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Genetic relationship between free movement and under rider gaits in young Pura Raza Española horses

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HIGHLIGHTS

- An early preselection in young horses saves costs and increases the genetic progress in the improvement of the range of functions of the PRE horse.
- The heritability for the three natural gaits, can be considered suitable for genetic selection of breeding stock based on genetic values.
- The high genetic correlations found between the same gaits according to the type of presentation of the young horse allow us to carry out an early pre-selection that can participate in dressage competitions.

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ABSTRACT

The Pura Raza Española (PRE) horse is an autochthonous Spanish horse characterized by its versatility, mental balance, and its balanced conformation, which makes it suitable for sports disciplines such as dressage. The aim of this study was to determine the genetic correlation between the quality of natural gaits in young horses, when the horse is evaluated in the Basic Aptitude Test (free movements, FM) and during dressage competitions (functionality tests and gaits under rider, UR). A total of 37,822 and 2730 PRE horses were evaluated for FM and UR, respectively, of which 1023 horses had records for both (coincidence animals). Genetic parameters were estimated using VCE software. Effects were included in the final model according to significant results in analyses of variance (*GLM*). For FM and UR, the genetic model included age as a linear covariate, gender, coat colour and stud size as fixed effects, and for UR, the rider and permanent environmental effects were also included as random effects. The pedigree file information included a minimum of 4 generations: 88,558 horses (FM), 13,837 horses (UR) and 9072 horses (coincidence animals). Heritabilities were estimated for the two data sets (FM and UR) and, for the coincidence population, heritabilities and genetic correlations were also estimated. The heritability for walk, trot and canter (FM) were 0.20, 0.22, 0.22, while for UR they were 0.26, 0.31, 0.33, respectively. For coincidence animals, the heritability for walk, trot and canter (FM) were 0.43, 0.33, 0.22, while for UR they were 0.23, 0.11, 0.10, respectively. The genetic correlations between FM and UR traits were high and positive; 0.49 for walk, 0.61 for trot and 0.54 for canter. The genetic parameters obtained highlight the possibility of preselecting gait traits in young horses destined to participate in sporting competitions.

1. Introduction

The horse is an athletic animal whose economic value depends mainly on its sports performance (Wallin et al., 2003; Braam et al., 2011). However, such performance is the result of a complex combination of training, and conformational, physiological and behavioural characteristics which are largely inherited (Giulotto, 2001; Brooks et al., 2010; Solé et al., 2013; Sanchez et al., 2016a). In sport horse breeding programs, great importance has always been attached to improving gait quality, despite the differences between certain breeds (Barrey et al., 2002; Koenen et al., 2004; Komosa et al., 2013; Sánchez et al., 2014). Most countries select horses using conformation as an indication of later performance. Horses with a favourable conformation are assumed to perform better (Wallin et al., 2003). For this reason, there is a growing need for studying and accurately examining functionality and kinematic characteristics in most horse breeds, as in the case of the following breeds: Swedish Warmblood horses (Wallin et al., 2003), Warmblood sport Horses (Koenen et al., 2004), Lipizzaner (Baban et al., 2009),

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Jumping horses (Lewczuk and Ducro, 2012), Menorca horses (Solé et al., 2013), Lusitano (Solé et al., 2014), Campolina horses (Bussiman et al., 2018), French trotters (Górniak et al., 2020), Icelandic horses (Rosengren et al., 2021), and the Pura Raza Española (PRE) horse (Molina et al., 2008; Valera et al., 2008; Sanchez et al., 2013a; 2016a).

The PRE is the most important equine breed in Spain from the census point of view and one of those that generates the greatest impact on economy and tourism throughout the country (Sánchez-Guerrero et al., 2017a). Its characteristics make it a very versatile and functional animal, and it is one of the most valued equine breeds worldwide (Valera, 2017; Poyato-Bonilla et al., 2018), present in over 65 countries (Solé et al., 2018). The main objective of the PRE breeding program is to obtain animals with favourable functional aptitudes that enable outstanding performance in dressage competitions, for this reason, gait quality has a considerable impact on the value of a horse.

