

Apparent adiposity assessed by standardised scoring systems and morphometric measurements in horses and ponies

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Accepted 29 February 2008

Abstract

This study described a scoring system for the assessment of apparent neck adiposity and evaluated morphometric measurements for assessment of neck and overall adiposity. Twenty-one barren Thoroughbred mares, 13 Arabian geldings and 75 Welsh, Dartmoor, or crossbred pony mares, were clinically examined and blood samples analysed for insulin, glucose, leptin, and triglycerides. Bodyweight (BW), height, length, girth and abdominal circumferences, neck length, neck crest height and neck circumference were measured, and body condition scores (BCS) and cresty neck scores (CNS) were rated.

Girth:height ratio had the strongest associations with BCS ($r_s = 0.64$, $P < 0.001$ in horses; $r_s = 0.83$, $P < 0.001$ in ponies) and blood variables, such as leptin ($r_s = 0.39$, $P = 0.024$ in horses; $r_s = 0.68$, $P < 0.001$ in ponies). Crest height and neck circumference:height ratio had the strongest association with CNS ($r_s > 0.50$, $P < 0.01$) and blood variables, such as insulin ($r_s \geq 0.40$, $P < 0.05$).

Cresty neck score was useful in the assessment of neck crest adiposity and had physiological relevance, as demonstrated by associations with blood variables. Girth:height was the most suitable morphometric for assessment of overall adiposity, and either crest height or neck circumference:height was a suitable morphometric for assessment of apparent neck adiposity.

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Keywords: Body condition; Cresty neck; Adiposity; Morphometrics; Horse

Introduction

Anecdotal observations by equine veterinarians suggest that obesity is a growing problem in companion equid populations. Indeed, a recent cross-sectional study of 300 mature horses reported that 19% were obese with body condition scores (BCS) of 8 or 9, and 32% were overweight (BCS 6.5–7.5) (Thatcher et al., 2007). Obesity has been associated with insulin resistance (IR) in horses and ponies

(Frank et al., 2006; Treiber et al., 2006), and both obesity and IR have been associated with an increased risk of laminitis, particularly the pasture-associated form of this disease (Treiber et al., 2006).

The most common method for assessment of adiposity in horses is the rating of body condition (subcutaneous fat deposition) by use of a 9-point scale (Henneke et al., 1983). The Henneke BCS system, originally developed for use in Quarter horse broodmares, may be most appropriate for use in light breed horses (e.g. Quarter horses, Thoroughbreds and Arabians) that share similar body type and patterns of fat deposition. Although the Henneke system has been applied with modifications to other breeds, including warm-blooded horses (Kienzle and Schramme, 2004), its suitability for ponies has not been reported.

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Although BCS is a valuable estimate of apparent adiposity (Henneke et al., 1983), it is a subjective assessment. Use of more objective, yet easily obtained measurements of obesity may therefore be helpful in the clinical assessment of adiposity. In human medicine, morphometric measures such as body mass index (BMI) and waist to hip ratio are used for assessment of overall adiposity and regional (central) adiposity, respectively. Donaldson et al. (2004) applied a BMI to horses (estimated weight [kg]/height [m]²) and found a moderate correlation ($r_s = 0.60$; 95% confidence interval CI; range 0.44–0.73) between this index and BCS. Overall, however, there has been little application of morphometric measurements for evaluation of adiposity in equids.

The BCS system is not useful to differentiate the differences in regional adiposity that may indicate increased risk for disease. In human subjects, abdominal (visceral) adiposity is more closely linked to risk for diabetes and cardiovascular disease than generalised obesity, and measurement of waist circumference is a better indicator of abdominal fat accumulation than is BMI (Lee et al., 2006; Murphy and Bloom, 2006). Similarly, regional adiposity in horses and ponies, especially adipose tissue deposited more heavily along the crest of the neck ('cresty neck'), has been suggested to be associated with altered metabolic states, including insulin resistance, and an increased risk for laminitis (Johnson, 2002; Treiber et al., 2006). A standardised scale or system for assessment of neck crest fat accumulation would be beneficial for further evaluating the relationship of regional adiposity with metabolism and disease risk in horses and ponies.

