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Body condition evaluation in sows

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Abstract

In the porcine species the 'thin sow syndrome', the 'fat sow syndrome' and the 'second parity syndrome' have been related to problems with the regulation and dynamics of body condition. There is, therefore, a need to adequately monitor body condition. In a first study, a new body condition monitoring technique was developed. Several body measurements of sows were related, by multiple regression, to an indirect representation of body composition based on principal components derived from live weight and backfat measurements. In a second study, the reliability of this new technique was also determined and compared to that of a more traditional scoring system based on visual appraisal and palpation. Five observers independently evaluated thirty sows three times using the two techniques. Both techniques were found to be similarly repeatable. The new technique, however, was found to have higher reproducibility. It is concluded that body condition is better represented by the use of principal components and that they can be predicted from body morphology under field conditions.

Keywords: Sow; Body condition; Condition scoring; Reliability

1. Introduction

The knowledge of chemical body composition has become fundamental to the understanding of growth, nutrition and reproduction. The relationship between the reproductive function and body composition is well established in humans (Frish, 1988), as well as in the ovine (Gunn et al., 1984), bovine (Rasby et al., 1991) and porcine (King, 1987) species. At the individual and herd level, important variations in body composition may appear and have important consequences for production and health. The thin sow syndrome (MacLean, 1968) known for over 20 years, and more recently the fat sow and the accordion sow syndrome (Martineau, 1990), are situations which should be avoided and diagnosed at an early stage.

Furthermore, research on the relationship between energy and protein intake during the lactation period and the reproductive function, indicates that the knowledge of backfat thickness only is insufficient. It is also necessary to include weight to gain a better understanding of the phenomena involved (King,

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1987). Thus, there is an interest, from both a diagnostic and recommendation point of view, to be able either to evaluate directly a sow's body composition or to have a meaningful body condition index combining the information provided by both weight and backfat.

In the sow, body composition may be determined directly by dissection, but this is obviously inapplicable under field conditions. It can also be determined indirectly by techniques such as deuterium dilution or measurement of backfat and live weight (Knudson et al., 1985). Bio-electrical impedance (Swantek et al., 1992) has also been used in the growing pig. These indirect methods, even though relatively precise, are still difficult to implement in the farm on a large scale.

As an alternative, the evaluation of the animal's body condition using body scoring techniques has been advocated in the ovine, bovine (Evans, 1978; Edmonson et al., 1989), equine (Carrol and Huntington, 1988) and porcine species (Patience and Thacker, 1989). The context within which the above scoring techniques are used and their subjective character make them particularly susceptible to measurement error due to the observer. In the ovine and bovine species, reliability of condition scoring has been determined (Evans, 1978; Croxton and Stollard, 1976; Nicholson and Sayers, 1987). In swine, even though many studies have used condition scoring, systematic studies of reliability do not exist.

The objectives of the present project are thus: to derive a new method of representing body condition based on a principal component analysis of live weight and backfat, to study the relationship of a body scoring technique with the principal components, to develop a practical method aiming at predicting this new representation of body condition from body morphology and, finally, to assess the reliability of this new method and that of body scoring. Thus, two independent studies were undertaken. The first study was meant to design the new representation of body condition, to study its relationship to a body scoring technique and to develop regression equations allowing the prediction of this new representation from body morphology. The purpose of the second study was to assess the reliability of the new representation predicted from body morphology and that of the body scoring technique.

