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Effect of pony morphology and hay feeding methods on back and neck postures

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Abstract

The application of hay feeding devices, such as the use of hay nets or slow feeders, can help with the management of weight in ponies; however, there is still a lack of knowledge regarding their effect on equine posture. Therefore, the aim of the study was to assess the effect of different feeding devices on the posture of ponies using morphometric analysis. Two different breed types, Shetland type (SH, $n = 5$) versus Welsh Cob type (WC, $n = 4$), were fed the same forage in four different ways: on the ground (G), using a fully filled haynet (HF), using a partially filled haynet (HL) and using a slow-feeder hay box (HB). Video recordings were obtained and then geometric morphometric analysis was applied. Breed morphology was confirmed by body morphometric measurements. Data were analysed statistically using one-way ANOVA, canonical variate analysis (CVA), principal component analysis (PCA), partial least-squares (PLS) analysis and multivariate analysis of variance (MANOVA). Moreover, a mixed model was performed to study differences in mandibular angle. SH and WC ponies were shown to have significantly different body morphometric measurements. The geometric morphometric analysis results showed that ponies arch their back and modify their neck shape differently according to the feeding method and their morphological group. For the neck, the SH and WC ponies adapted similarly to the use of small-holed hay nets, but their posture varied when feeding from the ground or hay box. The back postures consistently differed according to the breed type and feeding method. The mandibular angle for both breed types was reduced with all the feeding devices compared to feeding from the ground. Further studies are needed to evaluate the long-term effects of slow-feeding devices on posture and mandibular angle, taking into consideration animals with different morphologies.

KEYWORDS

hay nets, morphology, pony, posture, slow feeding, welfare

Clara Bordin and Federica Raspa contributed equally to this study.

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1 | INTRODUCTION

Ponies, like all equids, evolved to consume small forage-based meals almost constantly during the day (Davidson & Harris, 2007; Janis, 1976). Naturally, provided there are adequate resources, equids spend around 50–60% of their time on foraging activities (Webster & Ellis, 2010), which is much higher than seen with many stabled horses. In fact, sport horses in particular are often fed diets rich in cereal-based complementary feeds coupled with reduced availability of forage (Henderson, 2007; Raspa et al., 2022). This type of feeding practice could be linked to the deep-rooted beliefs on feeding management of sport horses that persist amongst some stable managers and owners (Harris, 1999), but it could also be a consequence of reduced nutritional understanding amongst veterinarians, who are often the first source of advice (Vergnano et al., 2017). Such feeding regimens increase the risk of gastrointestinal problems and may be associated with the development of stereotypies (Durham, 2009; Hothersall & Nicol, 2009). Strategies to increase the time spent on foraging behaviours, therefore, have the potential to improve both health and welfare (Benhajali et al., 2009; Lundqvist & Elisabeth Müller, 2022). Hay nets can be used to increase the time spent foraging through the use of nets with different hole size and shape (Ellis, Redgate, et al., 2015). However, there are some potential crucial disadvantages ranging from a change in the natural head and teeth position (e.g., development of hooks in the dental arch; Dixon & Dacre, 2005; Peffers, 2016) to the development of 'frustration' behaviours against the feeding device (Glunk et al., 2014; Rochais et al., 2018). Work has shown, especially more recently using a geometric morphometric approach, that where the hay net is positioned in relation to the individual horse is also very important. Horses have unnatural postures when the hay nets are hung too high from the floor, that is, at their head level (Correa et al., 2020; Raspa et al., 2021). This could over time lead to, or exacerbate, existing neck and back problems (Lesimple et al., 2012; Rochais et al., 2018). Alternatives to hay nets include various devices that can be placed, for example, on the ground but continue to slow the intake rate through the use of various holes, grids or grills placed over the forage, for example, the Pacefeeder® (Rochais et al., 2018), the Equine Hay Basket and the Natural Feeder (Grev et al., 2014). These are often referred to as slow feeders. Despite the claim that horses have a more natural position when using such devices, there does not appear to be any objective study on their effect on horse or pony posture. In addition, there has not been an evaluation, as suggested by Raspa et al. (2021), of how individual features such as the breed type might influence posture when using them. Finally, most studies on the effect of hay nets and slow feeders on posture and even intake rate have been undertaken on horses, and not ponies. Therefore, the aim of the study was to assess the effect of different types of slow feeding devices (ground-based hay box and hung hay nets) on the posture and mandibular angle of ponies, using geometric morphometric analysis. The hypothesis tested was that back and neck posture, as well as the mandibular angle, can be affected not only by the feeding devices themselves, but also by how much forage is within these and by the animal's morphology.

2 | MATERIALS AND METHODS

Two different breed types—Shetland type (SH, $n = 5$) versus Welsh Cob type (WC, $n = 4$)—were fed the same forage in four different ways: on the ground (G), using a fully filled haynet (HF), using a partially filled haynet (HL) and using a slow-feeder hay box (HB).

2.1 | Ethics statement

The study was approved by the Ethical Committee of the Department of Veterinary Sciences of the University of Turin (Prot. No. 1976; 05/07/21). All the ponies involved in this project were kept in their normal home environment. The animal husbandry as well as their care and daily management were under the responsibility of the pony's normal owner and grooms. Full authorization was obtained from the owner to perform the study.