The objectives of the current study were: (1) to describe a scoring system for the assessment of apparent neck crest adiposity in horses and ponies, and (2) to evaluate morphometric measurements for assessment of neck and overall adiposity through associations with condition scores and blood variables. It was expected that after successful implementation of a scoring system for neck crest adiposity, chosen morphometric measurements would display relationships with scoring systems, and that these measurements of adiposity would be related to metabolic blood variables.

Materials and methods

All procedures were approved by the Virginia Tech Institutional Animal Care and Use Committee.

Subjects and blood sampling

Twenty-one barren Thoroughbred mares of age (median (interquartile range)) 11 (8–14) years and bodyweight (BW) 568 (539–595) kg, 13 Arabian geldings (age 13 (11–14) years and BW 455 (422–468) kg) and 75 Welsh, Dartmoor, or crossbred pony mares (44 pregnant, 31 barren; age 10 (6–20) years and BW 345 (312–371) kg) were examined and sampled. All horses and ponies were maintained on a routine vaccination and deworming program, had regular dental exams, and were healthy in appearance at the time of sampling.

The horses and ponies were maintained on pasture and supplemented with mixed grass hay because the study occurred during the winter season

when pasture was minimal. No concentrate feed had been fed for >3 weeks prior to sampling. Horses and ponies had ad libitum access to fresh water and salt blocks. While at pasture and before daily hay feeding, blood samples (20 mL) were collected between 0800 and 1000 h by jugular venepuncture into 10 mL evacuated tubes (Vacutainer, Becton–Dickinson) containing sodium heparin or potassium EDTA as an anticoagulant. Plasma was separated by centrifugation (1500g) within 30 min of sample collection, separated into 1 mL aliquots, and then stored at -20°C until analysis.

Plasma analyses

Each analysis was performed in a single assay run on separate aliquots of plasma. Analyses were performed 1–5 months after sample collection. Plasma glucose (in heparin) and triglyceride (in EDTA) concentrations were assayed enzymatically with commercial kits and an automated analyser (CX5 Chemistry Analyser, Beckman Instruments). Plasma insulin (in heparin) and leptin (in EDTA) concentrations were measured by use of commercial radioimmunoassays (Coat-A-Count Insulin, Diagnostic Products Corporation; Multi-species Leptin RIA, Linco Research) previously validated for use in equine plasma (Freestone et al., 1991; McMannus and Fitzgerald, 2000). All analyses were performed in duplicate. Intra-assay coefficients of variation, calculated from duplicate analyses, were 0.7% for glucose, 8.5% for insulin, 2.8% for triglycerides, and 6.3% for leptin. Assay sensitivity was 5 mg/dL for glucose, 1.2 mU/L for insulin, 10 mg/dL for triglycerides, and 1 ng/mL for leptin. Range of linearity for each assay was 5–700 mg/dL for glucose, 5.4–460 mU/L for insulin, 10–1000 mg/dL for triglycerides, and 1–50 ng/mL for leptin.

Body measurements

Bodyweight, height (at the wither), body length, girth and waist (abdominal) circumferences, neck length, neck crest height, and neck circumference (NC) at 0.25, 0.50, 0.75 of neck length were measured. Body length was measured from the point of the shoulder (intermediate tubercle of the humerus) to the point of the buttock (ischiatric tuberosity). Girth circumference was measured caudal to the elbow (olecranon tuber) and immediately behind the slope of the withers. Waist was taken as the abdominal circumference measured two-thirds of the distance from the point of the shoulder to the point of the hip (tuber coxae). All neck measurements were taken while the neck was held in a relaxed position, at approximately a 45° angle. Neck length was measured from the poll to the highest point of the withers. Crest height was measured at 0.50 of neck length from the dorsal midline of the neck to estimated differentiation between the crest (tissue apparent above the *ligamentum nuchae*) and neck musculature, identified by palpation and visual assessment. Intra-assay coefficients of variation, calculated from three repeated measurements on three horses, were 1.1% for girth, 0.4% for waist, 3.0% for neck length, 2.1% for 0.25 NC, 2.4% for 0.50 NC, 0.7% for 0.75 NC, and 2.4% for crest height.

Four evaluators graded body condition score (BCS) from 1–9 (Henneke et al., 1983) and neck crest adiposity as cresty neck score (CNS) from 0 to 5 (Table 1; Fig. 1). Scores were rated to the nearest whole- or half-score increment and the median of the four scores for each horse or pony was used for data analysis. Intra-class correlation coefficients for the reliability of individual scores were 0.74 for BCS and 0.70 for CNS.

