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Original study

Relationship between conformation traits and gait characteristics in Pura Raza Español horses

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Abstract

In the breeding program of breeds such as the Pura Raza Español horse, selection by gait quality is of great interest because of their use for dressage performance. However, biokinematic analyses are expensive and data processing is time consuming. So, indirect measurements related to movement quality are alternatively used for a precocious selection of the animals. The aim of this study is to estimate the genetic correlations between 13 conformation measurements and 16 biokinematic variables at trot (4 linear, 6 temporal and 6 angular) in order to identify objective selection criteria for locomotion ability. A total of 130 Pura Raza Español horses from 24 studs, aged between 4-7 years old, were measured and their biokinematic variables were obtained in experimental conditions on a treadmill. There were 155 significant genetic correlations between conformation and biokinematic traits. Croup length was the most correlated trait with biokinematic variables at trot (16), and croup width was the least correlated one (7). Forelimb length and forelimb duration were the most correlated with conformation measurements (12), whereas minimal angle of carpus was the least correlated one (5). All the conformation measurements were genetically correlated with biokinematic variables, and through these relationships when trotting, a total of 6 body measurements were selected for the indirect and precocious selection of gait quality, which could be included directly or combined in body indices.

Keywords: body measurement, equine locomotion, genetic correlation, treadmill

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Abbreviations: CH: croup height, CL: croup length, CmA: minimal angle of carpus, CV: coefficients of variation, CW: chest width, FD: forelimb duration, FL: forelimb length, FMH: forelimb maximum height of hoof, FMRP: maximal retraction-protraction angle of the forelimb, FStD: forelimb stance duration, FSwD: swing phase duration, HD: hindlimb duration, HeL: head length, HL: hindlimb length, HMH: hindlimb maximum height of hoof, HmRP: minimal retraction-protraction angle of the limb, HNP: head-neck perimeter, HP: hock perimeter, HStD: hindlimb stance duration, HSwD: swing phase duration, KP: knee perimeter, NBP: neck-body perimeter, PMA: maximal angle of pelvis, REML: restricted maximum likelihood procedure, SmA: minimal angle of stifle, TD: thorax depth, TmA: minimal angle of tarsus, TP: thorax perimeter, TW: thorax width, WC: croup width, WH: withers height

Introduction

The sport horse is an athletic animal whose value depends mainly on its performance in competitions. However, performance is the result of a complex combination of conformational, physiological and behavioural traits, which are heritable (Giulotto *et al.* 2001).

Traits included in breeding programs have to show good correlations with competition performance and they should also be possible to measure accurately early in life (Holmström *et al.* 1994). Conformation assesses the unalterable structure of an animal in relation to its function and it is of primary interest to breeders and owners, since overall body shape defines the limits for range of movement, the function of the horse and its ability to perform (Bakhtiari & Heshmat 2009, Rustin *et al.* 2009, Schroderus & Ojala 2010). Such results support the common practice of indirect performance selection via selection for functional conformation (Schröder *et al.* 2010). Therefore, it plays an important role in horse breeding and almost all breeding objectives for sport horses include functional-conformation and movements (Koenen *et al.* 2004), as an aid to improve performance in sport. In fact, gait traits have moderate to high positive correlations to dressage (Ducro *et al.* 2007).

Although talent can be considered as a very complex combination of more or less substitutive traits (Borowska et al. 2011), conformation traits in sport horses are not difficult to define and evaluate (Posta *et al.* 2007), and are used in indirect selection for performance traits, since most performance variables have low levels of heritability and can be measured only late in life (Koenen *et al.* 1995). The efficiency of indirect selection for performance depends on the genetic variation of conformation traits and on the genetic correlations between conformation and performance variables (Koenen *et al.* 1995).

In the Pura Raza Español horse breeding program, although selection by gait quality is of great interest, biokinematic analyses are very expensive. Therefore, indirect measurements related to gait quality would allow some cost saving, and it is used instead for a precocious selection of the animals. Thus, the genetic correlations between conformation measurements and biokinematic variables when trotting were estimated, in order to identify objective selection criteria for locomotive ability.

