A functional approach to body condition assessment of lactating donkeys as a tool for breeding management (#10983)

First submission

Functional approach to the assessment of the body condition of lactating donkeys as a tool for breeding management

Emanuela Valle [Corresp., 1] , **Federica Raspa** [1] , **Marzia Giribaldi** [2] , **Raffaella Barbero** [3] , **Stefania Bergagna** [3] , **Sara Antoniazzi** [2] , **Amy Mc Lean** [4] , **Michela Minero** [5] , **Laura Cavallarin** [2]

1 Department of Veterinary Science, University of Turin, Grugliasco (TO), Italy
2 ISPA-CNR, Institute of Sciences of Food Production, Grugliasco, Italy
3 The Veterinary Medical Research Institute for Piemonte, Liguria and Valle d'Aosta, Torino, Italy
4 North Carolina State University, Animal Science, Ralaigh, USA
5 Department Veterinary Science and Public Health, University of Milano, Milano, Italy

Corresponding Author: Emanuela Valle
Email address: emanuela.valle@unito.it

Background. The assessment of the body condition of donkeys is a complex task that is influenced by several factors. The present study was aimed at defining the factors that have most effect on the body condition of lactating donkeys by evaluating parameters that can easily be measured in field conditions. The aim was also to implement a specific scoring system for the neck adiposity of donkeys, and to evaluate farmers' perception of the body condition of lactating donkeys.

Methods. Fifty-three healthy lactating donkeys of various breeds, including 7 Martina Franca, 10 Ragusano, 2 Romagnolo and 34 crossbreeds, were evaluated. The body weight, length, heart girth, abdominal (waist) circumference, neck length, neck height (NH), neck thickness (NT) and neck circumference (NC) were measured, and the body condition score (BCS) and the fatty neck score (FNS) were rated. The farmers' evaluation of the BCS was also reported. An oral cavity examination was also performed on all of the animals included in this study, and the month of lactation of each animal was recorded.

Results. A principal component analysis (PCA) of all the variables revealed that the first 2 components (PC), combined together, explained 71% of the variance among the lactating donkeys. PC1 revealed a meaningful positive correlation between the BCS and the neck measurements (NT, NH and FNS), while a negative correlation was found for dental abnormalities. The NH and NT had the strongest positive association with the FNS. The mean NC:NH ratio and the mean NC:NT ratio had the strongest negative association with the FNS. No correlation was found between the BCS and the other morphometric body measurements. The farmers' evaluation tended to be influenced by the abdominal circumference, and was different from the researchers' assessment. A significant inverse relationship was identified between the BCS and the presence of dental abnormalities.

Deleted: the
Deleted: of the body condition

Deleted: lactating

Comment [PJ1]: Two aims here: 1: defining the factors that have most effect … 2: Implement a specific scoring system for the neck adiposity of donkeys. Although all the subjects were lactating donkeys, it is not made clear and therefore difficult to see what connection any of this has with the fact that the donkeys were lactating. 'Breeding management' is mentioned in the title, and this is the place briefly to explain it.

Comment [PJ2]: As donkeys do not actually *have* waists, it is better not to use this word at all.

Deleted: have been

Comment [PJ3]: Presumably these were not just any farmers, but the owners of the donkeys. This should be made clear.

Comment [PJ4]: Needs a better description. Presumably 'PC' stands for principal component, but two are mentioned, so what were they ? Only PC1 is mentioned subsequently. In an abstract, anyway, it is not necessary to give actual statistical measures. A reader goes to the full description of the results for those.

Deleted: (rs = 0.83; P < 0.001)
Deleted: (rs = -0.83; P < 0.001, and rs = -0.82; P < 0.001, respectively)
Deleted: (waist)
Deleted: (rs = 0.41; P = 0.002)
Deleted: (Chi squared: P < 0.05)

Discussion. A new score system has here been proposed to judge the adiposity status of the necks of donkeys. FNS has resulted to be significantly and highly correlated to BCS. The oral condition of donkeys should also be considered as a farm-based indicator in the evaluation of the body condition of lactating donkeys.

The results obtained in the present study allow us to speculate that FNS may become a useful farm-based indicator that could be used together with the BCS to identify the body condition of lactating donkeys and possibly all donkeys. Furthermore, the findings of the present study suggest that breeders need additional training in order to be able to properly evaluate the body condition of donkeys, in order to avoid misjudging their overall welfare.

Deleted: preliminary

Deleted: it possible

INTRODUCTION

In the last few years, the breeding of donkeys for the production of milk has increased, as has the number of published research papers on donkey milk. This is due to the fact that donkey milk has been demonstrated to be a useful substitute food for children who are affected by an allergy to the milk protein of cows or who suffer from multiple food intolerances (Monti et al., 2007; Monti et 68 al., 2012). It has recently been demonstrated *in vivo* that dietary supplementation with donkey milk is associated with to a decrease in inflammatory status, and that this decrease is in turn associated with an improvement in the lipid and glucose metabolism, compared to a diet supplemented with bovine milk (Trinchese et al., 2015). Donkey milk also has a long tradition of cosmetic use. These potential uses of donkey milk have led to a positive trend in the European donkey population, with an increase in the number of animals bred in Italy (D'Alessandro e 74 Martemucci, 2012; Cavallarin et al., 2015).