Statistical analyses

Two body mass indices were calculated as BW (kg)/[height (m)]² (BMI 1; Donaldson et al., 2004) and BW (kg)/[length (m) × height (m)] (BMI 2; Hoenig and Ferguson, 2002). Ratios of girth:height, girth:length, girth:BW, waist:height, waist:length, waist:BW, waist:girth, NC:neck length, and NC:height were calculated. Mean NC was calculated as the average of 0.25 NC, 0.50 NC, and 0.75 NC.

Results of the Shapiro–Wilk test revealed that not all variables were normally distributed within breed; therefore, associations between vari-

Table 1
Cresty neck scoring system

Score	Description
0	No visual appearance of a crest (tissue apparent above the <i>ligamentum nuchae</i>). No palpable crest
1	No visual appearance of a crest, but slight filling felt with palpation
2	Noticeable appearance of a crest, but fat deposited fairly evenly from poll to withers. Crest easily cupped in one hand and bent from side to side
3	Crest enlarged and thickened, so fat is deposited more heavily in middle of the neck than toward poll and withers, giving a mounded appearance. Crest fills cupped hand and begins losing side to side flexibility
4	Crest grossly enlarged and thickened, and can no longer be cupped in one hand or easily bent from side to side. Crest may have wrinkles/creases perpendicular to topline
5	Crest is so large it permanently droops to one side

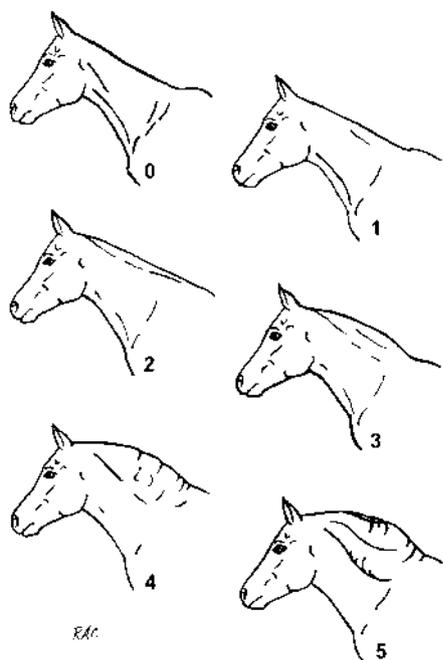


Fig. 1. Illustrations of individual cresty neck scores.

ables were quantified with Spearman rank correlation coefficients (r_s). Data were analysed as two groups (horses and ponies) and differences in relationships of variables between groups were determined by comparison of regression lines if correlations were significant ($P < 0.05$) for both groups. Comparison of regressions lines was analysed by an F test of the null hypothesis that one line fits both data sets (constraining both intercept and slope) with an alternate hypothesis that separate lines fit the data sets. Comparison of strength of associations was based on numerically higher r_s and lower P values. Groups were compared by use of Kruskal–Wallis tests and data are reported as median (interquartile range). Increased likelihood of hyperinsulinemia ($[\text{insulin}] \geq 30 \text{ mU/L}$) above a certain BCS or CNS was assessed by odds ratios. Software programs (Intercooled Stata 9 and GraphPad Prism 4) were used for statistical computations.

Results

Body condition score, CNS, leptin, and triglyceride concentrations were lower in horses compared to ponies

Table 2
Variable medians (25th–75th%) for horses and ponies

Variable	Horses ($n = 34$)	Ponies ($n = 75$)	P^a
Body condition score	6.0 (5.5–6.5)	7.0 (6.0–7.5)	<0.001
Cresty neck score	2.0 (1.8–2.3)	3.0 (2.0–4.0)	0.001
Insulin, mU/L	9.6 (5.9–28.2)	16.0 (8.1–38.2)	0.12
Glucose, mg/dL	94.2 (89.6–99.2)	93.8 (89.1–100.0)	0.80
Triglyceride, mg/dL	23.9 (18.0–32.5)	47.2 (35.2–58.2)	<0.001
Leptin, ng/mL	3.8 (2.4–5.4)	5.8 (3.4–8.1)	<0.001

^a P value for Kruskal–Wallis test comparing horses and ponies.