Material and methods

A total of 130 Pura Raza Español horse males from 24 different studs, chosen randomly, registered in the official stud-book, were evaluated at the Laboratory of Equine Performance Control (Veterinary Faculty of Cordoba, Spain) for conformation and biokinematic variables. Their age ranged from 4-7 years old (4.6 ± 1.5) and they were selected in order to be representative of most of the genetic lines of the Pura Raza Español horse population, with an average inbreeding of 0.9 and coancestry of 0.05. Because of the complex methodology applied for the estimation of biokinematic variables in this work (with high spend of time and money), the reduced number of animals used for the estimation of genetic parameters is justified as in other published equine papers, with a number of animals ranging between 100 and 362 (Rivero *et al.* 1996, Barrey *et al.* 1999, Rivero & Barrey 2001, Górecka *et al.* 2006).

Conformation measurements

Conformation analysis was carried out through quantification of the main body measurements (Figure 1), following the methodology described by Cervantes *et al.* (2009). A total of 13 conformation measurements were included, instead of subjective evaluations, because these would improve the traditional judgement procedure, increasing the accuracy of the prediction of performance potential (Holmström *et al.* 1994), since they could be used as a descriptive tool (Barrey *et al.* 2002) and are more repeatable.

The measurements were taken by one person from the left hand side of the horse, on a flat, firm surface. The analysed measurements were (Figure 1): *head length* (HeL), *head-neck perimeter* (HNP), *neck-body perimeter* (NBP), *chest width* (CW), *thorax width* (TW), *thorax depth* (TD), *thorax perimeter* (TP), *croup length* (CL), *croup width* (WC), *knee perimeter* (KP), *hock perimeter* (HP), *withers height* (WH) and *croup height* (CH).

Biokinematic variables

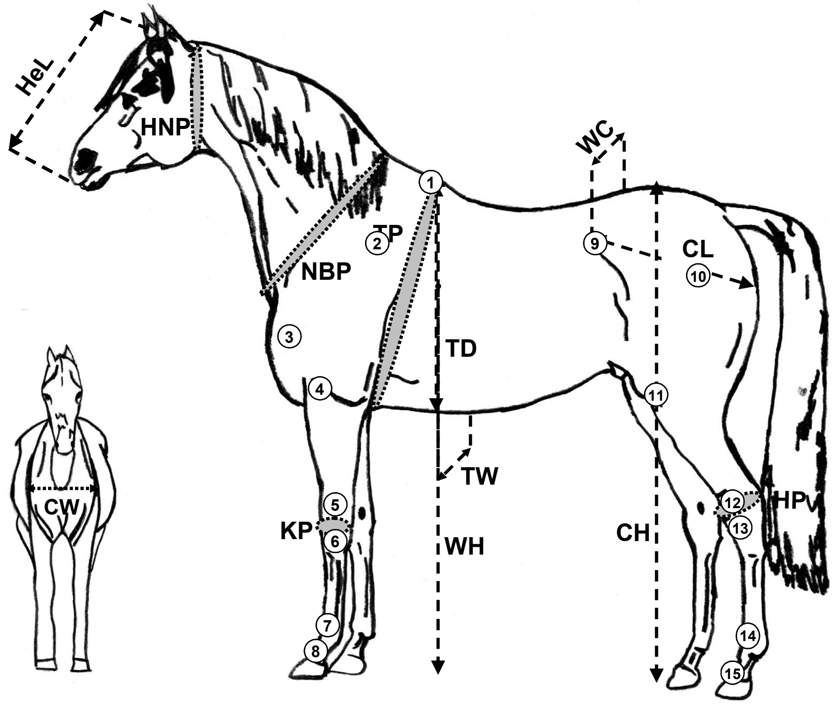
All variables were recorded using a camcorder while horses were trotting on a treadmill at the constant speed of 4 m/s, following the methodology described by Valera *et al.* (2008). Adhesive markers were attached at pre-defined skeletal reference points which were easily identifiable and representative of the joints and radii under investigation (Figure 1).