Although several reports regarding the potential of donkey milk are available, information concerning the management and assessment of the body condition of lactating donkeys is lacking. Body condition is considered an indicator of overall animal welfare, and studies have shown its importance in dairy animal breeding (Mulligan et al., 2006). A body condition assessment involves a complex evaluation that includes a physical examination, as well as 80 morphometric and body composition measurements (Carter and Dugdale, 2013)

The most widely used physical examination method involves making an assessment using a body condition score (BCS). By means of a visual appraisal and palpation of the adipose tissue sites, it is possible to rate the body condition using a numerical scale (Carter and Dugdale, 2013). Different BCS scoring systems, based on 5- or 9-point scales, are available for donkeys (Pearson & Ouassat, 2000; Burden, 2012). Although the BCS system suffers from some limitations, mainly due to the subjectivity employed, other approaches to measure body composition, such as dilution techniques, or dual-energy X-ray absorptiometry (Quaresma, Payan-Carreira & Silva, 2013), also suffer from noteworthy

Deleted:

Deleted: *in vivo*

Comment [PJ5]: Of what ? Presumably of human consumers.

Deleted:

Deleted: tradition

Comment [PJ6]: I haven't consulted these sources, but seriously doubt that donkey populations elsewhere in the world are much affected.

Deleted:

Deleted:

Deleted: The

Deleted: the

Deleted: ~~i~~ncludes

Deleted: in its evaluation

limitations, since they are expensive and impractical to perform on farm. For this reason, alternative objective measures such as morphometric descriptors could theoretically reduce the bias of subjective scoring, as in the case of BCS, by comparing relative body condition with body size (Carter and Dugdale, 2013). The association between morphometric measurements and overall adiposity has been evaluated in different studies on ponies and horses (Carter et al., 2009; Dudgale et al., 2009, Fernandez et 94 al., 2009; Giles et al., 2014;) but knowledge is scanty where donkeys are concerned.

In the last few years, many studies have established that equids, like humans, store regional fat. In particular, they have a unique fat deposition site along the crest of the neck. This regional adiposity is classified in horses and ponies by means of a scoring system developed by Carter and colleagues in 2009. The first proposal for a neck score of the adiposity of donkeys, based on a 0-4 scale rather than the 5-point scale used for horses, was made by Mendoza et al (2015). The monitoring of this fat deposit can be useful to detect diseases, and to track changes 101 in the body condition following variations of diet regimes (Bruynsteen et al., 2015).

In addition, the body condition also depends on other non-morphometric parameters, such as age, physiological status and dental health status (Du Toit et al., 2008; Du Toit, Burden & Dixon, 2009). Moreover, since farm workers play an important role in maintaining the body condition, it is also important to assess their perception of the overall adiposity status of the animal (Hemsworth & Coleman, 2000).

The aims of the present study have been: 1) to set up a scoring system for neck adiposity, specifically designed for donkeys; 2) to evaluate which morphometric measurements for the assessment of adiposity may be readily performed on a farm to describe BCS; 3) to evaluate breeders' perception of the body condition – all in terms of the body condition of lactating donkeys.

MATERIALS AND METHODS

All the farms were visited during official surveillance activities, in collaboration with a Regional Veterinary Officer of the local government. This paper describes the results of a surveillance program put in place by health authorities of the region (Regional Surveillance Working Group, Protocollo 9641/DB2017, 23/03/12). All the procedures of the study that did not involve any invasive experimental work were part of the activities of the Regional Surveillance Working Group and were conducted in the presence of regional veterinary services. The group was working for the production of

Deleted: the
Deleted: more
Deleted: ,
Deleted: ,
Deleted:
Deleted: putting in relation the
Deleted: the
Deleted:
Deleted: for
Deleted: identified
Deleted: , which was
Deleted: ,
Deleted: on the
Deleted: the
Deleted: s
Deleted: his
Deleted: the
Deleted: ,
Deleted:
Deleted:
Deleted: ,
Deleted: ,

the regional guidelines for the donkey milk production (Regione Piemonte, BU29 18/07/2013 Codice DB2017 D.D. 17 giugno 2013, n. 461).

Population description

The monitoring was conducted during Spring, from May to June 2014. All the lactating donkeys on dairy farms in the North-West of Italy were screened. The animals were housed on 6 breeding farms authorized for the production and commercial sale of donkey milk, according to the welfare guidelines of the Italian government (Codice DB2017 D.D. 17 June, 2013, no. 461). All the donkeys included in the study were bred in semi-extensive/extensive farms, and had free access to drinking water and forage.