2. Material and methods

2.1. Study 1

Seven commercial sow herds, of Yorkshire-Landrace genotype, in the St. Hyacinthe area, were selected in order to obtain as large a spectrum as possible of body conditions. Within each of those herds, a number of non-lactating sows amounting to 25% of the total sow inventory were randomly selected for a total of 191 sows. For each of these sows, three sets of data were recorded. A first set describing the sow's production status: number of last parity (PARITY), last weaning to conception interval (WNTOCON), days in gestation (DAYGEST). A second set providing a morphological description. The tail setting (TAIL) was scored as (1) tail head prominent with deep cavity around tail setting; (2) tail head visible with slight cavity; (3) tail head smooth with no cavities around tail; (4) tissue folds on the sides of the tail; (5) tail buried in fat with tissue folds around the tail. The thighs (THIGHS) were scored as (1) severe muscle atrophy; (2) light muscle atrophy; (3) muscles distinguishable; (4) muscles invisible; (5) fat folds present; (6) fat folds abundant. The iliums (ILIUM), ischiums, spinous and transverse processes of the lumbar vertebrae, spinous process of the thoracic vertebrae (THORAX) and shoulder blades (SCAPULA) were scored by visual appraisal ((1) marked protrusion; (2) distinguishable; (3) invisible) and by palpation ((1) palpable; (2) difficult to palpate; (3) impossible to palpate). For analytical purposes, the visual and palpation scores were regrouped in a 1 to 5 scale by adding the two scores and subtracting 1 from the total since when one of those structures is declared as markedly protruding or distinguishable they are necessarily palpable. A third set of linear measurements, in centimeters, was taken for the tail root circumference (TAILCIRC), hearthgirth (GIRTH), pelvic height (HEIGHT) and width across the rear hams (WIDTH). Sows were scored (SCORE) for their body condition according to the technique described by Patience and Thacker (1989). The technique involves the combination of visual assessment of the sow's general appearance and the estimation of its body fat reserves by applying finger pressure over the top-rear of the pelvic girdle. The animal is scored on a scale of 1 to 5 with increments of 0.5. A high score means a fat sow. Backfat thickness was measured at the level of the last rib, 65 mm from the median (P2), with a Scanmatic SM-1 (N-DEX Instruments Ltée, Montréal) ultrasonic probe. Live weight (LW) was measured using a gestation crate mounted on Senstek 2000U load cells connected to a Senstek DF2000 Nema (Senstek, Saskatoon) indicator.

Principal components were calculated from the correlation matrix of live weight and backfat using the SAS PRINCOMP procedure (SAS Institute Inc., 1987). To predict principal components (INDEX1 and INDEX2) from morphological variables, equations were obtained by multiple regression using the 'backwards' variable selection procedure with $\alpha = 0.001$ as a removal threshold. The initial set of variables submitted to the regression analysis was composed of TAIL, ILIUM, ISCHIUM, LOIN, THORAX, HEIGHT, HEIGHT × HEIGHT, WIDTH, WIDTH × WIDTH, PARITY, PARITY × PARITY. Regression equations were fitted by least-squares through the use of the SAS REG procedure (SAS Institute Inc., 1987).

2.2. Study 2

The notion of reliability amounts to determining to what extent an instrument is measuring in a reproducible and repeatable fashion. In our particular case we will adopt definitions close to that of other authors (Evans, 1978; Nicholson and Sayers, 1987). Thus, repeatability is defined as the agreement between measurements made by the same means, on the same animal by the same observer within a short time period. Reproducibility is defined as the agreement between measurements made by the same means, on the same animal by different observers within a short period of time.

In order to determine repeatability and reproducibility, thirty pregnant sows were randomly selected within a herd different from the ones used in the first study. Each of these sows were evaluated independently by five observers, three times the same day, using two body condition evaluation techniques: SCORE and the technique developed herein to predict principal components from morphology. The observers had previous experience with either SCORE or other similar schemes. Prior to the trial they were provided with instructions and training for the techniques used. Results were analysed with the following random effect variance component model.

$$Y_{ijk} = \mu\ldots + O_i + A_j + OA_{ij} + R_{k(i)} + e_{ijk}$$

Y_{ijk}:	individual,
$\mu\ldots$:	average,
O_i:	observer effect ($i = 1$–5),
A_j:	animal effect ($j = 1$–30),
OA_{ij}:	animal * observer interaction,
$R_{k(i)}$:	replicate within observer ($k = 1$–3),
e_{ijk}:	error term.

Variance components were estimated by the SAS VARCOMP procedure. Initial calculation of the variance components using the TYPE1 sum of squares yielded some negative variance components estimates, making their interpretation tedious. The components were thus estimated using the maximum likelihood method. Following Evans (1978) and Nicholson and Sayers (1987), repeatability (r_1) was calculated as the proportion of total variance due to the animals, the observers and their interaction,

$$r_1 = [s^2A + s^2O + s^2OA]/s^2_{\text{total}}$$

whereas reproducibility (r_2) was the proportion due only to the animals

$$r_2 = s^2A/s^2_{\text{total}}$$

where $s^2_{\text{total}} = s^2A + s^2O + s^2OA + s^2R + s^2_{\text{error}}$.

These definitions yield ratios such that zero indicates poor performance and one indicates no measurement error.

The range of average measurements across repetitions for each observer was depicted using box and whisker plots.

3. Results

3.1. Study 1

Sows varied in parity, live weight, backfat, condition score, days in gestation, weaning to conception interval and in all morphological variables (Table 1). The parity distribution and the weaning to conception interval is similar to that of the P.A.T.P.Q.