A total of 16 biokinematic variables at trot (4 linear, 6 temporal and 6 angular) were analysed. All of them were selected because of their relationship with dressage ability.

The linear variables were: *forelimb* and *hindlimb length* (because of their importance in the »overtracking« or »overreach« length in the trot, which is a desirable feature in Dressage), longer forelimb and hindlimb stride lengths are associated with lower stride frequencies, which are desirable in Dressage, according to Merz & Knopfhart (1996), and *forelimb* and *hindlimb maximum height of hoof* (because the Pura Raza Español horses exhibited elevated movements rather than extended movements of the limbs).

The temporal variables were: *forelimb* and *hindlimb duration*, *forelimb* and *hindlimb stance phase duration* (according to Holmström *et al.* [1994], horses judged as good at trot had longer stance phase duration compared to the poor horses and the stance phase duration increased with increased collection) and *forelimb* and *hindlimb swing phase duration* (because elite horses typically exhibited shorter stance durations in both fore and hindlimbs, which results according to Drevemo *et al.* [1980] on a longer swing phase duration).

Finally, the angular variables were: minimal angle of carpus, stifle and tarsus, minimal retraction-protraction angle of hindlimb, maximal retraction-protraction angle of forelimb, (because of their importance in dressage performance they could be characteristics to be included in the breeding program of the Pura Raza Español horse), and maximal angle of pelvis (which represents the maximum angle of the croup with respect to the horizontal when the horse is moving). All this angles are important to get the movement described in the official breed standard: agile, high, extensive, harmonic and rhythmic, with a particular predisposition for collection and turns on haunches (Valera *et al.* 2009).



Markers are placed: 1: withers, 2: tuber of the spine of the scapula, 3: greater tubercle of the humerus (caudal part), 4: lateral collateral ligament of the elbow joint, 5: lateral styloid process of the radius, 6: base of the 4th metacarpal bone, 7: lateral collateral ligament of the fore fetlock joint, 8: coronet of the fore hoof (over the pastern axis), 9: tuber coxae, 10: greater trochanter of the femur (caudal part), 11: lateral collateral ligament of the stifle joint, 12: lateral malleolus of the tibia, 13: base of the 4th metatarsal bone, 14: lateral collateral ligament of the hind fetlock joint, 15: coronet of the hind hoof (over the pastern axis)

Figure 1
Graphical representation of the conformation measurements taken in the Pura Raza Español horse

Genetic and statistical analysis

A preliminary study of the phenotypic relationships between the analysed traits was carried out by making a factor analysis, using Statistica for Windows (StatSoft, Inc. Tulsa, OK, USA, version 8.0).

The genetic correlations were estimated by VCE v 6.1 (Groeneveld et al. 2010), using a mutivariate mixed animal model. For the genetic analysis, the general model for this analysis was:

$$Y = X\beta + Z_1 a + e \quad (1)$$

where ***Y*** is a vector of animal observations, $\boldsymbol{\beta}$ is the fixed effects vector (stud-season of evaluation, age of the animal), associated with the incidence matrix ***X***, $\boldsymbol{\alpha}$ is the vector of direct genetic effects, associated with the incidence matrix $\boldsymbol{Z_1}$, and ***e*** is the random error effects matrix.

To complete the pedigree for the calculation of the inverse of the relationship matrix, the Pura Raza Español horse stud-book was used, and all the registered ancestors of the recorded animals were added until the fourth generation, making a total figure of 1 704 animals.

The additive genetic variance and covariance of the traits were estimated according to a Restricted Maximum Likelihood procedure (REML), using a Quasi-Newton algorithm with exact derivatives to maximise the log likelihood. An approximate standard error of the genetic correlations was estimated from the inverse of the approximation of the Hessian matrix when convergence was reached (Groeneveld *et al.* 2010).