Morphometric measurements

The following body measurements were assessed for each animal, using a soft measuring tape (see Figure): i) body length, measured from the shoulder point (intermediate tubercle of the humerus) to that of the pin bone (ischiatic tuberosity); ii) body length, measured from the shoulder point intermediate tubercle of the humerus) to that of the hip (tuber coxae); iii) heart girth, measured as the circumference of the body, at the point caudal to the elbow (olecranon tuber), 2 cm behind the highest point of the withers; iv) abdominal circumference, measured at two-thirds of the distance from the shoulder point to that of the hip; v) neck length, measured from the poll to the highest point of the withers; vi) neck circumference (NC), measured at 0.25, 0.50 and 0.75 of the neck length; vii) neck height (NH), measured at 0.50 of the neck length, taken from the dorsal midline of the neck to the point of the estimated differentiation between the crest (tissue apparent above the *ligamentum nuchae*) and the neck musculature; and viii) neck thickness (NT), measured from one side of the neck to the other at 0.50 of the neck length, taken from the point of the estimated differentiation between the crest and the neck musculature (Fig. 1, Fig. 2).

The body weight (BW) was calculated using the formula proposed by Pearson and Ouassat 145 (2000):

$$BW\ (kg) = [girth\ (cm)^{2.12} \times length\ (cm)^{0.688}] / 3801$$

Four independent researchers, all of whom were experienced in assessing the nutritional status of animals, rated the body condition score (BCS) on a scale of 1 (poor) to 5 (obese), using a previously established scoring system (Burden, 2012). The median of the 4 scores, rounded to the nearest whole or half-score increment, was used for the analysis. The donkey owner/farmer was also asked to evaluate the BCS according to a 5-point scale, with the help of a chart in which the different scores were defined (Burden, 2012). The farmers rated the BCS after palpation and a visual assessment of the animals. A new system has been developed by the authors to judge the deposition of neck fat (the fatty neck score FNS),

Comment [PJ7]: A good illustration exists, but does not seem to have a number. It would also help at this stage to provide something of a descriptive table in which you introduce a code *for each* of the variables, so it is not necessary to keep searching through your text to see what the different codes (e.g. NC, NT), mean. Codes for two different body lengths and two different girths – i.e. for every variable – could also be usefully introduced.

Deleted: on

Deleted: waist (

Deleted:)

Comment [PJ8]: If these are the right numbers, then mention them at the top of the description. In fact, it would be useful to have the figures themselves right here.

Comment [PJ9]: You actually have TWO girth measurements: heart girth and abdominal circumference (*not* a waist) and also two body length measurements; you need to say how they relate to the measurements provided by Pearson & Ouassat.

Deleted: farmer

considering a 0-5 point scale, reported in Table. 1, based on one already developed for horses (Carter et al., 2009). The 4 researchers judged the FNS by means of a visual inspection and palpation of the fat deposition between the top line of the neck and the muscular line, as described in Table 1.

Oral cavity assessment

The mouth condition of the donkeys was examined to assess the presence of quidding and dental abnormalities, such as sharp points and hooks. The same group of expert evaluators assessed the oral conditions by evaluating the following on a scale of 0–2: i) the appearance of the incisors; ii) the condition of the cheek teeth (by opening the mouth and be means of cheek palpation); iii) any evidence of quidding and iv) inability to chew. A scale value was used with 0 to indicate "normal mouth conditions" (good incisors, no sharp points, no quidding), 1 to indicate "discrete mouth conditions" (the presence of sharp points, good chewing ability), and 2 to indicate "poor mouth conditions" (the presence of damaged incisors and or the presence of sharp points with quidding).

Statistical analyses

The statistical analyses were performed with the IBM SPSS Statistics 21 software (SPSS Inc., Chicago, USA). The median (interquartiles) and mean values (± standard deviation, SD) were calculated for the following parameters: age, month of lactation and body measurements. The following ratios were calculated: heart girth:length, heart girth:BW, abdominal circumference:length, abdominal circumference:BW, abdominal circumference:heart girth, 0.50 NC:neck length, 0.50 NC:NH, 0.50 NC:NT, mean NC:neck length, mean NC:NH and mean NC:NT. The mean NC was calculated as the average of 0.25 NC, 0.50 NC and 0.75 NC. The possible associations between the variables were quantified using Spearman's Rank Correlation Coefficient (r_s). A principal component analysis (PCA) (correlation matrix) was applied to reduce the variables to factors. Data assumption was checked, and the Keiser-Meyer-Olkin (KMO) and Barlett tests were performed to test the suitability of the data for structure detection. Only factors with Eigen values greater than 1 were considered. Only variables showing a significant correlation with BCS, according to r_s, were included in the PCA: these turned out to be age, month of lactation, mouth condition, 0.50 NH, 0.50 NT, FNS.

The inter-observer reliability of the researchers and farmers in their assessment of the BCS and FNS was evaluated by means of intra-class correlations and by means of Kendall's Coefficient of Concordance.

Comment [PJ10]: Why is this mentioned here ? Isn't it what the analysis of results was supposed to achieve ? Otherwise say: "A new system HAD been developed …" and then say who used it (farmers ? researchers ?) in this study.