($P < 0.05$), while insulin ($P = 0.12$) and glucose ($P = 0.80$) concentrations were similar between horses and ponies (Table 2). All blood variables were more strongly associated with BCS and CNS than morphometric measures, with similar relationships between horses and ponies for leptin and triglyceride ($P > 0.05$; Tables 3 and 4).

For the assessment of overall adiposity in horses, BCS had the strongest associations with girth:height and waist:height (Table 5). Leptin was associated with girth:height. There were no other significant associations of blood variables with morphometrics in horses (Table 3). In ponies, girth:height had the strongest association with BCS (Table 5; Fig. 2) and blood variables (Table 3).

For the assessment of neck crest adiposity in horses, CNS was most strongly associated with 0.50 NC:height and mean NC:height (Table 6). Crest height was associated with insulin and glucose, whereas mean NC:height was associated with leptin, insulin, glucose, and triglyceride concentrations (Table 4). In ponies, crest height had the strongest association with CNS (Table 6), and mean NC:height had the strongest association with blood variables (Table 4).

Regression lines of morphometrics with BCS, CNS, and blood variables were different between horses and ponies ($P < 0.01$; Tables 3–6; Fig. 2). The only exceptions were for the regressions of girth:length or waist:length with BCS (Table 5).

To further evaluate the relationship of body condition with blood metabolic variables, horses and ponies classified as moderate ($4 < \text{BCS} < 7$), overweight ($7 \leq \text{BCS} < 8$), or obese ($\text{BCS} \geq 8$) were compared to classification of hyperinsulinemia ($[\text{insulin}] \geq 30 \text{ mU/L}$). Nineteen percentage of the moderately conditioned horses (5/27) were hyperinsulinemic compared to 43% of the overweight or obese horses (3/7). Ten percentage of the moderately conditioned ponies (3/30) were hyperinsulinemic compared to 45% of the overweight ponies (13/29) and 63% of the obese ponies (10/16).

The relationship of a moderate neck (CNS < 3) or a cresty neck (CNS ≥ 3) with hyperinsulinemia ($[\text{insulin}] \geq 30 \text{ mU/L}$) was also evaluated. Twenty-one percentage of horses with a moderate neck (6/29) were hyperinsulinemic compared to 40% of horses with cresty necks (2/5). Six percentage of ponies with moderate necks (2/32) were hyperinsulinemic, whereas 56% of ponies with cresty necks (24/43) were hyperinsulinemic.

An overweight or obese horse ($\text{BCS} \geq 7$) was not more likely ($P = 0.19$) to be hyperinsulinemic than a moderately

Table 3
Associations of blood variables with body condition score (BCS) or morphometric measurements of body adiposity

Correlation variables	Horse (<i>n</i> = 34)		Pony (<i>n</i> = 75)		<i>P</i> ^c
	<i>r</i> _s ^a	<i>P</i> ^b	<i>r</i> _s	<i>P</i> ^b	
BCS × Leptin	0.44	0.010	0.72	<0.001	0.090
Girth:Height × Leptin	0.39	0.024	0.68	<0.001	<0.001
Waist:Height × Leptin	0.32	0.066	0.44	<0.001	
BCS × Insulin	0.48	0.004	0.49	<0.001	0.001
Girth:Height × Insulin	0.31	0.075	0.41	<0.001	
Waist:Height × Insulin	0.16	0.35	0.06	0.59	
BCS × Glucose	0.46	0.007	0.21	0.071	
Girth:Height × Glucose	0.12	0.51	0.22	0.055	
Waist:Height × Glucose	0.09	0.60	−0.01	0.97	
BCS × Triglyceride	0.41	0.017	0.43	<0.001	0.21
Girth:Height × Triglyceride	0.17	0.33	0.44	<0.001	
Waist:Height × Triglyceride	0.07	0.68	0.35	0.002	

Tests were performed only if correlations were significant for both horses and ponies.

^a Spearman rank correlation coefficient.

^b *P* value for a test of the null hypothesis that the variables are independent.

^c *P* value for a test of the null hypothesis that one line fits both pony and horse data sets.