Results and discussion

The assessment of a horse's merits by virtue of its conformation is as ancient as man's usage of the species. Conformation traits remain an interesting subject, because they are linked to desirable characteristics for breeders of performance and soundness (Bakhtiari & Heshmat 2009). Efficiency of horses is the main demand in all breeds with whatever purpose of use (Halo *et al.* 2008). Therefore, in sport horses, the objective evaluation of conformation and its relation to performance is of great importance (Moore 2010), and insufficient knowledge of the influence of conformation on performance and health can result in inaccurate selection. The breeding objective must be focused on the conformation traits (Jakubec *et al.* 2009), after all, the final aim of breeding programmes is a horse with certain conformation characteristics which stands out for its performance in sport (Belloy & Bathe 1996).

Nevertheless, the ideal conformation does not exist, because one conformation trait could be both advantageous for a certain locomotion characteristic and detrimental for others (Back *et al.* 1996).

When conformation measurements were analysed in the Pura Raza Español horse population (Table 1), the means obtained were similar to those reported in the same breed in previous analyses (Molina *et al.* 1999, Gómez *et al.* 2009) or in other breeds used for dressage performance, such as Lipizzan (Zechner *et al.* 2001) and Lusitano horses (Güedes 2008).

Descriptive statistics of the 13 conformation measurements are shown in Table 1. In general, their level of variation was medium to low, with coefficients of variation ranging between 2.3 % (*croup height*) and 9.3 % (*croup width*).

The coefficients of variation obtained were of a medium to low level (all of them lower than 10 %). Similar results were shown in the same breed and in other selected breeds (Molina *et al.* 1999, Zechner *et al.* 2001, Güedes 2008, Bakhtiari & Heshmat 2009). Therefore, we concluded that the analysed population is sufficiently homogeneous for these characters.

Consequently, we aim to detect conformation measurements that are good indicators of locomotive and gaits quality. Specific characteristics of trotting and canter are required for dressage, and so could be selected genetically and contribute to performance. Although the gait and conformation tests could be applied in breeding programs to detect more accurately young horses with good dressage performance (Barrey *et al.* 2002), its routine application is very expensive and the data processing takes a long time.

The present work aimed to estimate correlations between conformation measurements and biokinematic variables at trot (Table 2). Trotting quality (for dressage) is determined mainly by the amplitude of limb movements, the elasticity and a marked phase of suspension (Moore 2010). So, it is not a surprise that horse conformation conditioned locomotion ability (Güedes 2008). This relationship between conformation and function is a constant in physical issues.

Table 1
Descriptive statistics of 13 body measurements in 130 representative Pura Raza Español horses[1]

Traits	Mean ± SE	Minimum	Maximum	CV
WH	157.89 ± 0.337	147.0	167.0	2.42
CH	158.02 ± 0.313	149.5	169.0	2.25
CL	54.39 ± 0.217	48.5	61.0	4.20
WC	17.98 ± 0.161	15.0	24.0	9.29
HNP	89.81 ± 0.342	80.0	100.0	4.35
TD	66.67 ± 0.210	57.0	72.0	3.53
NBP	146.35 ± 0.761	123.0	165.0	5.60
CW	31.92 ± 0.285	26.0	40.5	9.20
HeL	61.30 ± 0.170	56.0	67.0	3.18
HP	44.14 ± 0.224	37.0	52.0	5.36
KP	33.80 ± 0.215	31.0	37.0	3.81
TP	188.96 ± 0.517	173.0	202.0	2.99
TW	40.61 ± 0.330	32.0	47.0	8.78

[1]The measurements are expressed in cm and the coefficients of variation in %.

The 155 significant genetic correlations between conformation measurements and biokinematic variables at trot (74.5 % of the total number of estimated correlations), are shown in Table 2 – 43.2 % of these were negative, most of them (49.2 %) with angular variables. The highest genetic correlation was 0.70 (*maximal angle of pelvis* with *neck-body perimeter* and with *thorax perimeter*), and the lowest (absolute value) was between *hindlimb stance phase duration* and *knee perimeter* (0.02). Only 10.32 % of them were higher than or equal to 0.50 (absolute value).