Comment [PJ11]: Perhaps you should mention how difficult it is to look inside a donkey's mouth !

Deleted:

Deleted: of 0

Deleted: was used

Deleted: was adopted

Deleted: waist

Deleted: waist

Deleted: waist

Comment [PJ12]: How ? Perhaps you need to say what you mean by "data assumption".

Deleted: performed

Deleted: :

Deleted: (

Deleted:)

RESULTS

Population description

Fifty-three healthy lactating donkeys of various breeds, including 7 Martina Franca, 10 Ragusano, 2 Romagnolo and 34 crossbreeds, with a median age of 9 years (range: 7–12 years), an estimated mean body weight (BW) of 314.5 kg (range: 269–350) and a mean month of lactation of 4 ± 3 months, were evaluated.

Fatty neck score definition and association with neck adiposity

Neck adiposity was assessed according to the newly designed "fatty neck score" (FNS), whose evaluation parameters are detailed in Table 1. Among the considered morphometric parameters, the FNS was found to be positively correlated to the NH and NT ($P < 0.001$), and negatively correlated to the mean NC:NH and mean NC:NT ratios ($P < 0.001$). Other significant, although lower, correlations were also found between the FNS and the 0.50 NC:NH and 0.50 NC:NT ratios ($P < 0.001$; Table 2). Upon consideration of anecdotal evidence that the neck of a donkey tends to droop sideways to the crest of the neck, NT was introduced as a new measure for the estimation of the neck adiposity.

Association of BCS with morphometric measurements and mouth condition

The median BCS and FNS for the lactating donkeys were 2.5 (2–3) and 2.5 (1.5–3), respectively. No significant correlations between the morphometric measurements and the BCS were found (Table 3). However, our results highlighted a positive and significant correlation between the BCS and the FNS ($P < 0.001$; Table 3).

Kendall's Coefficient of Concordance between the researchers' and the farmers' scores for the BCS was low (0.28), thus indicating a substantial disagreement in their evaluations. A significant, but also rather low correlation was only found between the abdominal circumference and the farmers' estimations of BCS ($r_s = 0.41$, $P = 0.002$; Table 3).

The intra-class correlation coefficients pertaining to the reliability of the scores of the individual assessors were 0.85 for the BCS and 0.58 for the FNS.

A Chi-squared test ($P < 0.05$) indicated a significant relationship between the BCS and mouth condition. The donkeys that had a BCS score of 1 and 2 showed the highest proportion of score 2 when assessed on the basis of the oral cavity inspection (poor mouth conditions).

Deleted: monitored
Deleted:
Deleted: resulted
Deleted: NT was introduced as a new measure for the estimation of the neck adiposity
Deleted: s
Deleted: waist (
Deleted:)
Deleted: scores for the
Deleted:
Deleted: the
Deleted: .
Comment [PJ13]: Expressed confusingly. Is "score 2" a BCS ? In which case, is this saying that more subjects with BCS 2 were found to have poor mouth conditions ?

PCA of animal-based indicators of the body condition

A principal component analysis (PCA) was performed in order to represent the variability of the animal-based indicators (BCS, FNS, mouth condition, NT 0.50, NH 0.50, age and month of lactation) of the 53 lactating donkeys. The suitability of the data for the PCA was evaluated (KMO = 0.80; Barlett's test, $P < 0.001$). The results are reflected in Fig. 3. In order to improve visualisation of the results, different symbols were arbitrarily assigned: BCS < 2 (dots), BCS < 3 (triangles), BCS < 4 (squares) BCS >4 (crosses). The PCA separated the samples according to the BCS on the first principal component (PC1). Table 4 shows the loadings of the variables of the first and second principal components, and shows how each variable contributes to each component. The PC1 (54 % of variance) was positively correlated to FNS, BCS, and to NH, with high positive loadings. Conversely, the presence of dental abnormalities always showed high negative loadings on PC1, indicating that the animals with high BCS had high FNS as well as poor mouth condition.

DISCUSSION

The most common animal-based indicator used to assess the physical status of donkeys is the Body Condition Score (BCS). The BCS system includes appraisal, both visually and by means of palpation of the adipose tissue, which is then scored either on a 5-point or a 9-point scale (Pearson et Ouassat, 2000; Burden, 2012). Donkeys are predisposed to fat deposition in localized areas, such as in the neck, rib cage and rump. However, when employing the BCS to measure the overall adiposity of the animal, it is necessary to bear in mind that there is a certain level of subjectivity in the assignment of scores. Consequently, it is better to include several parameters along with the BCS, even for lactating donkeys. Morphometric measurements of the body have been proposed to evaluate the body condition of animals (Becvarova et al., 2009). In particular, morphometric measurements have been suggested for the analysis of the body condition of equids (Cappai et al., 2013; Martinson et al., 2014). Correlations between the BCS and morphometric measurements have already been demonstrated for horses (Carter et al., 2009; Dugdale et al., 2011). However, when analysing the morphometric parameters in the present study, no correlation was found between the morphometric parameters and the BCS for lactating donkeys, thus leading the authors to question the suitability of morphometry as an indicator of body adiposity in this species. In this regard, it is important to recall that the donkey is *not* a small horse, although they both belong to the family Equidae. Donkeys also differ from each other in many ways, particularly as far as

