Estimation of the liveweight and body condition of working donkeys in Morocco

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The age, sex, liveweight and body measurements (heart girth, umbilical girth, height, length from elbow to tuber ischii and circumference of the foreleg cannon bone) of 516 donkeys used to transport goods in Morocco were recorded. There were few donkeys over 12 years of age. For adult donkeys weighing from 74 to 252 kg, the best equation with only one variable for predicting liveweight was: liveweight (kg) = heart girth (cm)$^{2.65}$/2188. The inclusion of two variables improved the prediction marginally, but the addition of further variables gave little further improvement. The best prediction equation for adult donkeys was: liveweight (kg) = (heart girth [cm]$^{2.12}$ x length [cm]$^{0.688}$)/380. For donkeys under three years of age, weighing from 52 to 128 kg, the best prediction equation was: liveweight (kg) = (umbilical girth [cm]$^{1.41}$ x length [cm]$^{1.09}$)/1000. Other liveweight prediction equations for donkeys and horses were tested on the data and tended to overestimate the weight of these working donkeys. A subjective method for assessing the body condition of the donkeys was developed, using a scale from 1 (emaciated) to 9 (obese).

A RELIABLE method for assessing the liveweight of donkeys would be useful for several reasons: to judge the correct dosages of drugs when treating them, to assess the adequacy of their diet and their well-being, to assess the effects of treatment or changes in diet, and to help in making sound recommendations for the loads to be carried by donkeys. Unfortunately, weighing machines are seldom available where donkeys are kept for work. The estimation of liveweight, making use of simple techniques such as body measurements, that could be used in markets or on farms, could provide an alternative to direct weighing.

For over a century, linear body measurements have been used in mathematical equations to estimate the liveweight of cattle (Brody 1945, Johansson and Hildeman 1954, Davis and others 1961). A linear relationship is normally used (Johnson 1940, Wanderstock and Salisbury 1946, Burt 1957). The allometric equation: liveweight = a x heart girth^b, where a and b are constants for a particular breed, corresponded best with the regression of liveweight on heart girth (Johansson and Hildeman 1954); the value of b approaches 3 because bodyweight varies approximately with the cube of the heart girth. The error involved in the estimation of liveweight from heart girth may be reduced if the heart girth is combined with other linear body measurements (Johnson 1940, Burt 1957).

In estimating the liveweight of horses, researchers have used length in addition to the heart or umbilical girth (Milner and Hewitt 1969, Carroll and Huntington 1988, Jones and others 1989). These measurements appear to give reasonably accurate predictions of liveweight for horses and ponies.

Neale (1990) and Eley and French (1993) each developed a prediction equation for donkeys, because they found that the methods used to estimate the liveweight of horses were inappropriate. Neale (1990) used heart girth and length as body measurements and Eley and French (1993) used girth and height. Neale measured 69 donkeys and Eley and French measured 217 adult and 26 young donkeys kept at a donkey sanctuary in Britain. An equation derived from measurements of these largely sedentary donkeys in Britain may not be appropriate for use with the working donkeys found in the semi-arid and mountainous areas of the world. The purpose of the present study was to obtain sufficient data on the liveweight and body measurements of working donkeys to derive an equation for estimating their liveweight and to compare the actual and estimated liveweights with those predicted from other equations used for horses and donkeys.

A large number of donkeys was examined over a relatively short time and, the opportunity was therefore taken to develop and test a method of body condition scoring for donkeys and to examine the age structure of the working donkey population. Carroll and Huntington (1988) found that body condition score and height gave almost as accurate an estimate of the liveweight of thoroughbred horses as girth and length measurements. However, in the present study it was decided to restrict the analyses to the objective measurements and not to use the subjective measurement of body condition in the predictive equations.

Materials and methods

Four hundred donkeys in the souks around Rabat and Settat were measured in May 1993, and 116 donkeys from Khemisset and Tifelt were measured in June 1993. These donkeys were used by local farmers to bring their goods to the weekly markets. They were weighed on a portable electronic weight scale (Ruddweigh).