Table 1
Means, standard deviations and/or mode, minimum and maximum value for measured variables ($n = 191$)

Variables	Mean	S.D.	Mode	Minimum	Maximum
PARITY	3.56	2.47	3	0	14
DAYS IN GESTATION	52.19	30.32	11	1	111
WEANING TO CONCEPTION (days)	12.03	19.81	5	2	143
SCORE	2.70	0.68	2.5	1	5
TAIL			3	1	5
THIGHS			3	1	6
ILIUM			3	1	5
ISCHIUM			3	1	5
LOIN			3	1	5
THORAX			4	1	5
SCAPULA			3	1	5
HIGHT (cm)	85.16	3.58	86.0	74.5	98.0
WIDTH (cm)	36.59	2.97	35.0	28.0	43.0
GIRTH (cm)	126.86	9.08	124.0	105.0	153.0
TAILCIRC (cm)	13.30	1.41	13.0	10.0	18.0
LW (kg)	193.09	33.40	165.8	113.2	279.6
P2 (mm)	16.57	5.49	16.0	5.0	28.0

(Richard, 1991), a provincial sow performance recording database. Backfat and live weight were found to be moderately correlated ($r = 0.46$). The results of the principal component analysis performed on backfat and live weight may be found in Table 2. The first component represents 73% of the observed variance. The second component represents 27% of the variance. SCORE correlates well with the first component ($r = 0.73$) but poorly with the second component ($r = 0.22$).

Eqs. (1) and (2) provide an indirect mean of predicting principal components (INDEX1 and INDEX2) without the inherent problems of measuring backfat and/or live weight. The variables DAYGEST, WNTOCON, SCAPULA and TAILCIRC were not selected due to low correlation with the indexes. GIRTH was not included because of the impracticality of measuring it in gestation crates. THIGHS was not included because it was found to be highly prone to unreliability in a pre-trial. There is no relationship between INDEX1 and PARITY but INDEX2 is inversely related to PARITY.

$$\text{INDEX1} = -15.116 + 0.350\,\text{TAIL} + 0.270\,\text{THORAX} + 0.190\,\text{WIDTH} + 0.070\,\text{HEIGHT}, \quad (1)$$

$R^2 = 0.78$,

$$\text{INDEX2} = -13.512 + 0.923\,\text{WIDTH} + 0.204\,\text{TAIL} - 0.220\,\text{PARITY} + 0.180\,\text{LOIN} - 0.014\,(\text{WIDTH} \times \text{WIDTH}) + 0.014\,(\text{PARITY} \times \text{PARITY}) - 0.0003\,(\text{HEIGHT} \times \text{HEIGHT}), \quad (2)$$

$R^2 = 0.58$.

Table 2
Latent vectors and latent roots (λ) of the live weight–backfat correlation matrix

Variable	First component	Second component
LW	0.707	−0.707
P2	0.707	0.707
λ (variance)	1.46	0.54
% variance	73.11	26.89

Table 3
Variance components, repeatability and reproducibility of INDEX1, INDEX2 and SCORE

	INDEX1	INDEX2	SCORE
Var (observer)	0.0000	0.0057	0.0507
Var (animal)	1.0427	0.1740	0.7604
Var (obser. * anim.)	0.0087	0.0051	0.0652
Var (repl. (obser.))	0.0072	0.0001	0.0030
Var (error)	0.0825	0.0247	0.1049
Repeatability	0.9277	0.8817	0.8934
Reproducibility	0.9137	0.8302	0.7726

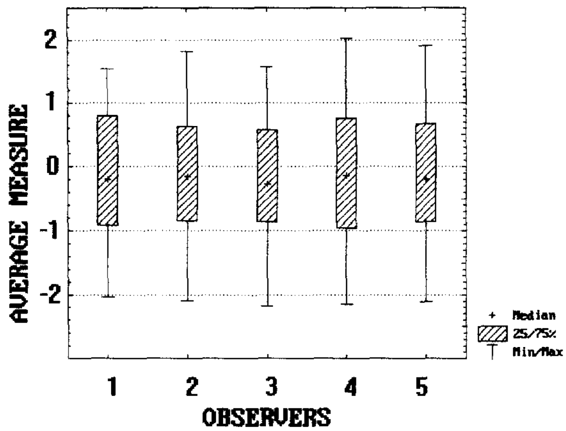

Fig. 1. Box and whisker plots of the average measurements of INDEX1 made by each observer across repetitions.