2.2 | Ponies and management

Nine adult ponies with a mean age of 12 ± 4 years (±standard deviation, SD) were used. The ponies were regularly checked by the treating veterinarian and were all apparently clinically healthy, even if predominantly in an overweight condition. At the beginning of the study the teeth condition was assessed on the basis of the scale from 0 to 2 proposed by Valle et al. (2017) where 0 represents normal dental condition, 1 indicates the presence of non-clinically significant dental conditions and 2 is used to indicate poor dental condition. All the animals were evaluated by a vet (E.V.) and a mean teeth condition score of 1.00 ± 0 was reported. Accordingly, no dental management was deemed necessary pre-trial. Eight ponies lived in pairs in dry lot paddocks; the ninth pony was kept alone but in close contact with the others due to the riding school management and needs. They were normally fed on the ground with 2% of their BW (as fed) of a long stem first-cut meadow hay daily. The daily hay intake was supplied in three meals a day and hay represented the only constituent of their diet as no complementary feed, including balancers, was provided. Water was available ad libitum through water buckets which were daily checked and filled as required. All the ponies were owned by a riding school, and they were mainly involved in leisure activities such as pony games. Ponies were preliminarily divided into two type groups considering three factors: passport genealogy data, general morphology and the membership of a specific category during pony games competition. The latter being based on the height at the withers (a cut-off of 117 cm without shoes was used to differentiate between Shetland and Welsh/Cob type Ponies, according to Pony Club Rulebook 2022 of Italian Equestrian Federation). According to these three factors, five ponies were classified as Shetland breed type (SH; <117 cm) and four ponies were classified as Welsh/Cob breed type (WC; >117 cm).

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2.3 | Body morphometric measurements

All the ponies were scored for their body condition score (BCS, 9-point scale; Henneke et al., 1983) and their Cresty Neck score (5-point scale, Carter et al., 2009). Body weight was estimated using the formula based on the study of Carroll and Huntington (1988), which uses the heart girth (cm) and the body length (point of the shoulder to the point of the buttock/pin bone; cm):

$$\text{body weight (kg)} = \frac{(\text{heart girth} \times \text{hearth girth}) \times \text{body lenght}}{11,877}.$$

In addition, other morphometric measurements of body shape were made (Gee & Harris, 2005; Valle et al., 2017): heart girth (HG), obtained by the circumference of the body at the point caudal to the elbow, 2 cm behind the highest point of the withers; body length 1 (BL1), measured from the shoulder point to that of the hip; body length 2 (BL2), measured from the olecranon tuber to the pin bone; neck length (NL), measured from the poll to the highest point of the withers. In addition, to these measurements, the height at the withers (HW), measured from the highest point of the withers to the ground, and the height at the chest (HC), measured from the elbow to the ground, were evaluated (see Figure 1).

2.4 | Study setup

2.4.1 | Feeding devices

The hay nets used for this study were small holed hay nets (3.5 × 3.5 cm holes, Greedy Feeder Net, Shires Equestrian®). The nets were hung as suggested by Raspa et al. (2021) with the bottom of the hay net positioned at the height of each individual pony's elbow, allowing the hay net placement to be specific for each pony. An on-the-ground slow feeder was developed, and hand-built: the hay box (patent pending, proposal no. 63358392). This slow feeder was based on a wood container (80 × 60 × 45 or 50 cm) with a feeding restrictor (3.5 × 3.5 cm holes, Greedy Feeder Net, Shires Equestrian®) placed on top of the forage and connected by straps to the container. The straps provided tension between the feeding restrictor and the container, allowing the feeding restrictor to move within the container in a vertical direction. The height of the hay box was 50 cm for the Welsh Cob breed type ponies and 45 cm for the smaller ponies, belonging to the Shetland breed type (n = 5), in order to adapt the hay box height relative to the general height of the two breed groups.

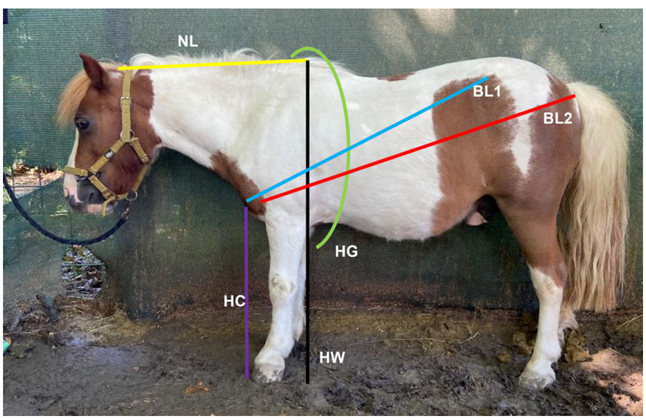

FIGURE 1 The morphometric measure of the body. Yellow line: neck length (NL); green line: heart girth (HG); blue line: body length 1 (BL1); red line: body length 2 (BL2); black line: height at the withers (HW); violet line: height at the chest (HC). [Color figure can be viewed at wileyonlinelibrary.com]

2.4.2 | Feeding methods

All ponies were adapted to being fed from the hay nets and the hay box during a 5-day adaptation period (Ellis, Fell, et al., 2015) followed by a 3-day data recording period. After the ponies had been adapted, a 2 × 4 Latin Square design was used, in order for each pony to be fed the same hay by each of the four different methods:

1. 3 kg of hay provided on the ground (G), taken as the control (natural feeding position; Raspa et al., 2021; Figure 2a).
2. 3 kg of hay in a small holed hay net: fully filled haynet (HF) hung to reach elbow height (Figure 2b).
3. 1 kg of hay in a small holed hay net: partially filled haynet (HL) hung to reach elbow height (Figure 2c).
4. 3 kg of hay inside the slow feeder hay box (HB) with the feeding side adjusted according to pony height (Figure 2d).

The hay used throughout was the hay normally given to the ponies, which was a long stem first-cut meadow hay. The same batch of hay was used for the whole study (89.9% dry matter).