The following body measurements were taken: the heart girth (the circumference measured from the caudal edge of the withers around the girth behind the elbow), the umbilical girth (the body circumference around the umbilicus), the height (measured with a measuring stick at the highest point of the withers with each donkey standing squarely on level ground with its head in a normal position), the length from the olecranon process of the elbow to the tuber ischii (taken with a measuring stick) and the circumference of the foreleg cannon bone measured around its narrowest part. The age (from an assessment of the incisors), sex and body condition of the donkeys were also recorded. Jones and others (1989) reported that the measurement of body length from the tuber ischii to the elbow was easier and more repeatable than the measurement from the tuber ischii to the point of the shoulder. The former measurement of length was therefore used. Carroll and Huntington (1988) measured heart girth after a respiratory expiration. Neale (1990) reported little difference between the measurements of girth taken during peak inspiration and expiration. As a result of these observations, and of the practicalities of measurements in the field, the time during the respiratory cycle at which the measurements of girth were taken was not standardised. A measuring stick, with a right angle bend approximately 20 cm from one end, greatly facilitated the measurement of length. The short piece at right angles to the main stick was placed against the point of the buttock (the tuber ischii) and the stick (graduated in length) was laid alongside the animal to the elbow, where its length was then read. In preliminary tests, measurements on each side of the animal showed little variation between the two sides. The liveweight was recorded to the nearest kilogram, the length, girth and height to the nearest centimetre and the circumference of the cannon to the nearest 50 mm.

The animals were marked with an indelible pen when they had been measured to prevent them being recorded a second time. A standard weight was used to check the weigh-scale each time it was set up and at regular intervals throughout each series of weighings. Fifty donkeys were weighed twice, having stepped on and off the scale, to check the repeatability of the measurement; it

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TABLE 1: Guide to the body condition scoring of donkeys

Score	Description
1 Very thin (emaciated)	Animal markedly emaciated; condemned; bone structure easily seen over body; little muscle present; animal weak; lethargic
Thin	Animal emaciated; individual spinous processes, ribs, tuber coxae, tuber ischii and scapular spine all prominent, sharply defined; some muscle development; neck thin; prominent withers; shoulders sharply angular
3 Less thin	Vertebral column prominent and individual spinous processes can be felt (palpated); little fat, but superspinous musculature over spinous processes apparent. Ribs, tuber ischii and tuber coxae prominent; loin area and rump concave; little muscle or fat covering over withers and shoulders
Less than moderate	Vertebral column visible; tuber ischii palpable but not visible, tuber coxae rounded but visible; rump flat rather than concave; ribs palpable but not obvious; withers, shoulders, neck with some muscle and fat cover; scapulare less clearly defined
5 Moderate	Superspinous muscles developed and readily apparent; can palpate vertebral column; tuber coxae rounded; rump rounded, convex; tuber ischii not visible; some fat palpable in pectoral region and at base of neck; can palpate ribs, but not visible
6 More than moderate	Cannot palpate spinous processes easily; back becoming flat, well covered; rump convex and well muscled; some fat palpable on neck, base of neck and pectoral region; neck filled into shoulder, tuber coxae just visible
7 Less fat	Back flat, cannot palpate spinous processes; tuber coxae just visible; fat on neck and pectoral region beginning to expand over ribs; flank filling; neck thickening
8 Fat	Animal appears well covered with body rounded with fat and bones not discernible; flanks filled; broad back
9 Very fat (obese)	Bones buried in fat; back broad or flat, in some cases crease down back; large accumulations of fat on neck, over pectoral area and ribs; flank filled with fat

1 to 3 frame obvious; 4 to 6 frame and covering balanced, 7 to 9 frame not as obvious as covering
Individual donkeys can deposit their body fat in different areas of the body, so the individual neck, shoulders, ribs, rump and flank condition should be assessed and combined to give an overall condition score

was found to be virtually 100 per cent, because only two donkeys gave values differing by up to 2 kg. The donkeys were selected for weighing in the markets on a completely random basis. Little difficulty was experienced in getting the donkeys to stand on the weigh-platform.

Body condition

A subjective assessment of the body condition of the donkeys was developed, using a scale from 1 (emaciated) to 9 (obese) (Table 1). The scale took into account the deposition of body fat in different areas by a separate examination of the neck, shoulders, back, ribs, pelvis and rump. Two people condition scored 144 of the donkeys independently, and the repeatability of the scores was computed.

