) between the sexes (0.004 and 0.005 in the males and in the females respectively). Such differences can be explained by the different morphology and growth trends of the two sexes.

The general means computed on the mean weights for each girth class are reported in table 5 and the equations estimated in table 6. Some differences have to be noted between the two breeds; the intercept value was lower in the Appenninica (-9.66 vs -6.37) and the linear coefficients were lower in the Merinizzata (0.17 vs 0.24 and 0.16 vs 0.27 in males and females respectively). The difference between the slopes in the two sexes was significantly different for both the breeds (almost always at 0.0001 level). The determination coefficients were all extremely high (~ = 0.99), due to the reduction in the variability implied by this method.

### Conclusions

The estimated regression equations, both on the entire data set and on the mean weight values for each girth class, show a very good prediction. This fact is clearly highlighted by the value of the determination coefficients and by the other statistical parameters. The practical use of chest girth as a reliable, indirect way to estimate weight in selection work should be encouraged by these results. The ease of execution could enable the introduction of this measurement in to the performance recordings, and bridge the gaps still present in the field of meat sheep breeding.

The choice between the equation calculated on the entire data set or that on the mean weights in each class of girth will only be possible after a period of field tests. The use of easily obtainable measures, like the chest girth, which allows an accurate estimate of the weight to be made, could cre-

| Table 5. | The traits (X ± SD) estimated on the mean weights in the chest girth classes. |
|----------|--------------------------------------------------------------------------|
|          | APPENNINICA | MERINIZZATA | APPENNINICA | MERINIZZATA |
| Weight kg | 16.2±7.0     | 15.6±6.8     | 17.8±7.1     | 15.0±6.3     |
| Girth cm  | 57.3±8.9     | 56.9±8.1     | 57.6±10.3    | 53.5±9.1     |

M=male; F=female.

| Table 6. | Parameters (±SE) of prediction curves estimated on the mean weights in the chest girth classes. |
|----------|--------------------------------------------------------------------------|
|          | APPENNINICA | MERINIZZATA | APPENNINICA | MERINIZZATA |
| Intercept | -9.66±1.32   | -9.66±1.32   | -6.37±1.61   | -6.37±1.61   |
| Linear    | 0.24±0.05A   | 0.27±0.05B   | 0.17±0.06a   | 0.16±0.06b   |
| Quadratic | 0.0035±0.0004A | 0.0030±0.0004B | 0.0041±0.0005A | 0.0043±0.0006B |
| R^2       | 0.996        | 0.989        |

M=male; F=female. 
The parameters with different lower or capital letters are different for P≤0.05 and P≤0.01 respectively.
ate the basis for the assignment of performance recording to the farmers and allows a more efficient planning of the selection process that could be based on advanced statistical methods (such as BLUP-AM indices). This would in turn allow an adequate economical qualification of breeds that, being unique in their environment, could actively contribute to the conservation of their habitat.

The present results, besides their direct application to the studied breeds, can also properly show the way to solve the same problems in performance recording in other sheep meat breeds with similar environmental and managerial situations.

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