2.4.3 | Video recordings

The video recordings were performed as described by Raspa et al. (2021) in detail. During the feeding trial, each pony stood on its left side, with the hay treatment presented on the same flat ground zone of its paddock in front of it. This enabled standardized locations for the video recordings to be obtained. Each pony was recorded during their midday meal with two 2D cameras (HDR-CX240 a 1080p HD of resolution, Sony®). The cameras were held using a specific tripod and were placed 1 m above the ground parallel to the pony, at a distance of 2 m from the pony. During the feeding method adaptation periods, ponies were adapted to the presence of equipment and operators. Each of the feeding methods (G, HF, HL and HB) was recorded for each pony on three consecutive days with the aim of obtaining at least 30 min of video per pony per feeding method. The observed pony needed to have the head, neck and back in line, parallel to the camera, and therefore in case of problems during the video recording (e.g., external factors or the pony moving out of the

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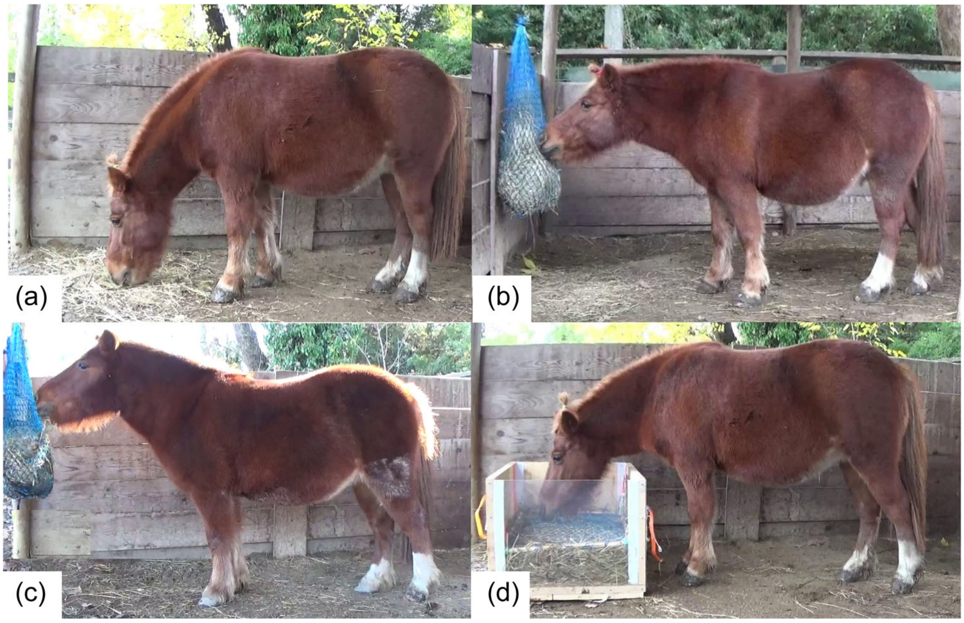

FIGURE 2 The four feeding methods: (a) hay provided on the ground (G); (b) hay net filled with 3 kg of hay (HF); (c) hay net filled with 1 kg of hay (HL); (d) the hay box (HB). [Color figure can be viewed at wileyonlinelibrary.com]

optimal position), the video was stopped and then restarted again (Raspa et al., 2021).

2.4.4 | Frames selection

The video recordings obtained were analysed by a trained operator, using VLC Media Player (version 3.3.4). The operator picked the best frames from each pony's data for the various feeding methods—G, HF, HL and HB—to proceed with the analysis. At least ten frames per pony were selected for each feeding method.

2.4.5 | Landmarks and semilandmarks configuration

The geometric morphometric approach was applied to analyse the overall shape variation of back and neck postures whose point configurations (Figure 3) were defined by placing eight points along the back and seven points along the neck (tpsDig 2.31, Rohlf, 2018). Two configurations were separately estimated in order to minimize the "Pinocchio effect," that is, the occurrence of an artefact which can negatively affect the evaluation of the overall shape variation (Klingenberg, 2021). If the neck and back were analysed together, any subtle differences between feeding methods and breed type would most likely be missed, since the total body shape would be influenced by the general neck position (i.e., down for ground and hay box and up for the haynets). Back and neck were therefore considered separately, and in this framework each pony breed was also separately analysed to avoid withers height influencing the results. Landmarks and semilandmarks (Palestrini et al., 2012; Rohlf, 2015; Tocco et al., 2011) were coded (tpsUtil 1.82; Rohlf, 2021), then the goodness of fit for each the configuration was assessed (tpsSmall 1.36; Rohlf, 2021).

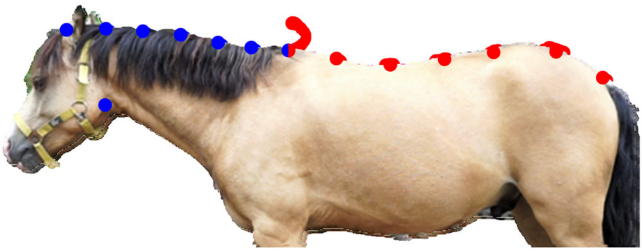

FIGURE 3 The configuration applied in geometric morphometric analysis, with seven points along the neck (blue dots) and eight points along the back (red dots) using tpsDig 2.31 (Rohlf, 2018). [Color figure can be viewed at wileyonlinelibrary.com]

2.5 | Data analysis

The software SPSS Statistics v28 (IBM SPSS ©) was used for statistical analysis unless stated otherwise and significance was set at $p < 0.05$.

2.5.1 | Comparison of the two breed types according to general features and morphometric measurements

To compare differences between SH and WC according to body weight (BW), BCS, cresty neck (CN) and the body morphometric measurements, a one-way analysis of variance (ANOVA) analysis

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was performed. Statistical analyses were carried out using JMP v16.0 (SAS Institute Inc.). Data were checked for distribution by means of the Shapiro–Wilk test. The statistical significance was set at $p < 0.05$.