Analysis of data

Johansson and Hildeman (1954) in reviewing the data for cattle reported that the relationship between weight and body measurements was linear when the animals were mature. It was only when growing animals, whose body proportions are changing, were included, that a curvilinear function was appropriate. Linear regression techniques were therefore used to derive 'best' equations for predicting liveweight from the other variables measured. Plots of weight against individual measurements suggested that there was an increase in the variance of weight with increasing values of any of the measurements. The measured values were therefore transformed to logarithms to the base 10 ($\log_{10}$) for use in the regression analyses. Significant improvements in fit, as judged by the adjusted R^2 measure of correlation, were obtained in all cases

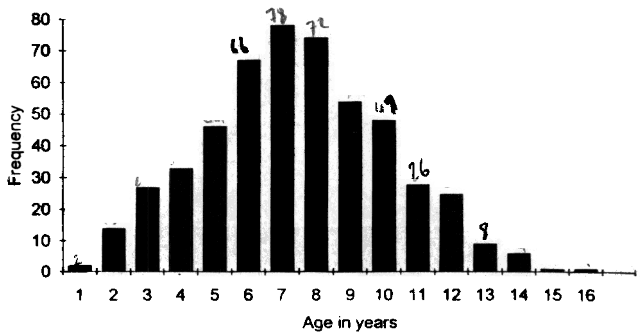

FIG 1: Histogram of the age distribution of 516 donkeys in markets in eight different locations in Morocco

by using $\log_{10}$ values in place of the original values. Accordingly, only results for $\log_{10}$ values have been reported. Separate prediction equations were produced for immature animals less than three years old, and for adult animals. A nomogram was constructed according to the procedure described by Smith (1966) to assist in practical use of the prediction equation for adult animals.

The equation derived by Eley and French (1993) for predicting the liveweight of adult British donkeys: liveweight (kg) = (heart girth $[cm]^{2.576}$) x (height $[cm]^{0.24}$)/3968, and that derived for horses by Jones and others (1989): liveweight (kg) = (umbilical girth $[cm]^{1.78}$) x (length of body from tuber ischii to elbow $[cm]^{0.97}$)/3011 were tested on the data, and the results were compared with the results predicted by the equation developed in this study. Plots of the estimated and actual liveweights, and histograms of the residuals, defined as the differences between the actual weights and the predicted weights were made.

Results

Characteristics of the donkeys sampled

The sample of adult donkeys contained a good cross-section of the types of donkeys found in Morocco, with a range of liveweights from 74 to 252 kg, height from 82 to 129 cm and length from 64 to 106 cm.

A histogram of the distribution of the ages of the donkeys measured is given in Fig 1. Donkeys over 12 years of age were rarely seen in the markets, suggesting that the life expectancy of working donkeys in Morocco is unlikely to be much over this age.

Practical considerations in the measurement of body parameters

The heart girth, circumference of the cannon bone and height were the easiest measurements to take. Umbilical girth was the most difficult. It tended to be taken at the widest part of the animal rather than over the umbilicus and was most difficult in pregnant or large animals and easiest in young animals.

Estimation of liveweight of mature animals

For the 500 adult donkeys weighing from 74 to 252 kg, the prediction equations were derived by pooling all the data regardless of sex, age, type, body condition and, in the case of females, pregnancy.

All the variables, with the exception of body condition, age and sex were found to have significant effects in an equation with only one predictive variable. The 'best' single predictor variable was the heart girth (adjusted $R^2 = 0.81$):

$$\text{Liveweight (kg)} = \text{heart girth (cm)}^{2.65}/2188$$

followed by umbilical girth (adjusted $R^2 = 0.59$) and length (adjusted $R^2 = 0.58$).