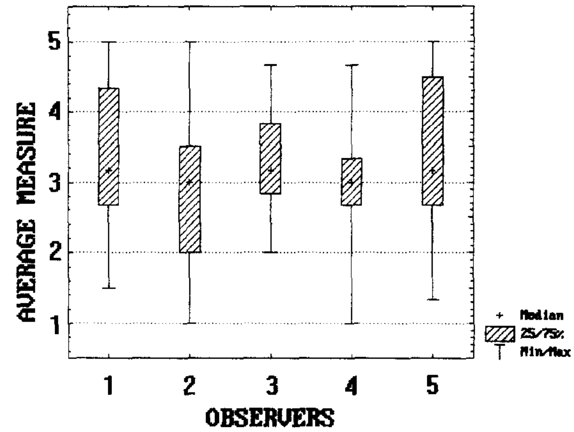

Fig. 3. Box and whisker plots of the average measurements of SCORE made by each observer across repetitions.

These equations represent the best possible compromise between the statistical requirements and the practical considerations of field work. The time necessary to gather the measurements was found to be about one minute per sow.

3.2. Study 2 (reliability)

The estimated variance components, repeatability and reproducibility for INDEX1, INDEX2 and SCORE can be found in Table 3. For all traits, most of the variance is due to the animals. For INDEX1 the variance due to the repetition is higher than that due to the observer. For INDEX2 and SCORE the variance due to the observer is higher than that of the replicate. Repeatability was found to be similar and good for all techniques, whereas reproducibility was found to be different. This last point is illustrated by the box and whisker plots of the average measurements of each observer (Figs. 1–3). These plots summarize the range of average measurements across repetitions as well as the distribution of those measurements. SCORE is least consistent between observers. Even though the average measurements are similar between observers, the distributions of the measurements are quite different between observers. For INDEX1 the measurements are very consistent while for INDEX2 they are slightly less. Still, the distributions of the measurements are homogeneous when compared to SCORE.

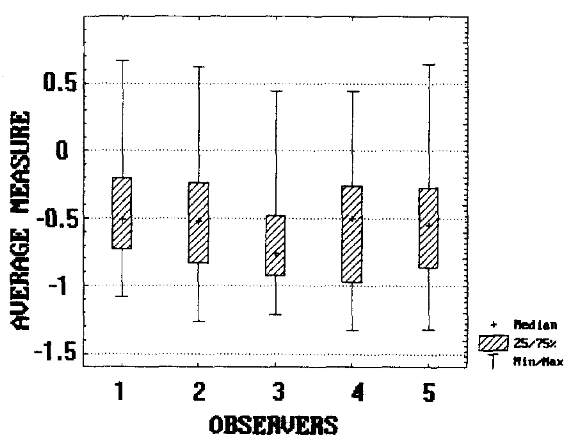

Fig. 2. Box and whisker plots of the average measurements of INDEX2 made by each observer across repetitions.

4. Discussion and conclusions

Since live weight and backfat are correlated, a change in backfat thickness is not only related to a change in body fat content but also in body weight. Consequently, to evaluate gain or loss of body condition by the sole measurement of backfat thickness can be highly misleading due to this correlation with body mass. This is well illustrated by the publication of King (1987) that points to the necessity of considering both backfat and weight. Hence the interest of using principal components, a statistical technique that linearly transforms a set of variables into a new uncorrelated set of synthetic variables to which specific interpretations can be applied while preserving the representation of the original data points relative to each other.

A value of 0 for both components represents the sow sample's center of gravity, and the values taken by the principal components indicate in which direction and to what extent an observation deviates from the center of gravity. A sow can be viewed as a volume of finite size. As volume (size) increases, weight increases, this volume being filled with protein, fat, water, ash in specific proportions governed in part by allometric relationships. Backfat, as is well known, is an indirect means of representing the amount of fat. Thus, an increase in backfat may be related to either a change in total weight or in the proportion of fat relative to weight. In the first case, this will be reflected by a move along the axis of the first principal component. In the second case, this will be reflected by a move along the axis of the second principal component. Hence, the first principal component is taken to represent a physiological axis associated with the sow's normal development and growth while the second principal component is taken to represent sows that deviate from the first axis, loosing or gaining backfat irrespective of development and growth, thus loosing or gaining body condition. Thus, going back to the results of the principal component analysis (Table 2), 73% of the variance in the live weight–backfat relationship is related to normal growth and 27% is deviation from this normal process.