2.5.2 | Geometric morphometric data analysis

The back and neck postures were examined separately by performing various different analyses:

- To describe the overall shape variation of each posture the principal component analysis (PCA) was applied retaining the RWs scores for further analyses (tpsRelw 1.75; Rohlf, 2021).
- To assess the group membership accuracy according to the breed type (SH and WC), and to analyse the variation for the four feeding methods for each breed type (SH and WC) separately, the canonical variate analysis (CVA) was used on the dataset of all the RWs which explained together the 100% of the overall shape variation (Palestrini et al., 2012; Tocco et al., 2011).
- To verify the covariation between back and neck postures the partial least-squares (PLS) analysis was used including ponies and feeding methods all together in a unique dataset with 1000 random permutations in the permutation tests (tpsPLS, v1.25; Rohlf, 2021).
- To test the effect of breed types on body shapes, multivariate analysis of variance (MANOVA) was applied using the multivariate tests of significance (Wilks' Lambda), Goodall *F*-test and permutation Tests (1000 random permutations) to confirm the results obtained (tpsRegr v1.50, Rohlf, 2021).
- Mandibular angle was assessed using 624 video frames according to Raspa et al. (2021). A BoxCox transformation was used to normalize data followed by a mixed model Anova including feeding method, breed type and their interaction as the fixed effect, with individual ponies as the random effect (with post hoc Tukeys for pairwise comparison).

3 | RESULTS

All the ponies remained healthy throughout the study.

3.1 | Validation of breed types using body morphometric measurements (SH vs. WC)

The one-way ANOVA results (Table 1) showed that the SH and WC were significantly different across all the body morphometric measurements. The Shetland ponies overall were less tall, and shorter in the neck and body length than the Welsh/Cob ponies. In addition, they had a lower body weight, smaller heart girth, higher body condition and cresty neck score. These results confirmed that the two breed types differed in their body shape.

TABLE 1 Morphometric measurements between the Shetland (SH) and Welsh/Cob (WC) breed types.

Morphometric measures	SH, *n* = 5	WC, *n* = 4	*p* Value
Body weight, kg (BW)	158.08 ± 35.53	219.85 ± 31.72	0.03*
Body Condition Score (BCS)	7.80 ± 0.14	7.28 ± 0.15	0.02*
Cresty Neck Score (CN)	3.30 ± 0.14	2.64 ± 0.15	<0.01*
Heart girth, cm (HG)	133.80 ± 1.81	147.31 ± 1.91	<0.01*
Height at the withers, cm (HW)	98.80 ± 1.29	125.11 ± 1.36	<0.01*
Height at the chest, cm (HC)	57.20 ± 1.30	70.67 ± 1.37	<0.01*
Body length 1, cm (BL1)	82.40 ± 1.18	93.83 ± 1.24	<0.01*
Body length 2, cm (BL2)	103.60 ± 1.64	120.72 ± 1.73	<0.01*
Neck length, cm (NL)	58.80 ± 1.75	73.06 ± 1.85	<0.01*

Note: Data expressed as mean ± SD.
*One way ANOVA statistical significance: $p < 0.05$.

3.2 | Effect of breed type on back and neck postures according to the feeding device

3.2.1 | PCA analysis between breed types and feeding device

The percentage of the overall shape variation shown in the scatterplots of first two RWs of each posture (Figures 4 and 5) was 77.61% for the back and 66.45% for the neck. In the scatterplots the feeding methods and breed types were defined by different symbols.

The PCA scatterplots for the back posture (Figure 4) showed that there were differences in the overall back shape between the breed types according to the G, HF and HL feeding methods; however, this was not so obvious for HB results. The PCA scatterplots for the neck posture (Figure 5) show clear differentiation between SH and WC when foraging from each feeding method. There was a high degree of consistency in the neck position within each breed type when considering the on-the-ground feeding method (i.e., the dots were really close to each other) underlying a clear posture characterization of the two breed types when having a natural feeding position.

3.2.2 | CVA analysis of back and neck shape variation of each breed type according to the feeding methods

The SH plot of the CVA factors (Figure 6) is characterized by a homogeneous and dense distribution of the data for the back posture. In addition, the HF and HL postures overlap, as do the G and HB postures. The group centroids for the G and HB are so close to each other that they are almost on the same point on the graph. The WC scatterplot of

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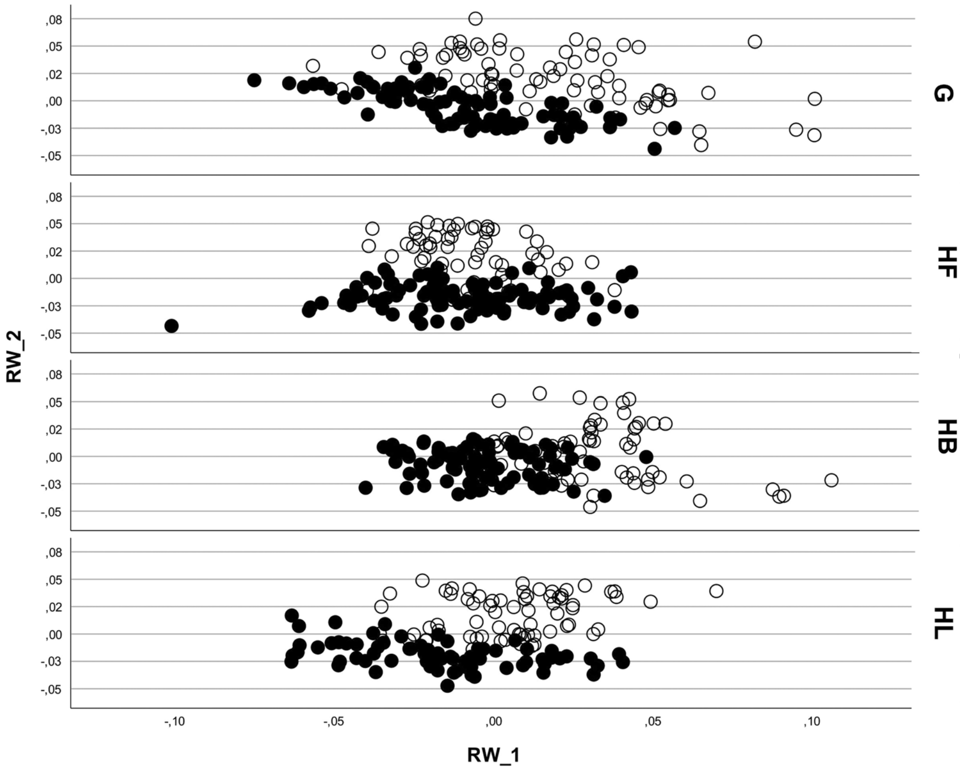