Table 4
Associations of blood variables with cresty neck score (CNS) or morphometric measurements of neck crest adiposity

Correlation variables	Horse (<i>n</i> = 34)		Pony (<i>n</i> = 75)		<i>P</i> ^c
	<i>r</i> _s ^a	<i>P</i> ^b	<i>r</i> _s	<i>P</i> ^b	
CNS × Leptin	0.48	0.005	0.62	<0.001	0.086
0.50 NC ^d :Height × Leptin	0.43	0.010	0.70	<0.001	<0.001
Mean NC ^e :Height × Leptin	0.53	0.001	0.74	<0.001	<0.001
Crest Height × Leptin	0.19	0.27	0.57	<0.001	
CNS × Insulin	0.50	0.002	0.59	<0.001	0.005
0.50 NC:Height × Insulin	0.40	0.021	0.50	<0.001	<0.001
Mean NC:Height × Insulin	0.49	0.003	0.51	<0.001	<0.001
Crest Height × Insulin	0.41	0.017	0.49	<0.001	<0.001
CNS × Glucose	0.45	0.007	0.27	0.020	0.001
0.50 NC:Height × Glucose	0.32	0.069	0.28	0.014	
Mean NC:Height × Glucose	0.42	0.013	0.28	0.016	<0.001
Crest Height × Glucose	0.39	0.023	0.23	0.046	<0.001
CNS × Triglyceride	0.43	0.012	0.43	<0.001	0.52
0.50 NC:Height × Triglyceride	0.38	0.029	0.41	<0.001	0.002
Mean NC:Height × Triglyceride	0.50	0.003	0.42	<0.001	0.001
Crest Height × Triglyceride	0.17	0.33	0.36	0.002	

^a Spearman rank correlation coefficient.

^b *P* value for a test of the null hypothesis that the variables are independent.

^c *P* value for a test of the null hypothesis that one line fits both pony and horse data sets. Tests were performed only if correlations were significant for both horses and ponies.

^d Neck circumference at 0.50 neck length.

^e Average of 0.25 NC, 0.50 NC, and 0.75 NC.

conditioned horse. An overweight or obese pony was 9.4 times more likely (*P* = 0.001) to be hyperinsulinemic than a moderately conditioned pony. A horse with a cresty neck was not more likely (*P* = 0.36) to be hyperinsulinemic than a horse with a moderate neck, whereas a pony with a cresty neck was 18.9 times more likely (*P* < 0.001) to be hyperinsulinemic.

Discussion

This study is the first to describe a standardised scoring system for apparent neck crest adiposity in equids.

Although CNS is related to overall adiposity, as indicated by an association with BCS, the purpose of CNS is to assess fat deposition along the crest of the neck independent of overall adiposity. Fulfilment of this objective is supported by association of CNS with morphometric measurements of neck dimensions. However, without a direct measure of adipose tissue for comparison, CNS can only assess apparent or visibly appreciable neck crest adiposity. Although CNS is associated with blood variables relevant to assessment of insulin resistance and other aspects of metabolism, the current study did not determine crest adiposity as a causative factor for altered metabolism

Table 5
Associations of body condition score (BCS) with morphometric measurements of body adiposity

Morphometric measurement	Horse BCS (<i>n</i> = 34)		Pony BCS (<i>n</i> = 75)		<i>P</i> ^c
	<i>r</i> _s ^a	<i>P</i> ^b	<i>r</i> _s	<i>P</i> ^b	
BW ^d	0.09	0.61	0.05	0.67	
BMI 1 ^e	0.35	0.044	0.43	<0.001	<0.001
BMI 2 ^f	0.50	0.003	0.37	0.001	<0.001
Girth	0.21	0.22	0.20	0.091	
Waist	0.24	0.17	0.18	0.13	
Girth:Height	0.64	<0.001	0.83	<0.001	<0.001
Girth:Length	0.40	0.020	0.56	<0.001	0.86
Girth:BW	−0.01	0.96	0.05	0.69	
Waist:Height	0.68	<0.001	0.58	<0.001	<0.001
Waist:Length	0.51	0.002	0.45	<0.001	0.61
Waist:BW	0.06	0.72	0.07	0.57	
Waist:Girth	0.22	0.22	0.06	0.62	

^a Spearman rank correlation coefficient.

^b *P* value for a test of the null hypothesis that the variables are independent.

^c *P* value for a test of the null hypothesis that one line fits both pony and horse data sets. Tests were performed only if correlations were significant for both horses and ponies.

^d Bodyweight.

^e Body mass index 1 (BW (kg)/[height (m)]²).