Deleted: analysis
Deleted: PCA
Deleted: given
Deleted: On the contrary, on PC1
Deleted: thus
Deleted: ,
Deleted: s
Deleted: body condition of
Deleted: ,
Deleted: ne
Deleted: in
Formatted: Font:Italic
Deleted: family

their anatomical variation and physical conformation are concerned (Burden and Thiemann, 2015). This variability is thus not only interspecific, it is also intraspecific. In addition to this, according to Kugler et al. (2008), on the basis of an overview of the current situation of the donkey population in Europe, most animals are crossbreeds that cannot be categorized into specific breeds. The donkeys in the present study were also mainly crossbreeds, unlike most other livestock species, in which pedigree-breeding and high genetic selections usually exist. Owing to the development of such a great diversity in the donkey population, several differences among them can be noted, especially with regard to body size (Fig. 4). Therefore, in contrast to what is possible for horses and ponies, morphometric measurements, although easily performed even in the absence of trained evaluators, cannot provide an objective alternative to the evaluation of the body condition of lactating donkeys.

Other factors that should be considered in the evaluation of the body condition of lactating donkeys are analysed in the present study. Regional fat adiposity could be an important indicator that has not yet been included in body condition evaluations, for example in welfare assessment protocols. To this end, a new scoring system, based on the assessment of the morphology of fat deposition and called fatty neck score (FNS), is here proposed. This new scoring system differs from the one that is currently used for horses (cresty neck score, CNS), since it is based predominantly on an evaluation of neck thickness (NT). In factthe adipose tissue of donkeys, unlike that of other equids, tends to droop on both sides of the crest of the neck (Burden, 2012). As distinct from previous studies conducted on horses, the FNS for these donkeys was not positively correlated to the 0.50 NC:NH, the mean NC:NH, the 0.50 NC:NT, or the mean NC:NT ratios (Table 2). Instead, the FNS was significantly and negatively correlated to those ratios. This result could be explained by the fact that the shape of the neck of the donkey is different from that of the horse. The shorter neck and the more protruding manubrium of the donkey support a heavy skull (Burden and Thiemann, 2015), and this leads to the development of a remarkably thick *cutaneus colli* muscle, which even covers the middle one-third of the jugular furrow (Burnham, 2002).As a result, in the present study it has been possible to develop an objective scale of reference for the FNS in a population of lactating donkeys, considering its strong association with NT (Table 1).

At the same time it should be noted that, in agreement with the studies on cresty neck score (CNS) for horses, the present results show that the donkey FNS is closely correlated to the BCS (Carter et al., 2009; Mendoza et al., 2015). However, we should to bear in mind that FNS refers to *regional* fat deposition (Carter et al., 2009; Burden, 2012; Giles et al., 2015). Equids in fact store fat in localized areas, especially

Deleted: fact
Deleted:
Deleted: breeds
Deleted: unlike for
Deleted:
Deleted: ,
Deleted:
Deleted: during
Deleted: have been
Deleted: in,
Deleted: ,
Deleted: aim
Deleted: ,
Deleted: has
Deleted: been
Deleted: predominantly
Deleted: the
Deleted: , unlike other equids,
Deleted:
Deleted: Unlike the
Deleted: Thus
Deleted: ,
Deleted: .
Formatted: Font:Italic

on the neck, and these regional deposits can remain even when the overall body weight decreases (Burden, 2012; Burden and Thiemann, 2015). However, this regional adiposity could play a different role in donkeys than it does in horses. It is well known that the CNS in horses can be linked not only to the nutritional status, but also to the metabolic status, but this aspect has not yet been characterized in donkeys.

The mechanism for the overall determination of the body condition is too complex to be explained only through correlation and univariate analysis. The distribution of data characterized by a high complexity of representation can be simplified by means of an analysis of the main functional components through PCA, which indicates the most useful components to define the body condition. In the present study, PCA was performed on animal-based indicators that can readily be assessed on a farm, and which have shown a significant correlation to BCS, which is commonly used in the assessment of the body condition. PC1 displayed high loadings for the FNS, BCS and NH. FNS was the main variable that contributed to PC1, suggesting that it is important for the description of the body condition. The preliminary results obtained in the present study make it possible to speculate that FNS could be a useful farm-based indicator in addition to the BCS in defining body condition. Nevertheless, further studies are needed to investigate whether there is a link between FNS and the hormonal status of donkeys and disease.

Furthermore, the findings of the present study suggest that the oral conditions and particularly dental disorders, should also be considered as a useful farm-based indicator in the evaluation of the body condition of lactating donkeys. According to Rodrigues et al. (2013), dental disorders, such as sharp points and hooks, are recognized as major, but often unnoticed, and therefore often untreated, disorders of equids. In addition, several studies have demonstrated that dental disorders in donkeys are associated with poor BCS and weight loss (Du Toit et al., 2008; Du Toit et al., 2009). This is supported by our results, indicating a significant inverse relationship between the BCS and oral conditions.