Dressage is a discipline based on the harmony between rider and horse, and requires a lot of training to perform difficult movements. Here, the horse's gaits are of major relevance, since they determine the final score obtained by the animals participating in these events. For this reason, the rider has been considered a relevant environmental factor in the genetic evaluations of dressage horses (Kearsley et al., 2008; Viklund et al., 2011; Sánchez et al., 2014, 2016b).

The study of the natural gaits of PRE horses in free movement is performed by assessing the basic aptitudes of young horses at the age of at least three years old. This basic aptitude assessment is an essential requirement for the horses to be registered in the breed studbook.

The main objective of this study was to determine the genetic correlation between the quality of the natural gaits in young horses, when the horse's basic aptitude is evaluated (free movements, FM) during functionality tests and gaits under rider (UR), during dressage competitions.

2. Material and methods

2.1. Data set

The functional variables analysed correspond to the three gaits of the horse: walk, trot, and canter. In basic aptitude, each gait was evaluated separately by 1 judge, who gave the horse a score ranging from 1 to 9 points, on a linear scale where 1 was the worst mark and 9 the best (Sánchez et al., 2013a). These evaluations were carried out by a total of ten judges, all of whom had been previously trained and tested, and had the same evaluation criteria.

In dressage competitions, the score used was the average from the three judges for each gait trait (the total number of judges for dressage was 77). All the judges involved were international judges recognized by the Royal Spanish Equestrian Federation (RFHE). In addition, all the competitions were connected through the judge effect (repetition of judges in the different competitions).

The FM data consisted of 37,822 records of walk, trot, and canter from 37,822 PRE horses (12,752 males and 25,070 females) with an average age of 4.73 years old. The data was collected from 2012 to 2021 by the Royal Association of Spanish Horse Breeders (ANCCE), during basic aptitude assessment of the PRE for registration in the stud book of potential breeding stock.

The dressage data consisted of 13,694 records of walk, trot, and canter from 2730 PRE horses (2559 males and 171 females), with an average age of 4.92 years old. The data was collected from 2004 to 2021 by the ANCCE and the RFHE during dressage reprises.

To participate in the performance test (dressage and basic aptitude), the horse had to be registered in the Pura Raza Española horse studbook.

A selection of coincidence horses was made according to the following criteria:

- Horses participating in FM and UR.
- Horses ridden by more than one rider.
- Horses that had participated at least three times in dressage.
- Age between 4 and 6 years old.

The number of coincidence horses that met these criteria was 1023 (931 males and 92 females), with a total of 8142 records for UR (Table 1).

2.2. Genetic model

A General Linear Model was used to examine the associations between gaits (walk, trot and canter) and the potential effects. A Tukey Post-hoc analysis was also carried out to analyse the significant differences between factor levels. Statistical analyses were performed using SAS (Statistical Analysis System, version 9.2, 2011).

The genetic parameters were estimated with VCE software (Groeneveld, 2010) which allows us to analyse two different datasets with two different models at the same time, one for FM and other for UR. The analysis was performed with three different approaches: (1) Univariate genetic analysis for FM; (2) Univariate genetic analysis for UR; and (3) Bivariate genetic analysis with heterogeneity of variance for coincidence animals (FM+UR). The equations in matrix notation to solve the mixed model were:

$$Y_{FM} = Xb + Zu + e \quad (1)$$

The effects studied for FM were: age as linear covariate (expressed in months), gender (2 levels; male and female), coat colour (4 levels; bay, chestnut, black, and grey), and stud size (5 levels;1–2 foals born per year, 3–6 foals born per year, 7–12 foals born per year, >13 foals born per year, and non-breeding livestock).

$$Y_{UR} = Xb + Zu + Qr + Wp + e \quad (2)$$

The effects studied for UR were: age as linear covariate (expressed in months), gender (2 levels; male and female), coat colour (4 levels; bay, chestnut, black, and grey), and stud size (5 levels;1–2 foals born per year, 3–6 foals born per year, 7–12 foals born per year, >13 foals born per year, and non-breeding livestock). The two random effects also studied were rider (1113 levels) and permanent environmental effect (2730 levels).