^f Body mass index 2 (BW (kg)/[length (m) × height (m)]).

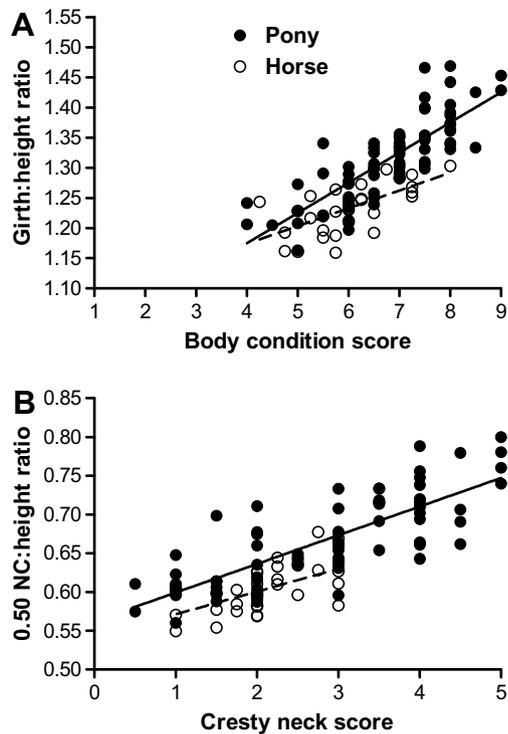


Fig. 2. Linear relationship of girth:height and body condition score (A) in horses ($y = 0.030x + 1.054$; $P < 0.001$) and ponies ($y = 0.050x + 0.975$; $P < 0.001$). Linear relationship of neck circumference at half neck length (0.50 NC):height and cresty neck score (B) in horses ($y = 0.030x + 0.541$; $P < 0.001$) and ponies ($y = 0.037x + 0.562$; $P < 0.001$). Solid and dashed lines represent linear regression lines of ponies and horses, respectively.

nor could it fully describe associations with CNS independent of BCS. Nonetheless, further validation of physiological relevance of CNS has been obtained through association with risk for metabolic disturbances or disease, as demonstrated by results of a recent study in which

ponies with CNS ≥ 3 were at increased risk for pasture-associated laminitis (Carter et al., 2007).

Another limitation of the present study was the female bias, as all of the ponies and 62% of the horses were mares. Some differences in blood variables between the Thoroughbred mares and Arabian geldings were observed (data not shown), however it could not be determined whether these were breed- or sex-dependent differences, and both groups were combined to provide enough power for statistical analyses. Further studies are necessary to determine specific differences in relationships of variables between mares, geldings, and stallions.

Body condition scoring is an accepted evaluation of apparent adiposity in horses, and previous studies showed that it correlated with subcutaneous fat thickness (Henneke et al., 1983; Gentry et al., 2004), leptin concentration (Buff et al., 2002), glucose tolerance (Frank et al., 2006), and insulin sensitivity (Vick et al., 2007). Obesity, as defined by a BCS above a certain cut-point, is associated with risk for laminitis (Treiber et al., 2006), reduced insulin sensitivity (Hoffman et al., 2003), and altered metabolic and reproductive activity (Vick et al., 2006). The findings of the present study supported that BCS is a useful tool in the assessment of apparent adiposity and affirm that BCS is associated with blood variables relevant to assessment of insulin resistance and other aspects of metabolism. Although the BCS used in the present study was originally developed on horses, it was successfully applied to both horses and ponies.

Morphometric measurements are more easily performed in the absence of trained evaluators and provide a more objective alternative for subjective scoring systems. The correlations of BCS with morphometric measurements, including BW, girth, BW:height, girth:height, and body mass index (estimated BW/height²) have been demon-

Table 6
Associations of cresty neck score (CNS) with morphometric measurements of neck crest adiposity

Morphometric measurement	Horse CNS (<i>n</i> = 34)		Pony CNS (<i>n</i> = 75)		<i>P</i> ^c
	<i>r</i> _s ^a	<i>P</i> ^b	<i>r</i> _s	<i>P</i> ^b	
0.25 NC ^d	0.55	0.001	0.48	<0.001	<0.001
0.50 NC ^e	0.39	0.023	0.61	<0.001	<0.001
0.75 NC ^f	0.27	0.13	0.44	<0.001	
Mean NC ^g	0.40	0.019	0.56	<0.001	<0.001
0.50 NC:Neck length	0.43	0.011	0.65	<0.001	<0.001
Mean NC:Neck length	0.37	0.028	0.61	<0.001	<0.001
0.50 NC:Height	0.58	0.001	0.80	<0.001	<0.001
Mean NC:Height	0.65	<0.001	0.83	<0.001	<0.001
Crest Height	0.51	0.002	0.91	<0.001	<0.001

^a Spearman rank correlation coefficient.