Interestingly, when the dairy donkey farmers were asked to evaluate the BCS for the present study, it was found that donkeys with a larger abdominal circumference received a higher BCS, a result that was clearly at odds with the evaluations of the researchers, who were trained in BCS scoring. The owners were probably misled by the innate anatomical conformation of the abdomen of the donkeys. In fact, donkeys are anatomically characterized by a pendulous abdomen (Pearson et al., 2001; Burden, 2012). Furthermore, this result suggests that, despite no correlation existing between the morphometric

Deleted: with respect to

Deleted: thus

Deleted: the definition of the

Deleted: ,

Deleted: ,

Deleted: ,

Deleted: ,

Deleted: , including horses and donkeys

Deleted: ally

Deleted: ,

Deleted: as confirmed

Deleted: thus

Deleted: the present study,

Deleted:

Deleted: waist (

Deleted:)

Deleted: in contrast

Comment [PJ14]: Which is why the term 'waist' is so inappropriate.

measurements and the BCS, producers usually rely on morphometric measurements to evaluate the BCS. This discrepancy also supports the idea that a different body condition score, such as FNS which is independent of the evaluation of abdominal size, could help to reduce the misjudgement of donkey condition.

Deleted:

Deleted: such as FNS,

Deleted: s

CONCLUSIONS

A new scoring system, called fatty neck score (FNS), is proposed to enable judgement of the adiposity status of donkey. FNS is shown to be significantly and highly correlated to BCS, and PCA reveals that FNS and BCS allow individual lactating donkeys to be separated according to their body condition. The preliminary results obtained in the present study make it possible to speculate that FNS could be a useful farm-based indicator that could be used together with the BCS to characterize body condition. Furthermore, the findings of the present study suggest that the oral condition of donkeys should also be considered as a farm-based indicator in the evaluation of the body condition of lactating donkeys. An additional conclusion to be drawn from the findings of the present study is that breeders may need additional training in the evaluation of the body condition, so that they may avoid misjudging the overall welfare of the donkeys.

Deleted: has been

Deleted: in the present study

Deleted: the neck of

Deleted: s

Deleted: has resulted

Deleted: has shown

Deleted:

Deleted: s

Deleted: identify the

Deleted:

Deleted: also indicate

Deleted: in order to

Deleted: ement

Deleted: of

REFERENCES

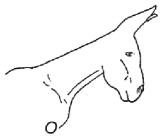
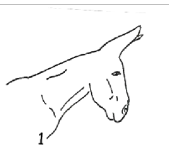
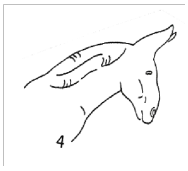
Comment [PJ15]: No attempt at editing here, as formatting too corrupted on conversion. From what I could see, the references were fully described and adequate in nature.

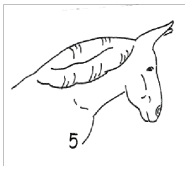
Table 1 (on next page)

Fatty neck scoring (FNS) system for donkeys. Donkey neck

images were drawn by FR

Comment [PJ16]: Give the whole name.

Illustrations of the Score individual fatty neck score		Description	Neck thickness range according to FNS (in cm)
0		Neck: thin with the absence of a visible and palpable crest.	< 14
1		Neck: thin with no visible crest, but a slight filling felt upon palpation.	> 14–19
2		Neck: with a moderate deposition of fat. Noticeable appearance of a crest, with fat deposited fairly evenly from the poll to the withers. Crest: easily cupped in one hand and easily bent from side to side.	> 19–22
3		Neck: enlarged and thickened. Crest: palpable from the poll to the withers, filling a cupped hand, and beginning to form longitudinal fat deposits on both sides of the neck.	> 22–27
4		Neck: very enlarged and thickened. Crest: grossly thickened with fat deposits from the poll to the withers, forming longitudinal bands of fat on both sides of the neck. Crest cannot be bent easily from side to side.	> 27–34

5		Neck: very enlarged and thickened. Crest: very thickened with hard fat deposits, rounded along the both sides of the neck.	> 34

1

Table 2

Association of the fatty neck score (FNS) with the morphometric measurements of neck adiposity

[a] Spearman rank correlation coefficient. [b] P value for a test of the null hypothesis that

the variables are independent.

[c] Neck circumference (NC) at 0.25 neck length (0.25 NC), 0.50 neck length (0.50 NC), at 0.75 neck length (0.75 NC). [d]

Average of 0.25 NC, 0.50 NC, 0.75 NC.