Croup length was the most correlated measurement with biokinematic variables at trot (16 genetic correlations), and *croup width* was the least correlated one (7). *Forelimb length* and *forelimb duration* were the variables most correlated with conformation measurements in this analysis (12), whereas the *minimal angle of carpus* was the least correlated one (5).

Croup length has been the trait which correlated most closely with all the biokinematic variables analysed. Previous papers have shown the importance of the croup, for example in the Spanish Arab horse, for »size« analysis, and the most significant differences between morphological and endurance aptitude were observed in the posterior triangle (Cervantes

Table 2
Significant genetic correlations (with standard errors) between 13 body measurements and 16 biokinematic variables at trot in 130 representative Pura Raza Español horses

TRAIT	VAR	CORR
WH	FL	0.25 ± 0.034
	FD	0.26 ± 0.035
	FStD	0.35 ± 0.033
	FSwD	0.34 ± 0.034
	FMH	−0.18 ± 0.055
	HL	0.55 ± 0.032
	HD	−0.55 ± 0.032
	HStD	−0.33 ± 0.045
	HSwD	−0.31 ± 0.059
	HMH	0.21 ± 0.130
	SmA	−0.32 ± 0.114
	TmA	−0.42 ± 0.118
	FMRP	0.32 ± 0.157
	PMA	0.36 ± 0.178
CH	FL	0.28 ± 0.060
	FD	0.29 ± 0.063
	FStD	0.39 ± 0.080
	FSwD	0.38 ± 0.078
	FMH	−0.20 ± 0.067
	HL	−0.17 ± 0.013
	HD	0.17 ± 0.013
	HStD	0.12 ± 0.014
	HSwD	0.07 ± 0.037
	HMH	0.29 ± 0.138
	SmA	−0.29 ± 0.137
	TmA	−0.35 ± 0.136
	FMRP	0.34 ± 0.165
	PMA	0.45 ± 0.172
CL	FL	0.27 ± 0.056
	FD	0.29 ± 0.056
	FStD	0.38 ± 0.054
	FSwD	0.36 ± 0.055
	FMH	−0.24 ± 0.071
	HL	−0.37 ± 0.038
	HD	0.37 ± 0.039
	HStD	0.11 ± 0.048
	HSwD	0.08 ± 0.063
	HMH	0.32 ± 0.113
	CmA	−0.12 ± 0.117
	SmA	−0.34 ± 0.117
	TmA	−0.39 ± 0.120
	HmRP	−0.23 ± 0.136
	FMRP	−0.33 ± 0.143
	PMA	0.48 ± 0.178
WC	FL	−0.25 ± 0.184
	FD	−0.27 ± 0.184
	HStD	−0.42 ± 0.180
	CmA	−0.69 ± 0.145
	HmRP	0.41 ± 0.242
	FMRP	−0.49 ± 0.224
	PMA	0.03 ± 0.012

