



## Original Research

## Morphological Variation in Gaited Horse Breeds

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## ABSTRACT

Gaited horses, renowned for their smooth gaits, are anecdotally noted to have proportionally longer hind limbs than nongaited breeds of the same height. However, gaited horses perform a wide spectrum of different gaits that we hypothesize may require diverse skeletal adaptations. To investigate the contribution of morphology to gait ability, we collected body measurements from gaited and nongaited individual animals and principal component analysis was conducted on 32 body measures for a set of 1,682 horses. Principal component (PC) 1 captured 65.3% of the trait variance, whereas PC2 comprised 6.6% and PC3 3.2% of variance in the data set. All body measures correlated positively with PC1 which quantifies a horse's overall body size. In contrast, PC2 quantifies body thickness. Principal component 3 represents a pattern primarily involving skull thickness and lower limb length. Because of the presence of sexual dimorphism and unequal sampling across sexes, we generated a pruned data set of 432 individuals with equal numbers of gaited and nongaited horses within each sex class. Analysis of variance and pairwise correlations were conducted to identify differences in the PC scores and measurements (normalized by wither height) due to sex, gait phenotype, breed, and age. After accounting for these fixed effects, gaited horses were significantly different from nongaited horses in PC2 and PC3 ( $P < .0001$ ). Comparisons of individual measurements demonstrate that gaited horses have smaller eye and jaw widths, proportionally longer front limb segments and thinner lower limb circumferences ( $P < .05$ ). This is the first study to identify different proportions in the front limb segments associated with gait.

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## 1. Introduction

Conformation has long been a driving force in horse selection and breed identification, particularly as a predictor for performance and injury susceptibility. In any equine discipline, there are certain conformations and body dimensions that are reportedly desirable and believed to be

advantageous for performance. For example, “good front limb action,” as would be desired in dressage, is determined mostly by leg and foot stances, the slope of the shoulders and pasterns, and the length of the leg [1–3]. In addition, limb conformation is the major factor in limb soundness and can be a predictor for future lameness or locomotor problems [4,5].

Gaited horses, defined as those able to perform a two-beat lateral or four-beat gait at speeds equivalent to a trot, are noted to have different body proportions than nongaited horses [6]. In particular, it is believed that they have longer hind limb lengths in proportion to the croup height and anecdotally longer gaskins as compared to

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nongaited horses. Gaited horses are able to innately perform a wide spectrum of different footfall patterns that are shared across different breeds [2], and yet, gaited breeds come in diverse morphologies, from the short and stout Icelandic to the tall and lean Saddlebred [7]. Although longer hind limbs may help initially identify a gaited horse from a nongaited horse, owners of gaited horses are much more interested in improving the accuracy of predicting which footfall patterns and gaits their horse can perform. Most performance conformation studies have focused on specific disciplines [8,9], single breeds [10,11], or height variation across breeds [7]. In this study, we compare morphological traits of multiple gaited breeds to nongaited breeds to identify morphological patterns unique to gaited breeds and assess the morphological impact on reported footfall pattern capability. In doing so, we aim to improve the understanding of the interplay between conformation and gait performance in gaited breeds of horses.

## 2. Materials and Methods

### 2.1. Sampled Horses

Horses ranging in age from 1 to 36 years and representing diverse breeds were phenotyped for a total of 35 body measurements and four subjective trait scores following a previously developed protocol [7]. Measurements that span

the head, neck, body, and limbs were collected from horses, along with vital statistics (breed, age, sex, and so forth) and owner-reported gait information. The 35 body measurements make use of easily palpable landmarks and a measuring tape to capture skeletal length and circumference as quantitative variables (Fig. 1). Measurements were recorded in inches to the nearest .125 inch and later converted to meters by use of JMP Pro 11 (SAS Institute, Inc, Cary, NC) software program. In addition, four subjective traits were recorded and included head profile (convex to neutral to concave), amount of hair on lower limbs (“feathering,” none to copious), bite evenness (underbite to neutral to overbite), and bone thickness, with each scored as a factor on a scale of 1 to 5 for each horse. Horses were phenotyped as “gaited” if they belonged to a breed known to be “gaited.” In addition, horses belonging to a breed in which only some animals are gaited were included in the gaited category if their owners reported they were able to perform an intermediate gait other than trot. Horses were phenotyped as “nongaited” if they belonged to a breed reported to have an intermediate gait of trot only.