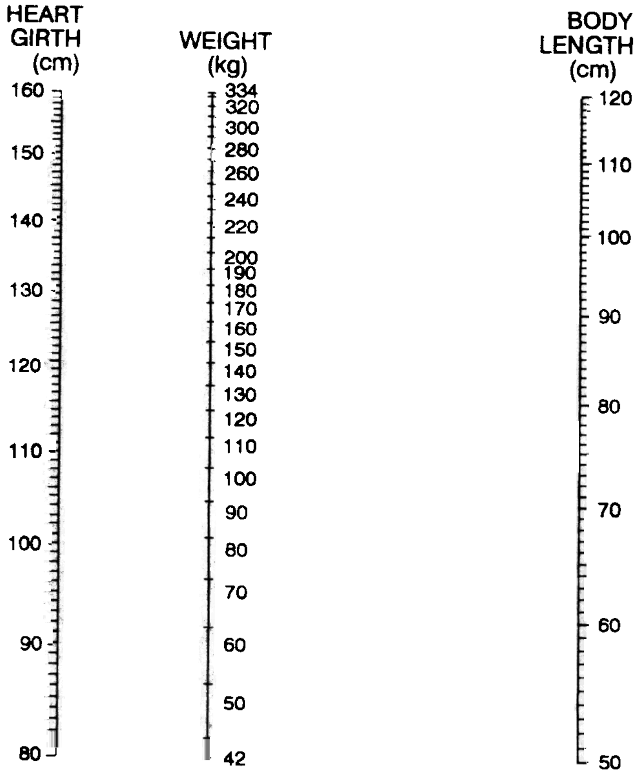

FIG 2: A nomogram for estimating the liveweight of adult donkeys from measurements of heart girth and body length from the tuber ischii to the elbow

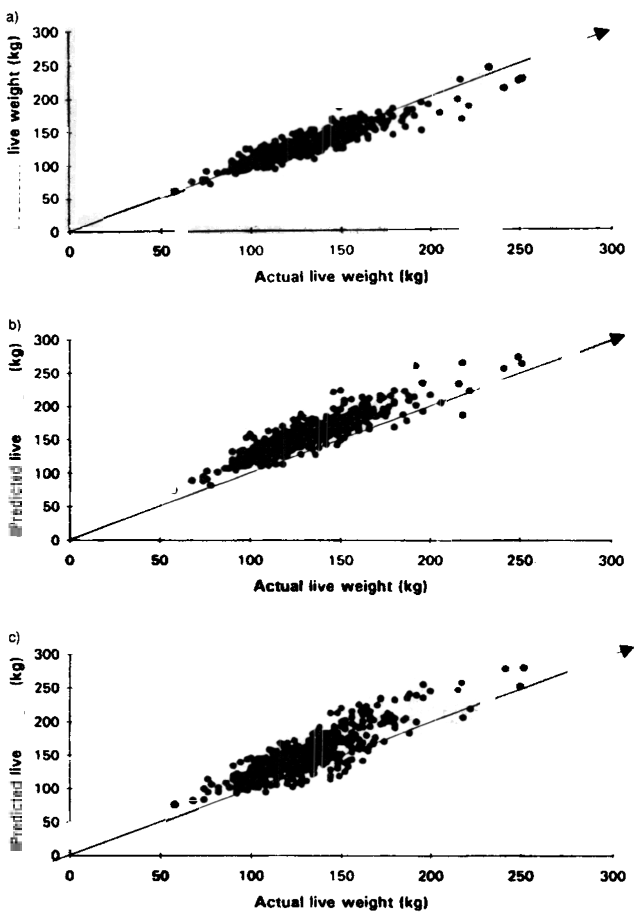

FIG 3: Predicted liveweights against actual liveweights of adult donkeys derived from the present equation (a), the equation of Eley and French (1993) for donkeys (b), and the equation of Jones and others (1989) for horses (c)

When two variables were included, heart girth and length together were better predictors than either umbilical girth with length, or girth with height. The best overall predictive equation using two variables for the adult donkeys was:

$$\text{Liveweight (kg)} = (\text{heart girth [cm]}^{2{\cdot}12}) \times (\text{length [cm]}^{0{\cdot}688})/3801; \quad \text{adjusted } R^2 = 0{\cdot}84.$$

This prediction equation was not improved by the inclusion of the additional variable height. About 95 per cent of the residuals lay within ±20 kg, with 73 per cent within ± 10 kg, with an average percentage error in the fitted values of 6·4 per cent.

A nomogram for estimating the liveweight of adult donkeys from the measurements of heart girth and body length was constructed to assist in the practical use of the equation (Fig 2). The inclusion of two variables in the equation marginally improved the accuracy of the prediction, but the addition of further variables gave little extra improvement.