TRAIT	VAR[b]	CORR
HNP	FL	0.25 ± 0.091
	FD	0.26 ± 0.091
	FStD	0.32 ± 0.089
	FSwD	0.30 ± 0.090
	FMH	−0.19 ± 0.099
	HL	−0.07 ± 0.029
	HD	0.07 ± 0.029
	HMH	0.53 ± 0.110
	CmA	−0.21 ± 0.133
	SmA	−0.23 ± 0.149
	TmA	−0.48 ± 0.128
TD	FL	0.40 ± 0.050
	FD	0.42 ± 0.052
	FStD	0.56 ± 0.047
	FSwD	0.53 ± 0.049
	FMH	−0.46 ± 0.077
	HL	−0.19 ± 0.020
	HD	0.19 ± 0.020
	HStD	0.08 ± 0.023
	SmA	−0.32 ± 0.141
	TmA	−0.47 ± 0.132
	HmRP	−0.42 ± 0.163
NBP	FL	0.14 ± 0.089
	FD	0.15 ± 0.089
	FStD	0.20 ± 0.088
	FSwD	0.17 ± 0.089
	HL	−0.36 ± 0.150
	HD	0.35 ± 0.150
	HMH	0.22 ± 0.174
	TmA	−0.31 ± 0.172
	PMA	0.70 ± 0.161
CW	FL	0.30 ± 0.105
	FD	0.32 ± 0.106
	FStD	0.44 ± 0.100
	FSwD	0.43 ± 0.101
	FMH	−0.37 ± 0.118
	HL	−0.13 ± 0.048
	HD	0.13 ± 0.048
	HStD	0.06 ± 0.049
	HMH	0.45 ± 0.151
	CmA	−0.26 ± 0.164
	TmA	−0.35 ± 0.180
	HmRP	−0.29 ± 0.201
	PMA	0.28 ± 0.193
HeL	FL	0.44 ± 0.109
	FD	0.46 ± 0.109
	FStD	0.65 ± 0.094
	FSwD	0.61 ± 0.098
	FMH	−0.38 ± 0.141
	HMH	0.26 ± 0.119
	SmA	−0.33 ± 0.122
	TmA	−0.54 ± 0.115
	FMRP	0.26 ± 0.172

TRAIT	VAR	CORR
HP	FL	0.15 ± 0.052
	FD	0.16 ± 0.052
	FStD	0.21 ± 0.052
	FSwD	0.20 ± 0.052
	FMH	−0.19 ± 0.057
	HL	0.32 ± 0.038
	HD	−0.32 ± 0.038
	HStD	−0.26 ± 0.039
	HSwD	−0.26 ± 0.049
	HMH	0.30 ± 0.152
	CmA	0.22 ± 0.162
	SmA	−0.35 ± 0.150
	TmA	−0.61 ± 0.143
	FMRP	0.33 ± 0.202
KP	FL	0.30 ± 0.044
	FD	0.31 ± 0.045
	FStD	0.43 ± 0.042
	FSwD	0.42 ± 0.044
	FMH	−0.08 ± 0.073
	HL	−0.05 ± 0.017
	HD	0.05 ± 0.018
	HStD	−0.02 ± 0.018
	HSwD	−0.06 ± 0.036
	HMH	0.36 ± 0.148
	SmA	−0.18 ± 0.162
	TmA	−0.45 ± 0.148
	HmRP	−0.43 ± 0.193
	FMRP	0.53 ± 0.177
	PMA	0.42 ± 0.214
TP	FL	0.16 ± 0.052
	FD	0.17 ± 0.053
	FStD	0.23 ± 0.052
	FSwD	0.21 ± 0.052
	FMH	−0.23 ± 0.056
	HL	0.31 ± 0.039
	HD	−0.31 ± 0.039
	HStD	−0.22 ± 0.041
	HSwD	−0.28 ± 0.050
	HMH	0.21 ± 0.148
	SmA	−0.22 ± 0.147
	TmA	−0.34 ± 0.139
	PMA	0.70 ± 0.145
TW	HL	0.57 ± 0.058
	HD	−0.57 ± 0.058
	HStD	−0.27 ± 0.078
	HSwD	−0.15 ± 0.100
	HMH	0.31 ± 0.174
	SmA	−0.34 ± 0.172
	TmA	−0.50 ± 0.157
	HmRP	−0.48 ± 0.185
	PMA	0.39 ± 0.226

2009). According to Koenen *et al.* (1995), a long, steep croup shows a very close correlation with trotting characteristics. Güedes (2008) showed that the *croup length* is a trait which correlates very closely with biokinematic variables at trot in Lusitano horses, with an important negative correlation with the *maximum retraction angle of hindlimb* and *maximum protraction angle of hindlimb*. In Pura Raza Español horse, *croup length* is associated with angles and temporal traits at trot. A total of 43.7 % of the genetic correlations obtained for this trait have been negative, mainly with angular traits. Back *et al.* (1996) reported that as this angle was smaller, more of it was tucked under the trunk of the hindlimb, which is conducive to concentration of gait. Clayton (2001) also considered that the pelvis should be nearer to the horizontal in dressage horses. *Croup width* was the lowest correlated trait with biokinematic variables at trot (6: 1 linear, 1 temporal and 4 angular traits).