FIGURE 4 Back posture: Scatterplot of the first two relative warp scores (RWs) considering the back posture of the two breed types (SH and WC) for each feeding methods: on the ground (G), fully filled hay net (HF), hay box (HB) and partially filled hay net (HL). Shetland breed type (SH) is represented by black dots, whereas that of Welsh/Cob breed type (WC) by white dots.

back (Figure 6) is more heterogeneous in the "on the ground" group, and (contrary to what was reported in the SH breed type) the group centroids of the G and HB are significantly distant from each other. However, the HF and HL plots overlap with the group centroids of WC closer than for the SH breed type (Figure 6). For the back posture the 54.8% of the cross-validated group are correctly classified in the SH breed type, thus slightly lower than the WC breed type, with the 63.6% of the cross-validated group correctly classified.

The CVA analysis of the neck (Figure 7) reflects in part the findings of the former analysis, in that the HF and HL are overlapped, and moreover, the SH appears to be a more homogeneous breed type. However, in the SH scatterplot the HB is placed in an intermediate position between the natural feeding management on the ground and the use of hay nets. In the WC scatterplot (Figure 7), G and HB are instead clearly separate from HF and HL, evincing marked differences in the feeding posture between the two breeds. For the neck posture, the 74.1% of the cross-validated group were correctly classified for the SH breed type; similarly, the WC breed type had 73.5% of the cross-validated group correctly classified.

3.2.3 | Relationship between back and neck postures

The PLS analysis of the total dataset (i.e., the two breed types and four feeding methods together, Table 2) gave a moderate ($r = 0.59$; $p < 0.05$) correlation between back and neck postures although the permutations test value equal to 0.10% proved and confirmed that there is a covariation stronger than what expected if due to chance between back and neck postures.

3.2.4 | Effect of morphology and feeding method on shape variation of back and neck postures

The multivariate tests of significance (Wilks' Lambda test $p < 0.001$) showed differences of shape variation of back and neck postures among the two breed types (SH and WC) and the different feeding methods (Figure 8). This suggests that ponies arched their back and modified their neck shape differently according to feeding method and their own morphology (Goodall F-test, $p < 0.001$; permutation tests 0.10%) (Table 3).

3.2.5 | Magnitude of the mandibular angle

Table 4 shows that overall, there was a strong effect ($p < 0.001$) of feeding method on the mandibular angle, but no significant difference between breed types ($p = 0.272$) and no interaction between the two ($p = 0.087$). In particular, there was a reduction in the magnitude of the mandibular angle for both breed types, when going from the natural ground feeding (G) to the use of any of the

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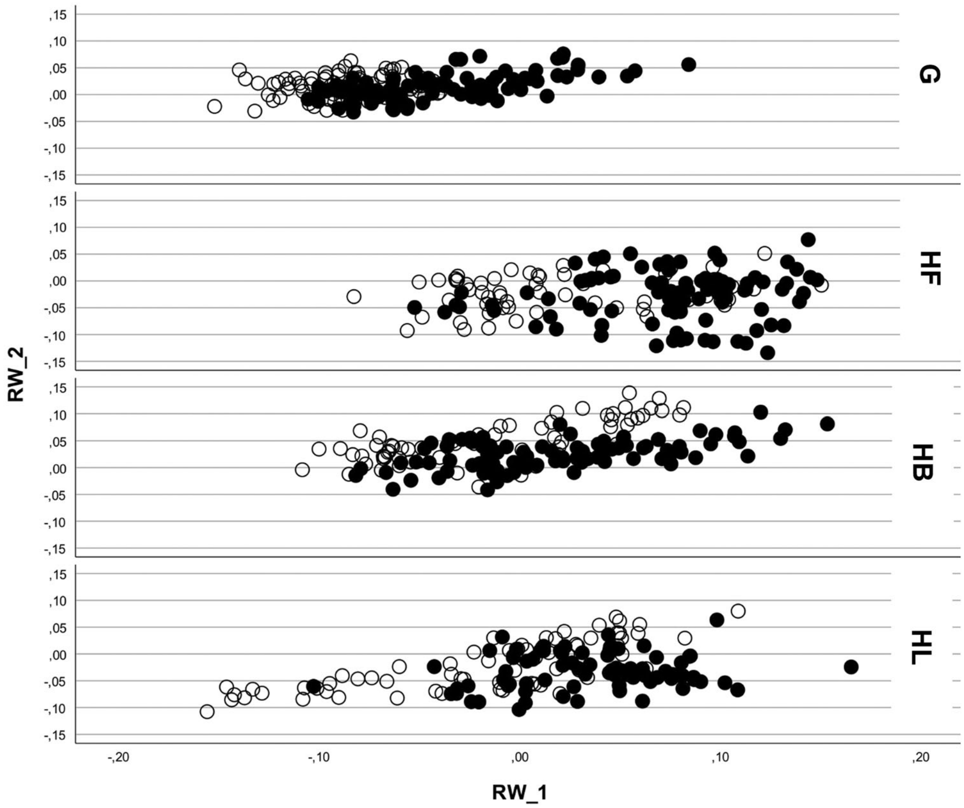

FIGURE 5 Neck posture: Scatterplot of the first two relative warp scores (RWs) considering the neck posture of the two breed types (SH and WC) for each feeding methods: on the ground (G), fully filled hay net (HF), hay box (HB) and partially filled hay net (HL). Shetland breed type (SH) is represented by black dots, whereas that of Welsh/Cob breed type (WC) by white dots.