Estimation of liveweight of young animals

The 16 donkeys under three years of age ranged in weight from 52 to 128 kg, and the best variable in a predictor equation with only one variable was umbilical girth:

$$\text{Liveweight (kg)} = \text{umbilical girth (cm)}^{2{\cdot}13}/302; \quad \text{adjusted } R^2 = 0{\cdot}77.$$

When two variables were used, umbilical girth and body length gave a better estimate of liveweight than heart girth and length. The best predictive equation for young animals was:

$$\text{Liveweight (kg)} = (\text{umbilical girth [cm]}^{1{\cdot}40}) \times (\text{length [cm]}^{1{\cdot}09})/1000; \quad \text{adjusted } R^2 = 0{\cdot}87.$$

Again, the animals' height did not improve any of the prediction equations significantly and it was therefore not included. About 95 per cent of the residuals lay between ± 11 kg, with an average percentage error in fitted values of 6·6 per cent.

Comparison with other predictive equations

The equation for predicting the liveweight of adult donkeys derived by Eley and French (1993) from British donkeys and an equation derived for horses by Jones and others (1989) were tested on the data, and compared with the 'best' prediction equation developed in this study (Figs 3 and 4). Both the other equations overestimated the liveweight of the Moroccan donkeys. The 'horse' equation fitted the data least well of the prediction methods tested, as shown by the wider spread of the residuals (Fig 4).

The equation of Eley and French (1993) for donkeys under two years old also had a tendency to overestimate the liveweight of the young animals in this study (Fig 5).

Body condition score

The condition scoring system was based on a visual appraisal and palpation of the neck, shoulders, back, ribs, pelvis and rump of each animal. Palpation was necessary, particularly in those animals that had a long hair coat, which made the visual appraisal more difficult. There was good agreement between the condition scores assigned by the two people to the 144 donkeys; the scores were the same in 74 per cent of the donkeys, and the maximum difference between the two scorers for any donkey was 1 point. The scoring system was independent of the size or conformation of the donkeys.

The distribution of the body condition scores in the sample of donkeys assessed is given in Fig 6. Most of the donkeys were of moderate to poor condition, 3 to 5 as assessed on the scale from 1 (emaciated) to 9 (obese). Within this range, no correlation was observed between the body condition scores and the differences calculated between the actual liveweight and the liveweight predicted from the equations for adult donkeys.

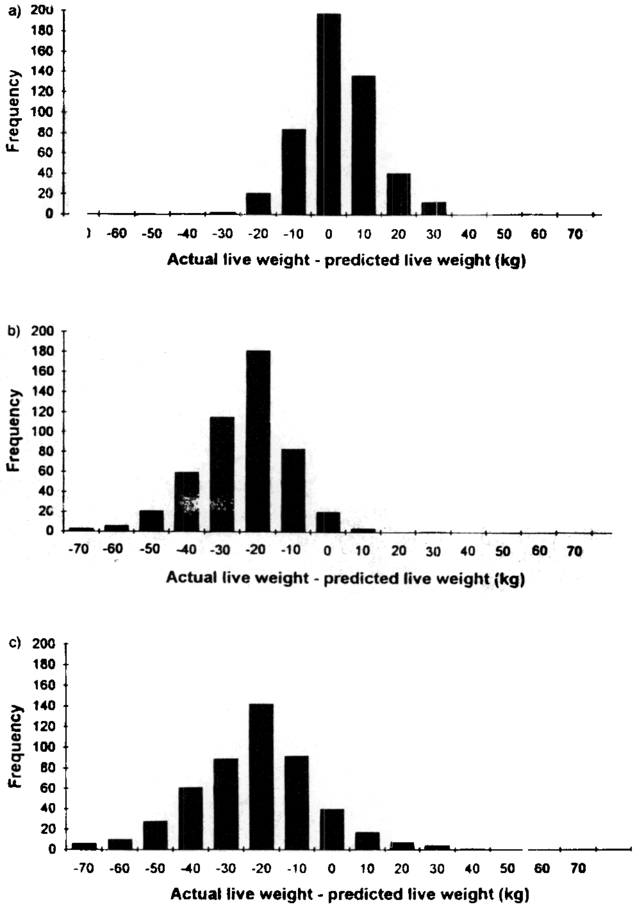

FIG 4: Histograms of residuals for three methods of estimating the liveweight of adult donkeys: the present equation (a), the equation of Eley and French (1993) for adult donkeys (b), and the equation of Jones and others (1989) for horses (c)