As regards *withers height*, different results have been shown in previous papers. Some analyses have shown a close correlation between *withers height* and performance or locomotion problems (Magnusson & Thafvelin 1985, Baban *et al.* 2009), whereas Dusek *et al.* (1970) affirmed that *withers height* was not correlated to stride length for different gaits. Galisteo *et al.* (1998) obtained positive correlations between *withers height* and stride length and overtracking; and they also record a moderate influence of *withers height* on angular parameters while trotting, without there being any temporal ones. Our results differ from those of the previous authors, because *withers height* correlated with most of the biokinematic variables (14: 6 temporal, 4 linear and 4 angular variables), including all the temporal and linear ones.

Croup height has similar genetic correlations with the biokinematic variables to *withers height* (same sign and similar values), except for those in the hindlimb (*hindlimb duration* and *length; stance* and *swing phase duration*). This could be caused by the close phenotypic correlation between both traits, the highest between all the conformation measurements included in this study (0.80, results not shown). The differences between them are related to the changes in hindlimb function due to changes in the relative measurements and angles (more influenced by *croup height*).

The head and neck determine athletic ability (Lawrence 2001), back movement and stride characteristics at trot, as well as *stride length* (Rhodin *et al.* 2005). In this regard, Holmström *et al.* (2001) suggested that good head-neck and neck-body insertion are more important than neck length for dressage ability. Lawrence (2001) also affirmed that the head-neck connection must be favourable to achieve free movement and flexion. Two conformation variables were analysed to illustrate these two insertions: *head-neck perimeter* and *neck-body perimeter*, both of which are correlated with biokinematic variables at trot (11 and 9 genetic correlations, respectively), ranging between 0.07 and 0.70 (1 correlation equal to or above 0.50, for both traits).

If the neck acts as a lever, *head length* acts as a counterweight. A total of 9 genetic correlations were significant, 3 of them are equal to or over 0.50 in absolute values. The closest correlations were with: *forelimb stance phase duration* (0.65), *forelimb swing phase duration* (0.61) and *minimal angle of tarsus* (−0.54).

Thorax perimeter, thorax depth and *chest width* have shown a large number of medium-range genetic correlations with biokinematic variables at trot (13, 11 and 13, respectively), all of which had similar values and signs, except for the hindlimb variables at trot. This could be explained because the horse's forelimbs are attached to the trunk by a strong muscular belt (no joints) and therefore the impact that traits like trunk width or trunk perimeter can have over the biokinematic traits of the forelimb. Finally, conformation measurements analysed in the limbs, *knee* and *hock perimeter,* correlated with most of the biokinematic variables at trot (15 and 14, respectively). Both of them correlated with all the linear and temporal variables analysed, and some differences were observed in angular traits. Although they have similar signs and values, the very close correlation between *knee perimeter* and *maximal retraction-protraction angle of forelimb* (0.53), and between *hock perimeter* and *minimal angle of tarsus* (−0.61) is remarkable.

In addition to this, *stifle angle* has been considered as an important variable for gait quality. A large opening *stifle angle* causes a significant constriction of the quadriceps in the thigh, which is probably the most overworked muscle in collected gaits. The inability of the quadriceps to support the maximum weight makes the horse shift the burden onto the forelimb, thus altering the balance (Holmström 2001). Magnusson & Thafvelin (1985) found a positive correlation between *stifle angle* and sports results. This could be caused by changes in maximum retraction-protraction range with a more upright pelvis and lower angles of the knee joint (Back *et al.* 1996). In this work, the *stifle angle* correlates negatively with most of the analysed traits, except *croup width*, *neck-body perimeter* and *chest width*.