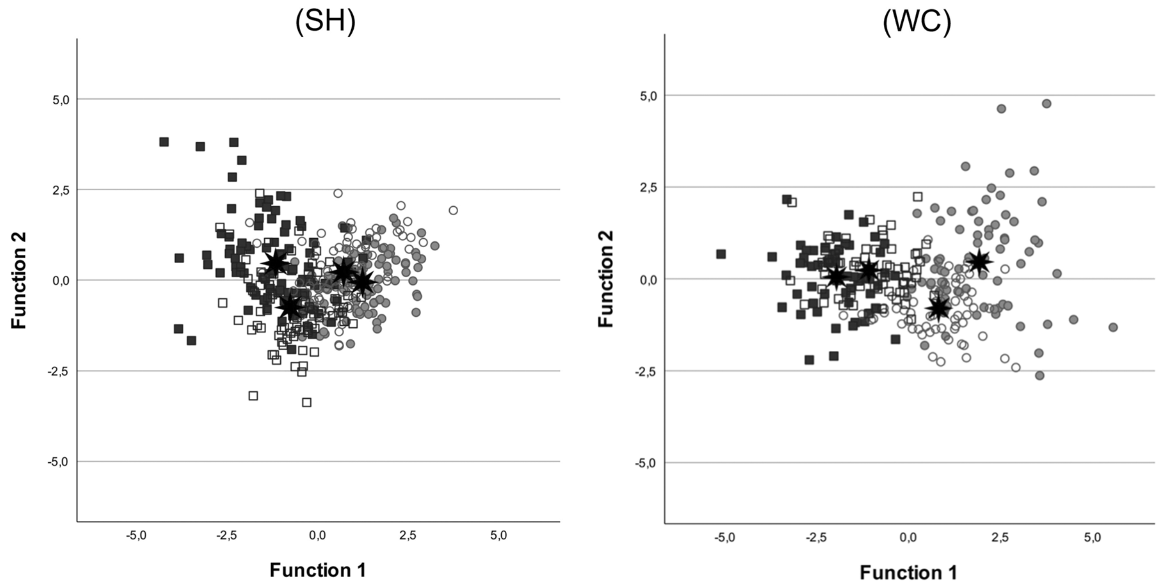

FIGURE 6 Back posture. Scatterplot of the canonical variate analysis for back shape variation of the Shetland breed type (SH) on the left and Welsh/Cob breed type (WC) on the right, according to the four feeding methods: grey circles, on the ground (G); black squares, fully filled hay net (HF); white circles, hay box (HB); white squares, partially filled hay net (HL).

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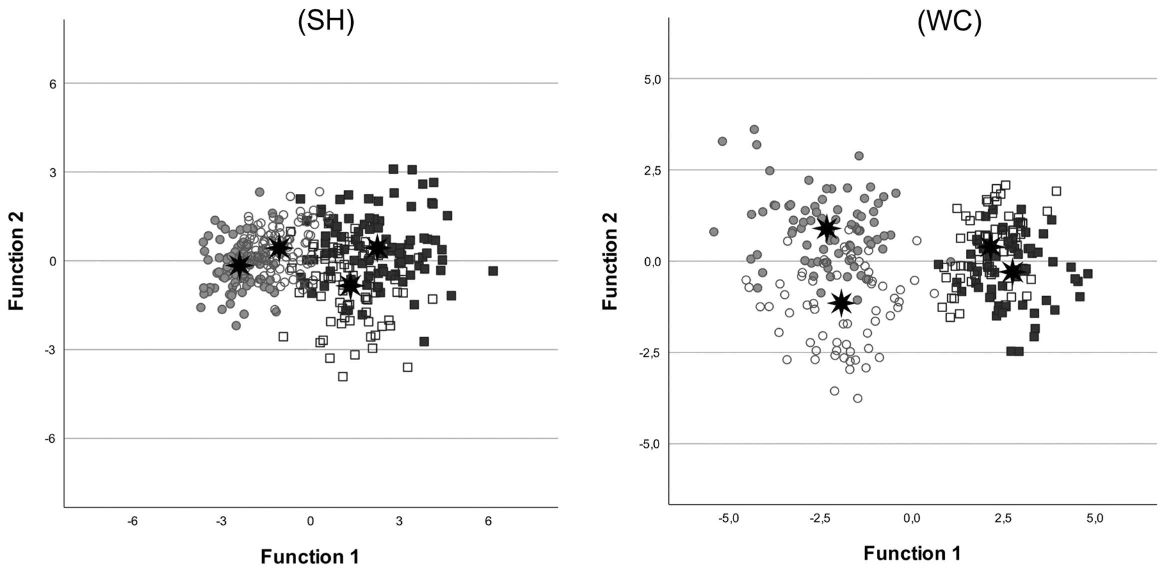

FIGURE 7 Neck posture. Scatterplot of the canonical variate analysis for neck shape variation of the Shetland breed type (SH) on the left, and Welsh/Cob breed type (WC) on the right, according to the four feeding methods: grey circles, on the ground (G); black squares, fully filled hay net (HF); white circles, hay box (HB); white squares, partially filled hay net (HL).

TABLE 2 PLS analysis according to the covariation between back and neck with the total dataset.