The correlation between INDEX1, INDEX2 and SCORE is of particular interest because of the popular usage of SCORE as a body condition evaluation tool. The good correlation between INDEX1 and SCORE ($r = 0.73$) and the poor correlation between INDEX2 and SCORE ($r = 0.22$), suggest that SCORE is a measure of overall body mass viewed as a size variable rather than a body condition measure. Furthermore, the inverse relationship between INDEX2 and PARITY is consistent with the loss of body condition with increasing parity reported by many authors (Whittemore et al., 1980; Esbenshade et al., 1986; Young et al., 1990).

Body scoring techniques consist of text descriptions, diagrams and photographs that detail changes in conformation at several body locations. These techniques were designed to describe the overall conformation of the animal. Only afterwards, they were fully validated by relating them to some objective measurements, whether it was body composition (Wright and Russel, 1984), subcutaneous fat depth (Boisclair et al., 1986; Garnsworthy and Topps, 1982; Whittemore et al., 1980), or body nutrient reserves (Wright and Russel, 1984). In the porcine species, the relationship between body condition score and body composition is not very reliable (Knudson et al., 1985). Although in the bovine species, body condition has been related to reproductive performance and milk yield, these relationships are still open to debate in the porcine species (Dial et al., 1992). Body scoring, whatever the detail of the technique used, is the result of the combined evaluation of several anatomical reference points. The basic process is to generate items (in our case descriptions of anatomical reference points) that are thought to adequately cover the range, and to correlate these items to body condition. These items are to be comprehensible and unambiguous. The number of scale categories is selected to allow for adequate discriminatory power and also to allow good reliability. Psychological research has dwelled deeply into this last issue and suggests a minimum number of categories between five and seven (Streiner and Norman, 1989). Items are then selected such that they should be moderately correlated with each other and should correlate with the total score. These items are then summed to obtain a final score. The final step of the process is to determine if the score is measuring what it was meant for, that is, the scale's validity.

Such a development process has not been reported for body condition scoring indexes in the ovine, equine and porcine species, and only partially in the bovine species (Edmonson et al., 1989). They assumed that the main difficulty in interpreting the literature lies in the variability in the ways authors apply scoring methods due to inadequate detail. They also strived to develop a scoring chart that emphasises repeatability, reproducibility and internal consistency without considering validity. We suggest that the main difficulty in interpreting the literature lies not only in the scoring technique but also in the absence of a described relationship between the score and an objective measurement of body condition.

The process we have followed is partly inspired by the psychological body of research referred to above, but differs by the use of multiple regression for the final combination of variables instead of using a simple sum. The advantage of this process is that it combines the process of validity evaluation and of index design into a single step.

The prediction equations obtained combine three types of variables, semi-quantitative volume measurements, linear morphological measurements and an indirect measurement of age through parity. TAIL, LOIN and THORAX are semi-quantitative measurements of flesh thickness relative to bones. The differences in their regression coefficients in the prediction equations and the cranio–caudal pattern of decrease in their value probably reflect regional differences in rates of changes with body weight and body condition. Such a cranio–caudal pattern is also evident in the cluster analysis of Edmonson et al. (1989). They showed that location specific scores fell into two areas: the loin and spinous region and the pelvic and tail region. HEIGHT has classically been related to nutritive condition in cattle (Brody, 1945). Indeed, HEIGHT is not easily influenced by nutrition and is moderately correlated to body weight ($r = 0.51$). On the other hand WIDTH is well correlated to body weight ($r = 0.81$). Taken together, HEIGHT and WIDTH can be regarded as proportional to the length of the two axis of girth viewed as an ellipsoid, thus reflecting body weight. On the other hand, taken relative to one another, they reflect fleshiness, HEIGHT being less affected by nutritional stress and mainly representative of stature while WIDTH being highly susceptible.

The data used for the construction of Eqs. (1) and (2), and the future cases to be predicted are a sample from the population defined in this study. This population is considered to be a representative sample of sows of the common Yorkshire-Landrace genotype found in Québec. As with all regression equations their application to other populations must be done with care. An example of this may be found in the publication of Rozeboom et al. (1994). They concluded that the accuracy of body composition estimates of mature gilts, from live weight, backfat thickness and deuterium oxide diminished as age, physiological status, genotype and nutritional history diverge from the sampled population. This, however, does not preclude the use of principal components to describe body condition.