The analysis of body measurements allows us to describe an animal or breed's conformation and to detect conformation traits that identify locomotion quality. Barrey *et al.* (2002) affirmed that, although conformation by itself can not explain the ability for dressage performance, differences in conformation can be responsible for some locomotion characteristics. The importance of the locomotor pattern is related to the fact that for each type of exercise, the horse uses a specific type of locomotion, where its individual characteristics determine the level of performance it can achieve (Leleu *et al.* 2005).

The factor analysis for the 13 body measurements and the 16 biokinematic variables at trot (Figure 2) showed that Factor 1 separates durations and limb length from the others. It also separates *minimal retraction-protraction angle of the hindlimb* and *maximal retraction-protraction angle of the forelimb*, whereas Factor 2 separates the temporal and linear variables (including the conformation measurements) from the other traits.

Temporal and linear traits were related between them (Factors 1 and 2), and with the conformation traits analysed (Factor 2), whereas angular traits measured in the distal area of the limbs were not related with conformation measurements (Factor 2). Therefore, the factorial analysis indicated that the length of body regions influence linear and temporal parameters for trotting more than angular parameters in the Pura Raza Español horses.

In conclusion, most of the analysed body measurements are genetically correlated with some biokinematic variables at trot. Therefore, their inclusion in the breeding programme of a breed, such as the Pura Raza Español horse, is recommended. This ensures the implementation of an indirect and precocious selection of the animals based on the objective conformation measurements proposed in this study, thus producing a suitable response. According to our results, the relationships of conformation traits between each other and with biokinematic variables while trotting show that it is important to study *withers height*, *croup length*, *croup width*, *knee perimeter*, *hock perimete*r and *thorax perimeter* in order to make an indirect and precocious selection of gait quality in Pura Raza Español horses. These could be included directly or combined in body indices.

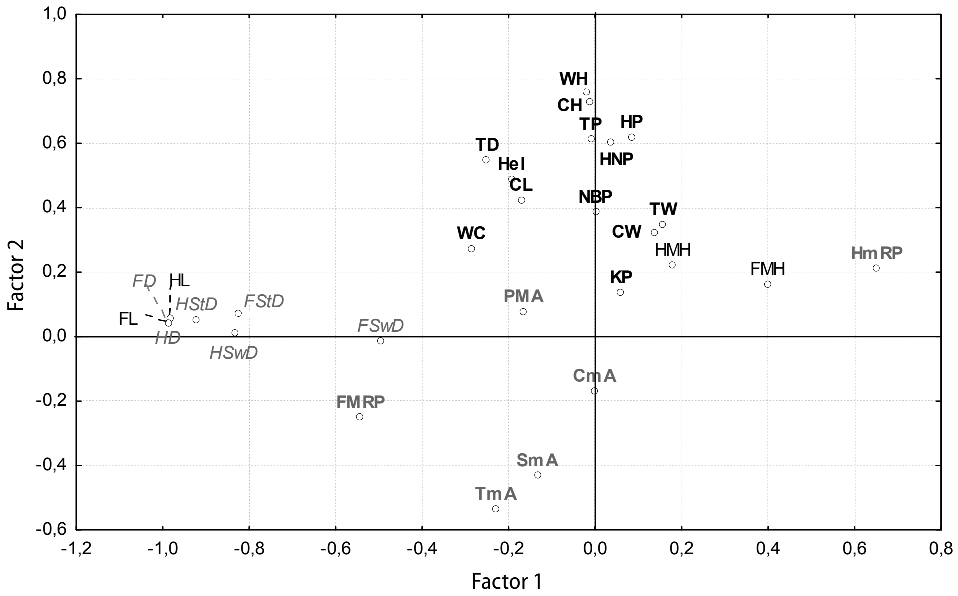


Figure 2
Factor loadings for 29 selected variables (13 body measurements and 16 variables biokinematic at trot) analysed in 130 Pura Raza Español horses

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