Breed type	r[a]	Cross-set analysis (%)[b]	Permutation test (%)[c]
Dataset tot	0.59	89	0.10

[a]Correlation index.

[b]Percentage of covariance.

[c]Percentage of correlation.

TABLE 3 Results from the Goodall *F*-tests and permutation test with 1000 random permutations of shape variation of back and neck postures.

	Goodall *F*-tests			
	F	df	*p*	Permutation tests (%)
Back	59.59	10, 62	0.0000	0.10
Neck	29.10	12, 75	0.0000	0.10

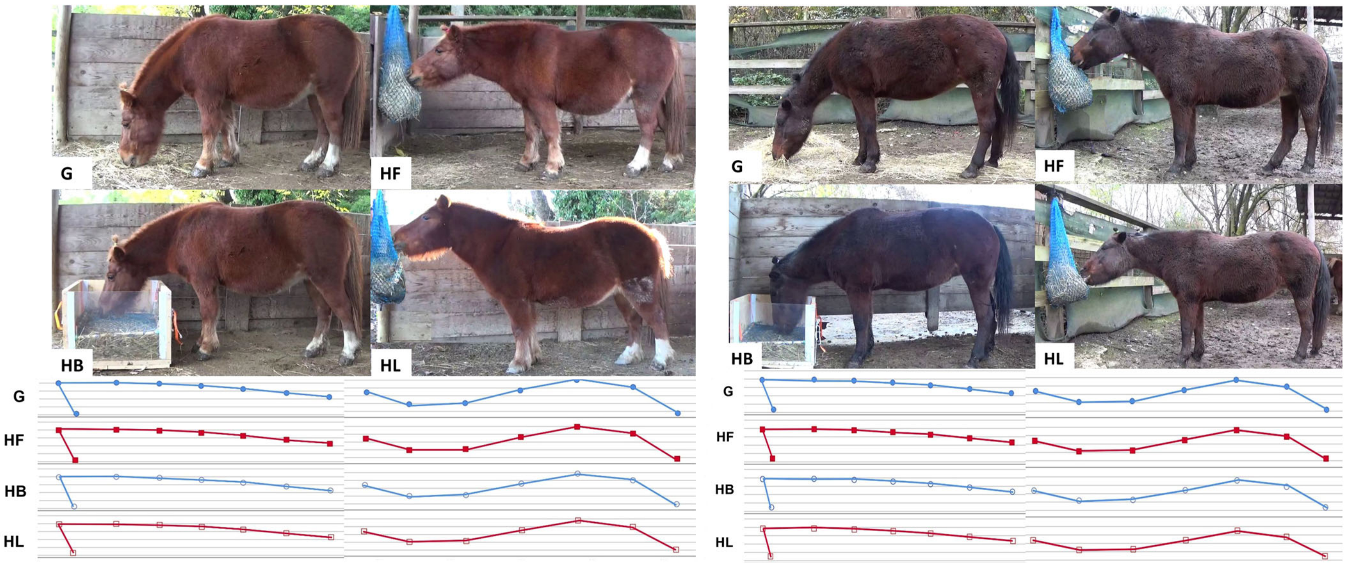

FIGURE 8 Mean shape variations in neck and back postures of Shetland (SH) ponies on the left and Welsh/Cob (WC) ponies on the right, according to the four different feeding methods ($p < 0.001$): blue, on the ground (G); red, fully filled hay net (HF); light blue, hay box (HB); light red, partially filled hay net (HL). [Color figure can be viewed at wileyonlinelibrary.com]

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TABLE 4 Mixed model test for the analysis of the magnitude of mandibular angle according to the feeding method (G, HB, HF and HL) and the breed type (SH and WC).

	Feeding method								p Value		
	G		HB		HF		HL		Feeding method	Breed type	Feeding method × Breed type
Breed type	SH	WC	SH	WC	SH	WC	SH	WC			
Mandibular angle	143.55 (4.46)	150.88 (4.98)	119.12 (4.46)	127.58 (5.01)	111.25 (4.45)	122.37 (5.02)	121.80 (4.49)	125.85 (5.00)	<0.0001*	0.27	0.09

Note: Data expressed as mean ± SD.

*Statistical significance: $p < 0.05$.

slow feeding devices (HF, HL and HB). This reduction was the highest when ponies were fed with HF, followed by HL, while when HB was used the magnitude of mandibular angle was closer to G.

4 | DISCUSSION

To our knowledge, this is one of the first studies that has investigated the influence of different hay feeding methods (G, ground; HF, fully filled haynet; HL, partially filled haynet; HB, hay box) on body shapes and mandibular angle, which also focuses on ponies. Furthermore, this is the first geometric morphometric study on the effect of using a ground-based slow-feeder, often reported as allowing for a more natural feeding posture (Rochais et al., 2018). The application of slow feeding devices in general to slow the time taken to ingest a set amount of forage can help with the feeding management of stabled equines (Ellis, Redgate, et al., 2015; Grev et al., 2014). In fact, although perhaps ideal, the provision of forage ad libitum is often an impractical strategy when applied to the feeding management of ponies (Harris et al., 2017). It is well known that ponies are often predisposed to be overweight, and accordingly have a high risk of developing metabolic disorders (Geor, 2008; Morgan et al., 2015; Valle et al., 2013). Looking at the ponies involved ($n = 9$) in this research, even though they remained healthy during the study, they all scored a BCS between 7 and 8 out of the 9-point scale of Henneke et al. (1983); accordingly, they should all have been classified as being obese (Dugdale et al., 2011). This highlights the need for slow-feeding devices and emphasizes how important it is to study their effects not only on feed intake but also on other welfare parameters (e.g., posture). With respect to the body posture analysis through the geometric morphometric approach, our results agree in general with the previous study of Raspa et al. (2021), which reported that different feeding methods (ground vs. haynet) can affect the shape variation of back and neck postures. This, therefore, provides additional support for the application of geometric morphometrics in the field of equine science, as it enables researchers to detect even subtle variations in the shape of the neck and back independently. Considering the back posture, the PCA analysis (Figure 4) showed that when evaluating the four feeding methods (G, HF, H and HB), the two breed types were easily distinguishable, suggesting the presence of a shape variation linked to their morphology. Even the CVA findings on back posture support this conclusion, as it did in a previous study in which an impact of individual characteristics (e.g., breed) on postures was suggested (Fureix et al., 2011). However, when looking at the effect of the ground feeding position (G), which represents the natural feeding posture, the breed type WC showed a higher intrinsic variability within the breed type, compared to the SH group which seemed to be more homogeneous. This may be due to factors related to the conformation of the individual animals (e.g., height and body shape) the effects of which could be explored further in future studies. However, it is reported that Shetland ponies have morphological characteristics that are highly hereditable, such as height at the withers (van Bergen & van Arendonk, 1993) and