^b *P* value for a test of the null hypothesis that the variables are independent.

^c *P* value for a test of the null hypothesis that one line fits both pony and horse data sets. Tests were performed only if correlations were significant for both horses and ponies.

^d Neck circumference at 0.25 neck length.

^e Neck circumference at 0.50 neck length.

^f Neck circumference at 0.75 neck length.

^g Average of 0.25 NC, 0.50 NC, and 0.75 NC.

strated in previous studies (Henneke et al., 1983; Donaldson et al., 2004). The present study compared these measurements, along with other morphometric measurements, and found that girth:height was the most suitable morphometric for assessment of overall body adiposity, as demonstrated by strong correlation with BCS and blood variables.

In ponies, but not horses, morphometric ratios using waist circumference had weaker associations with variables than morphometric ratios utilising girth circumference. This discrepancy may be attributed to the 58% of pony mares that were pregnant at the time of evaluation. Pregnant ponies had a greater (*P* < 0.001) waist:height than non-pregnant ponies (1.52 [1.48–1.57] and 1.40 [1.35–1.45], respectively), which indicated that waist should not be used during pregnancy, although it may be useful for adiposity measurement in non-pregnant equids.

Either crest height or NC:height was a suitable morphometric for assessment of neck adiposity, as demonstrated by its association with CNS and blood variables. Mean NC has previously been shown to be associated with glucose tolerance in horses (Frank et al., 2006). The present study demonstrated that correcting for body size by calculating the NC:height ratio is a more accurate assessment of neck adiposity than mean NC. Mean NC:height and 0.50 NC:height had similar (*P* > 0.20) associations with CNS and blood variables. As mean NC did not significantly improve associations with variables over 0.50 NC, the latter is recommended as a more practical measurement of neck crest adiposity.

Ideally, if morphometric ratios had completely adjusted for size, a single regression line for relationships between variables would fit both pony and horse data. However, relationships of morphometrics with BCS, CNS, and blood variables were different between horses and ponies, indicating that a morphometric measurement of a pony cannot be

compared with the same morphometric measurement of a horse. The same value in a horse and pony would not signify a similarity in adiposity or have the same physiological relevance.

Using the populations of horses and ponies in the present study, it is possible to develop estimates of morphometric measurements that would indicate obesity and a 'cresty neck'. An equid may be considered overweight (equivalent to BCS ≥ 7) with a girth:height ≥ 1.26 ± 0.01 for horses or 1.33 ± 0.01 for ponies. An equid may be considered obese (equivalent to BCS ≥ 8) with a girth:height ≥ 1.29 ± 0.01 for horses or 1.38 ± 0.01 for ponies. An equid may be considered as having a cresty neck (equivalent to CNS ≥ 3) with a 0.50 NC:height ≥ 0.63 ± 0.01 for horses or 0.68 ± 0.01 for ponies. Future studies should evaluate the validity of these estimates in other horse and pony breeds.

Conclusions

As the link between obesity and health problems in horses and ponies is further elucidated, it is important to find convenient methods for the assessment of overall and regional adiposity. While body condition scoring is an accepted method for assessment of overall adiposity, cresty neck scoring would standardise the assessment of regional fat distribution on the crest of the neck. Morphometric measurements of girth:height for overall adiposity, and crest height or 0.50 NC:height for neck crest adiposity are objective alternatives to subjective scoring systems.

Conflict of interest statement

None of the authors of this paper has a financial or personal relationship with other people or organisations that

could inappropriately influence or bias the content of the paper.

Acknowledgements

Research was supported in part by the late Paul Mellon, Upperville, VA; the John Lee Pratt Graduate Fellowship Program in Animal Nutrition at Virginia Tech; and the Waltham Centre for Pet Nutrition. We are grateful to Dr. David Kronfeld for intellectual contribution during study initiation.

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