[e] Neck height (NH) [f]

Neck thickness (NT)

(on next page)

	FNS (no = 53) Morphometric measurements	
	r_{sa}	p_b
0.25 NC [c]	0.37	0.007
0.50 NC [e]	0.42	0.002
0.75 NC [c]	0.40	0.003
Mean NC [d]	0.44	0.001
0.50 NC:Neck length	0.35	0.011
Mean NC:Neck length	-0.01	0.925
0.50 NC:NH [e]	-0.58	<0.001
Mean NC:NH	-0.83	<0.001
NH 0.50	0.83	<0.001
0.50 NC:NT [f]	-0.68	<0.001

1

Mean NC:NT	-0.82	<0.001
NT 0.50	0.83	<0.001

2

Table 3

Association of the body condition score (BCS) with the morphometric measurements of body adiposity

[a] Spearman rank correlation coefficient. [b] P value for a test of the null hypothesis that the variables are independent. [c] Body weight. [d] Fatty neck score.

(on next page)

Morphometric measurements	Researchers'-BCS (no = 53)	
	r_{sa}	p_b
BW[c]	0.15	0.13
Heart Girth	0.15	0.27
Abdominal circumference (AC)	0.22	0.11
Girth:Length	-0.02	0.87
Girth:BW	0.13	0.15
AC:Length	0.11	0.25
AC:BW	0.13	0.17
AC:Girth	-0.13	0.17
FNS[d]	0.84	< 0.001

2

Deleted: Waist (
Deleted:)
Deleted: Waist
Deleted: Waist
Deleted: Waist

1

Table 4

PCA loadings of selected variables for the monitored lactating donkey population .

[a] Body condition score. [b] Fatty neck score.

(on next page)

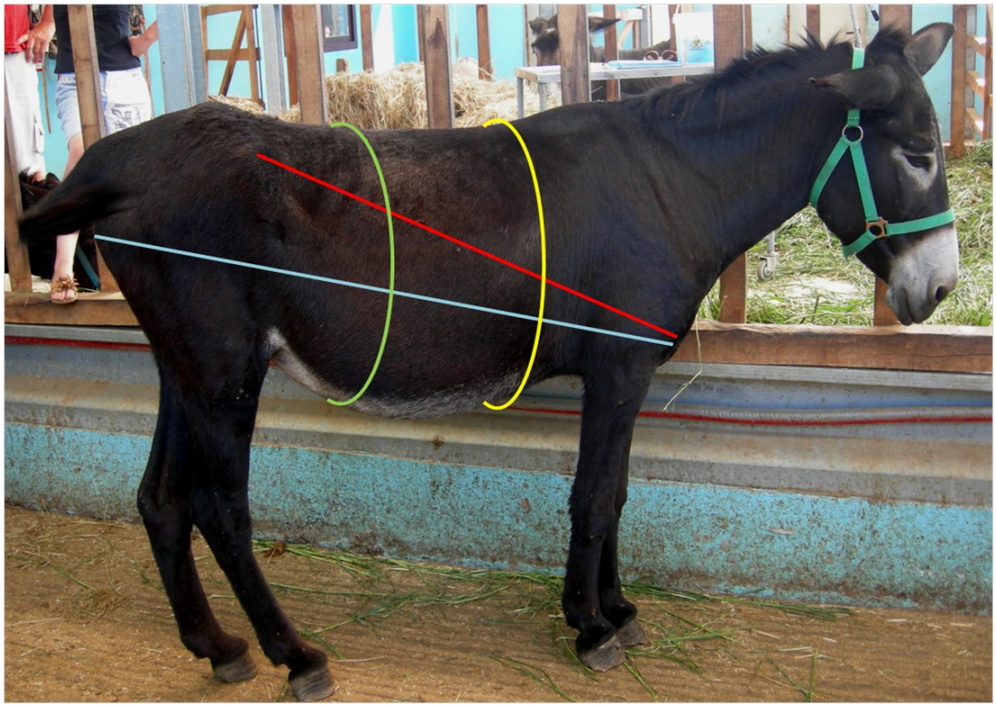
	Components	
	1 (53.69%)	2 (17.51%)
Age	-0.224	0.498
Month of lactation	-0.208	0.758
BCS[a]	0.896	-0.045
NT at 0.50	0.915	0.291
NH at 0.50	0.883	0.316
FNS[b]	0.944	0.042
Mouth condition	-0.594	0.463

2

Figure 1

Morphometric measurement of the body

Blue line: body length A, from the shoulder point to that of the pin bone; Red line: body length B, from the shoulder point to that of the hip; Yellow line: heart girth, circumference of the body at the point caudal to the elbow, 2 cm behind the highest point of the withers; Green line: abdominal circumference, at two-thirds of the distance from the shoulder point to that of the hip.