Associated to the concept of validity is the concept of reliability, paramount to any measuring device. The theory on which the reliability coefficients are used herein is based on the assumption that the variance of an observed measurement can be decomposed into the variances due to several sources, some of them sources of error. By identifying these sources, we can determine the relative importance of each component in adding variance to measurement (Streiner and Norman, 1989). It thus provides a critical examination of the sources of measurement error.

Repeatability of INDEX1, INDEX2 and SCORE compares well to that of ultrasonic backfat measurements. Webb (1975) obtained a value of 0.91 for the latter which he found similar to that estimated by Horst (1964) and higher than that of 0.83 found by Rittler et al. (1964). Sather et al. (1986) studied reproducibility of ultrasonic backfat measurements and found a significant operator effect, but they analysed their data by least-squares methods using the GLM procedure of SAS and results are given as least-squares means and standard errors rather than reliability coefficients.

The reliability coefficients obtained for SCORE are similar to those obtained for the ovine and bovine species. Evans (1978) found values of 0.81 and 0.70 for repeatability and reproducibility for cows and 0.88 and 0.81 for ewes. Nicholson and Sayers (1987) on the other hand, found values of 0.88 and 0.84 in cattle. For the porcine species, the 4% of the variance due to the observers found by Whittemore et al. (1980) compares well to the value of 5% that can be calculated for SCORE from Table 3. On the other hand, the lower values for the percent of variance for observers calculated from Table 3 for INDEX1 (0%) and INDEX2 (2.7%) indicate that the presently suggested approach provides more reproducible results.

The lower reproducibility coefficient for SCORE, a popular body condition scoring technique among producers and their consultants, implies important consequences. Even though all observers, on average, scored the group of sows similarly, the distributions of their scores are different (Fig. 3). For instance, observers 1 and 5 perceived a higher proportion of animals as fatter and observer 2 as leaner, whereas observers 3 and 4 did not perceive much differences between animals. Observers 3 and 4 would consider this group of sows to be well fed whereas observers 1 and 5 would consider some sows to be overfed and the opposite for observer 2. Their interpretation would thus lead to different feeding advice or condition diagnosis. On the other hand, the plots for INDEX1 and INDEX2 (Figs. 1 and 2) show similar evaluation distributions between observers. Using this last technique would lead to similar interpretations and conclusions. Thus, if an observer cannot reproduce consistently his own observations or if these observations cannot be reproduced consistently by other observers then such a measuring device may be deemed as unreliable and consequently less useful.

Possible strategies for improving the reliability coefficients are to take multiple observations by the same observer or single observations by multiple observers and averaging their results. Since the variance of the average of n observations is equal to the initial variance divided by n we can compare these two strategies by recalculating the repeatability and reproducibility coefficients. In the first scenario, this amounts to dividing the observer variance and the error variance by the number of observations. The other scenario divides replicate variance and error variance by the number of observations. In the situation where observer variance is small compared to that of the replicates, as for INDEX1, the appropriate strategy is to make several assessments by the same observer. In the situation such as for INDEX2 and SCORE the alternative strategy of using single observations from several observers would be more indicated. In practice this would not be necessary for INDEX1 and INDEX2. For SCORE, the use of two observers instead of one, would improve reproducibility to 0.87.

The nature of the two techniques may explain the observed differences in reliability. For SCORE, several items are considered in relation to each other and combined into a single scale. To predict INDEX1 and INDEX2 from body morphology, all items are scored independently from one another and they are then combined in equations where all items are weighted. This is more consistent with the patterning of fat accretion or loss in the different body areas. On the other hand, it could be argued that since there was no formal scheme to prevent the recognition of individual animals by the observers, repeatability may be biased. However, since each observer had to take nine measurements per animal and that an animal would be re-evaluated after twenty-nine other animals, we believe that, though theoretically possible, the probability of this bias occurring is remote.

In conclusion it is proposed that body condition is best described through the use of a principal component analysis of the live weight-backfat relationship. Principal components can be derived directly by measuring live weight and backfat or they can be predicted from body morphology. This last approach was formally developed by studying the relationship between a set of dependent variables describing body condition (principal components) and a set of predictor variables. This approach offers many advantages over traditional body scoring techniques. The combination of linear measurements with semi-quantitative scores improves the reliability of the measuring process. Time for their measurement is slightly longer than for SCORE but definitively simpler and faster than the measurement of both body weight and backfat thickness. Finally, in a morphological perspective using height, width and parity, all measures associated with the development and growth of animals make it a tool with biological meaning.

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