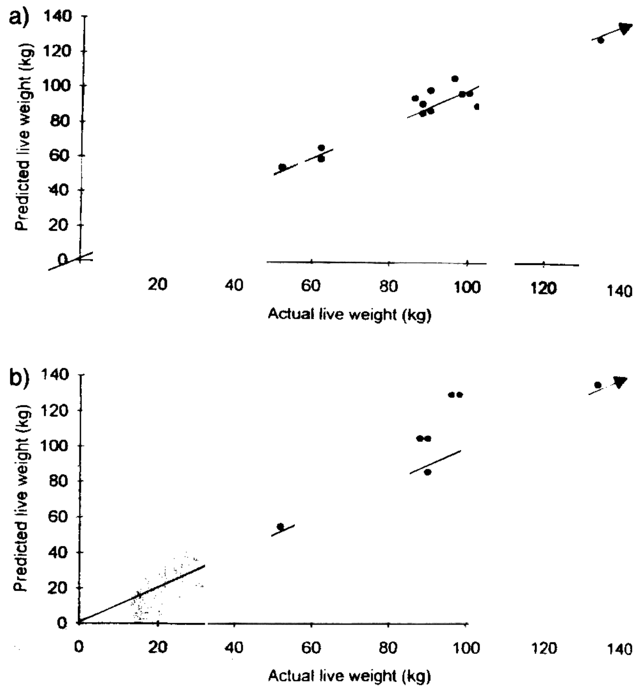

FIG 5: Predicted liveweights against actual liveweights of young donkeys derived from the present equation (a) and the equation of Eley and French (1993) for young donkeys (b)

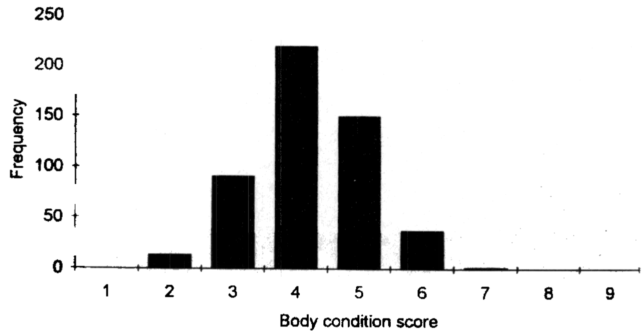

FIG 6: Histogram of the distribution of the body condition scores of 516 donkeys in markets in eight different locations in Morocco

Discussion

As reported by Eley and French (1993) heart girth and height were found to be the easiest and most reliable measurements to take, together with the circumference of the cannon bone. However, unlike the findings of Eley and French (1993) in British donkeys, height was not a good variable to use to predict the liveweight of donkeys in Morocco, and the results suggest that little benefit would be obtained by including it in a prediction equation at the expense of a measurement of length.

The measurement of umbilical girth has been favoured over heart girth for the estimation of the liveweight of horses (Jones and others 1989). In the present study, many of the mature donkeys had large abdomens, probably owing to the high roughage, low quality diets they were fed, rather than to their size and weight, and the measurement of umbilical girth was difficult. This, and the fact that the umbilical girth may vary with the interval since feeding and the quality of the diet fed, probably explains why the prediction equations including umbilical girth as a variable were worse than the equations using heart girth for these adult animals.

Few young donkeys were seen in the souks and the data on these animals are therefore not extensive. An indication that these animals were still developing was the correlation observed in the data between age and the various measurements made. Umbilical girth was as easy to measure as heart girth in these young animals and provided a better estimate of liveweight than heart girth, as Jones and others (1989) had found in mature horses.

The results suggest that it would be preferable to use heart girth rather than umbilical girth as a variable for estimating the liveweight of mature donkeys fed a diet of high roughage content, because they tend to be pot-bellied; for young growing animals umbilical girth may be more satisfactory.

Previous observations of horses (Milner and Hewitt 1969, Jones and others 1989) and donkeys (Neale 1990, Eley and French 1993) indicated that a predictive equation containing two variables produced a better correlation with liveweight than an equation with only one, but that little additional benefit was gained by the inclusion of three or more variables. In the present study, the inclusion of length and umbilical girth gave a better correlation with liveweight ($R^2 = 0{\cdot}87$) than umbilical girth alone ($R^2 = 0{\cdot}77$) for the young animals, but the addition of a second variable (length) in the adult donkeys improved the correlation by very little ($R^2 = 0{\cdot}84$ for heart girth and length together compared with $R^2 = 0{\cdot}81$ for heart girth only). This result is similar to the finding in adult *Bos taurus* cattle by Johansson and Hildeman (1954), who suggested that liveweight could be estimated with about the same accuracy by using heart girth on its own as by using a combination of two of more measurements. The use of more than two predictor variables becomes impractical in field conditions, and little value would be gained by producing more complex equations, particularly because they do not improve the accuracy of prediction significantly.