Morphometric measurement of the neck

Deleted: waist (

Deleted:)

Figure 2

Orange line: neck length, from the poll to the highest point of the withers; Pink, yellow and blue lines: neck circumference, at 0.25, 0.50 and 0.75 of the neck length; Red line: neck height (NH), at 0.50 of the neck length, taken from the dorsal midline of the neck to the point of the estimated differentiation between the crest and the neck musculature; Green line: neck thickness, from one side of the neck to the other at 0.50 of the neck length, taken from the point of the estimated differentiation between the crest and the neck musculature

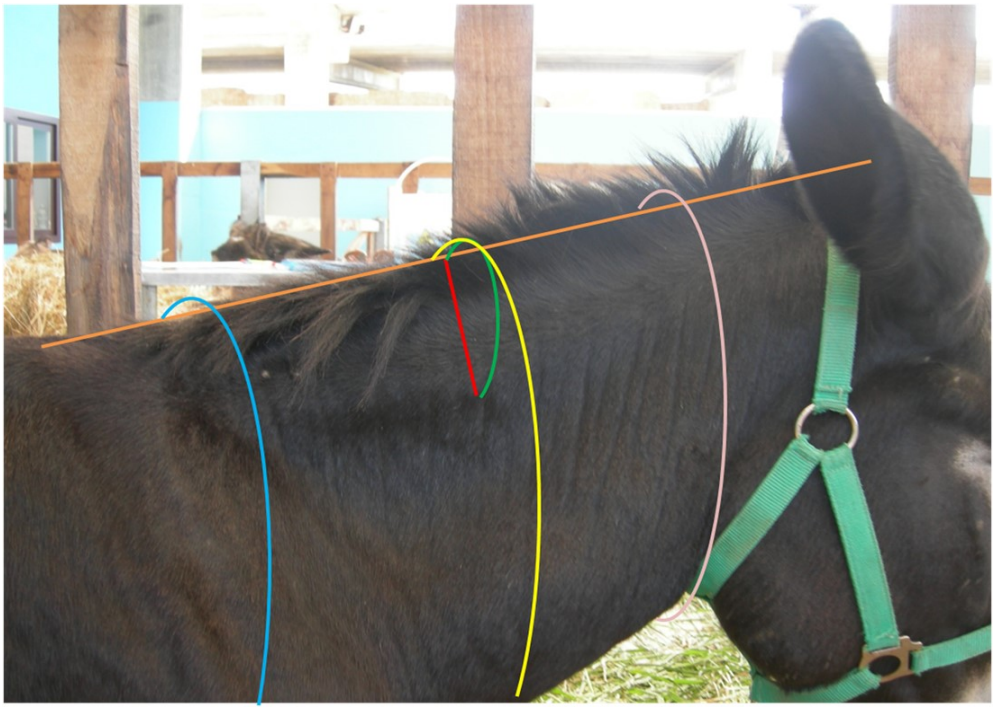
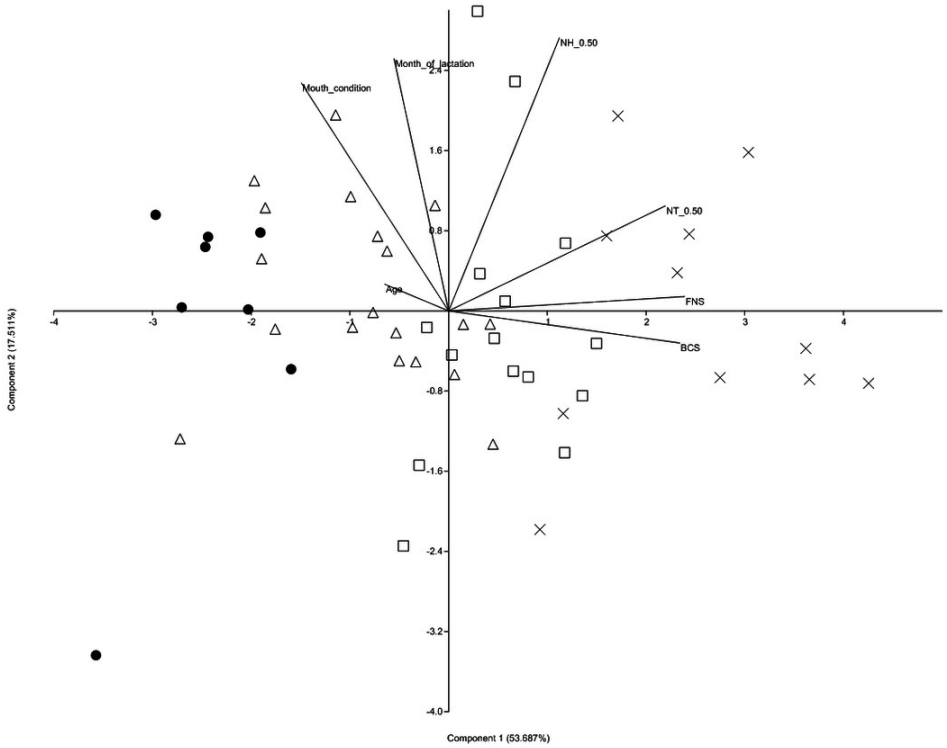


Figure 3

Principal component analysis performed on selectedanimal-based indicators of the body condition.

● body condition score (BCS) < 2; △BCS < 3; □ BCS < 4; x BCS >4. NT: neck thickness; FNS: fatty neck score; NH: neck height.



Diversity of the donkey population in Italian breeding farms

Figure 4