### 2.2. Data Quality Control, Data Sets, and Statistics

Thirty-five measurements were initially recorded, and three were excluded from analysis due to confounding measurements. Specifically, the horse would not perform

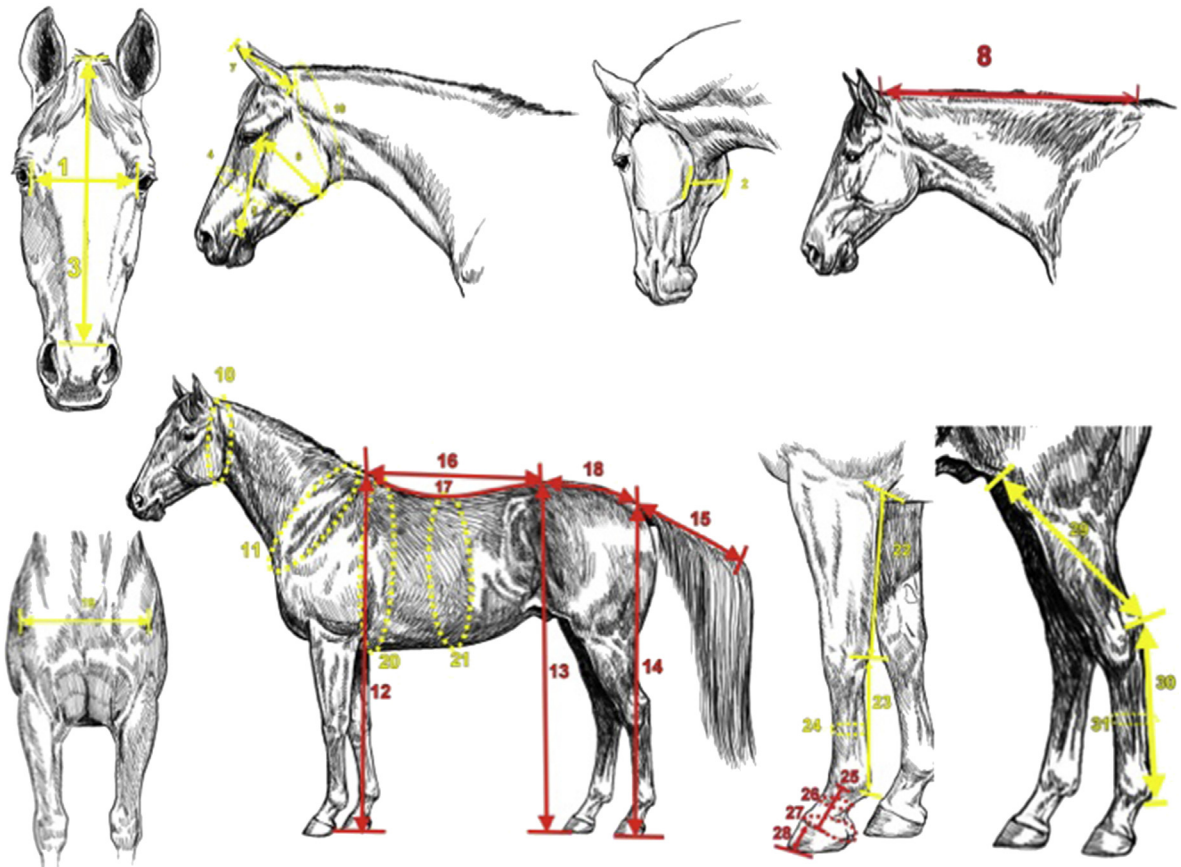


Fig. 1. Example of body measurements collected from each horse. Solid lines are lengths, whereas dashed lines are circumferences (illustrations by Susan Harris).

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