The equation derived to estimate the liveweight of horses (Jones and others 1989) was unsatisfactory for use with the donkeys in the present study because it overestimated the liveweight.

Furthermore, it made use of umbilical girth, which was difficult to measure in the donkeys.

The equation of Eley and French (1993) for adult donkeys also consistently overestimated the liveweights of the Moroccan donkeys. Hard working donkeys, particularly in areas where the feed supply is irregular, are more likely to be in poor than in good body condition. Unfortunately Eley and French (1993) did not provide information on the liveweight or body condition of the animals they sampled. However, if, as is probable, their equation was produced from donkeys in good body condition, doing little work, it would be expected to overestimate the liveweight of donkeys in generally poorer condition, such as those in the present study. It is also likely that there were differences in the age distributions of the adult populations sampled to produce the prediction equations in the UK and Morocco, although it is doubtful whether they would have greatly influenced the effectiveness of the equation.

Surveys of working donkeys in other Mediterranean countries (Egypt, Tunisia and Turkey) by the International Donkey Protection Trust (Bliss 1989, Svendsen 1991) have indicated that the average life span of a working donkey in these areas is rarely over 12 years. The age range of the sample of donkeys measured in the present study suggests that in Morocco too the life span of donkeys is short, in comparison with the average life span of British donkeys of 37 years reported by Bliss (1989) and of Zimbabwean donkeys of about 20 years (E. M. Nengomasha, personal communication).

Although the equations derived in the present study for adult and young donkeys performed well on the data, this is to be expected because the equations were derived from measurements pertaining to those particular donkeys. The ultimate validation, therefore, must rest on testing other samples of working donkeys in other parts of the world.

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Short Communications

Behavioural and cortisol response of pigs and sheep during transport

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PIGS and sheep are usually transported during the course of their life. Various behavioural and physiological effects of the transportation process have been reported in both pigs (Warriss and others 1991, Geers and others 1994) and sheep (Douglas-Hudson and Waran 1993, Knowles and others 1993, 1994). Journeys to slaughter are frequently of relatively short duration (a few hours or less) and road conditions vary. In the present study the behavioural and cortisol response of pigs and sheep were compared during short road journeys in order to establish whether welfare guidelines should be species specific and whether different domestic species are sensitive to specific types of journey (such as the degree of 'roughness').

Four 80 kg pigs and four 60 kg sheep were used, each social group comprising individuals which were familiar with each other.

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Each species was transported on alternate days in a car-towed twin-axle horse trailer (195 x 160 cm) on journeys characterised as 'rough' and 'smooth' (by means of an accelerometer). The rough condition involved journeys on minor roads in Cambridgeshire while the smooth condition consisted of journeys on the motorway. Each group travelled a distance of 761 km comprising 16 40 minute journeys (eight rough and eight smooth). The first journey type (rough or smooth) was alternated daily, with a total of two rough and two smooth journeys being conducted each day. A 20 minute rest period was allowed between each journey during which time the trailer remained stationary. Pigs and sheep were also loaded on a separate day, each for four hours, but the trailer remained stationary (control). In all cases fresh straw was provided at the beginning of each day on the trailer floor.

Behaviour was recorded by means of a remote controlled video camera mounted in the trailer and saliva samples were taken at the beginning and end of each journey for analysis of cortisol. The total number of minutes either lying, standing or walking was recorded for each animal and a mean was then calculated for the four animals. This mean was then expressed as a percentage of the total journey time. Mean frequency of social interaction, retching and vomiting were also calculated for each type of journey. Salivary cortisol was measured using an enzyme-linked immunosorbent assay (ELISA) (Cooper and others 1989). Sheep were fed ad libitum up to the point of loading and pigs were fed at the beginning of each day three hours prior to loading.

Analysis of accelerometer data revealed that there were four times more acceleration events during rough journeys (mean num-