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chondrodystrophy (Spoormakers et al., 2021). The actual genetic information for our ponies were not available since objective DNA analysis was not performed. However, the high heritability of these two morphological traits in Shetlands could explain the fact that the individual values within the SH group were close to the group centroid, whereas this was not the case for the WC breed type, as highlighted in Figure 6.

This study showed that morphological differences can affect posture when feeding; however, there were some differences between the effects on the back and the neck. In particular, whilst the back posture was always different between breeds and feeding methods, this was not the case for the neck. Whereas the extent of the net filling (either HF vs. HL) influenced back posture according to the breed type, fill did not have an effect on neck posture, at least under the circumstances of this study (Figures 5 and 7). SH and WC ponies adapted their neck posture similarly when the small-holed hay nets were used (HF and HL). This is an interesting finding as this similarity in posture occurred despite a significant morphological difference in neck length (58.8 ± 1.75 vs. 73.1 ± 1.85, respectively) and might reflect the benefit of placing the nets relative to the individual animal. However, further work on the effect of hay net fill under different circumstances is required before this conclusion can be confirmed. Moreover, it is important to note that our analysis demonstrated that HB did not exactly mimic the neck posture of natural feeding, although graphically the HB values were in the same axis as the G values (Figure 7). There was also a difference in the neck shape with the HB depending on the breed. This could be due to morphological features of the breed as previously described, but also the hay box (HB) features (e.g., height, depth) and it may be that the slight change in the height of the HB used for the two breed types was not sufficient, and a more individually tailored hay box height might enable this feeding device to provide an even closer posture to the natural ground feeding posture.

Analysing the overall posture (neck and back), showed that the two breed types demonstrated a significant correlation between back and neck postures, according to the PLS analysis and the subsequent permutation test value (Table 2). This is graphically evident when considering the MANOVA analysis (Figure 8), which provides a visual representation of how the ponies of the two different breed types arc their back and neck according to the different feeding methods (G, HF, HL and HB). However, this finding is perhaps not surprising since it is well known that the neck position has an influence on the thoracolumbar system (Álvarez et al., 2006; Rhodin et al., 2005). Furthermore, an effect on the mandibular angle was detected, as already shown by Raspa et al. (2021) in horses. The mandibular angle found in ponies in this study was wider than the one obtained in horses, confirming that work in horses cannot automatically be transferred to ponies. Although there did not seem to be differences between the breed types in their mandibular angles, there were significant effects of the different feeding methods ($p < 0.0001$) (Table 4). When ponies of both two-breed types were fed on the ground (G), the current study found a wider mandibular angle compared to being fed via all the other feeding methods (HB, HF and HL). It is possible that forcing an animal into a posture which reduces the mandibular angle especially over the long term could adversely affect their welfare status. An extreme example is the effect of hyperflexion in the ridden horse during which the larynx can be compressed and the air flow reduced (Zebisch et al., 2014). It could also be hypothesized that a change in the mandibular angle during feeding could influence the articulation of the jaws and chewing activity. However, further studies are needed to evaluate if there are any adverse effects over the long term. In the meantime, these results suggest that it is important not only to consider that the relative hay net height and fill but also the position and characteristics (e.g., height from the ground, physical features) of a slow-feeding device could exert an influence on the body posture according to the breed-type (e.g., SH vs. WC) or individual morphology. In this study effects were reported on posture and mandibular angle when the feeding devices were adapted to the individual animal (e.g., the hay nets were hung at the recommended height for the individual animal), therefore, is not possible to estimate the effects of devices not used in such a way. Overall, there were less differences between the hay box and feeding from the ground compared to the differences between the ground and the hay nets, which does support the view that the hay box provides a more (if not completely) natural feeding position. If the hay box has a similar effect on extending intake time to the hay nets, it could be hypothesized that the hay box, if properly adapted to the individual, could represent a compromise between the need for an increase in intake times and feeding naturally from the ground.

5 | CONCLUSION

Despite the limitations of our study with respect to the low number of ponies involved, this study showed that each feeding method can affect the posture of the two breed types in a distinctive way. The two breed types were easily distinguishable when considering their back posture but adapted their neck posture in the same way between fully filled and partially filled haynets (HF, HL). Interestingly, the mandibular angle was reduced by the use of all feeding devices, underlying the need for further analysis on the long-term effects of slow feeders. The findings demonstrated that the two breed types had their own characteristic feeding posture, particularly when they were fed on the ground, suggesting that the correct selection of the appropriate feeding may need to consider not only nutritional requirements but also the best feeding method based on individual body morphology (i.e., very high withers). To conclude, the strong influence of body morphology on the way pony posture adapts to different feeding methods, as seen in this study, highlights the need for further research into horse types with different morphologies in order to understand the physiological effect of feeding devices.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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