$$Y_{FM} = Xb + Zu + e \quad (3)$$

$$Y_{UR} = Xb + Zu + Qr + Wp + e$$

The effects studied for the coincidence animals were: age as linear covariate (expressed in months), gender (2 levels; male and female), coat colour (4 levels; bay, chestnut, black, and grey), and stud size (5 levels;1–2 foals born per year, 3–6 foals born per year, 7–12 foals born per year, >13 foals born per year, and non-breeding livestock). The two additional random effects studied were rider (565 levels) and permanent environmental effect (1023 levels). where $\boldsymbol{u} \sim N(0, A\sigma_u^2)$, $\boldsymbol{r} \sim N(0, I\sigma_r^2)$, $\boldsymbol{p} \sim N(0, I\sigma_p^2)$ and $\boldsymbol{e} \sim N(0, I\sigma_e^2)$; $\boldsymbol{y}$ = vector of observations (phenotypic values); $\boldsymbol{b}$ = vector of systematic effects; $\boldsymbol{u}$= vector of infinitesimal additive genetic contribution; $\boldsymbol{r}$ = vector of rider effects; p = vector of permanent environmental effect; e= vector of residuals; $\boldsymbol{X}$= incidence matrix of systematic effects; $\boldsymbol{Z}$= incidence matrix of additive genetic contribution; $\boldsymbol{Q}$ = incidence matrix of the rider effect and $\boldsymbol{W}$ = incidence matrix of permanent environmental effects. σ2 u = direct genetic variance; $\boldsymbol{\sigma_r^2}$ = rider variance; $\boldsymbol{\sigma_p^2}$ = permanent environmental variance; $\boldsymbol{\sigma_e^2}$ =

Table 1
Number of participants and records of Pura Raza Española horses during dressage competitions and basic aptitude test.

	Animals	Male	Female	Records
Basic aptitude	37,822	12,752	25,070	37,822
Dressage test	2,730	2,559	171	13,694
Coincidence horses	1,023	931	92	8,142

residual variance ; **A** matrix of additive genetic correlations between individuals, **I** the identity matrix that links all individuals in the pedigree.

The pedigree information for the genetic evaluation was collected from the PRE official studbook. At least four generations of all the horses in the control group were included in the pedigree file. For each of the assessments (FM, UR, and coincidence animals), a pedigree file was built with 88,558, 13,837 and 9072 individuals, respectively.

3. Results

The descriptive statistics of the FM and UR gaits analysed in PRE horses are shown in Table 2. The average values oscillated between 6.37 (canter-FM) and 6.74 (canter-UR), with a coefficient of variation of 17.62% and 7.68%, respectively. The highest mean value for FM was obtained for trot (6.56) while in UR the highest value was obtained for canter (6.74). It was also observed that the average values in FM were always lower than those obtained in UR, while the lowest coefficient of variation was obtained for UR. The minimum value obtained in the evaluation of both disciplines was 1 and the maximum 9; the trot was the gait which was awarded the most points in the horses under rider in dressage competitions (Table 2).

The general linear model results are shown in Table 3. All the factors studied in FM (gender, age, coat colour, stud size) and in UR (gender, coat colour, stud size, age, rider and permanent environmental effect) showed statistically significant differences for all the traits analysed.

The genetic parameters for FM and UR movements are shown in Table 4. The heritability ratios showed moderate values for all the variables, oscillating from 0.20 (walk) to 0.22 (canter) for FM and from 0.26 (walk) to 0.33 (canter) for UR. For coincident horses, heritability for FM oscillated between 0.22 (canter) to 0.43 (walk) and for UR from 0.10 (canter) to 0.23 (walk). The genetic correlations between FM and UR, estimated from coincident animals, were of a high magnitude, ranging from 0.49 for walk to 0.61 for trot.

Fig. 1 shows the percentage of coincident animals within 25% and 10% of the highest estimated breeding values (EBV) for each of the three gaits (walk, trot and canter). As can be seen, within 25% of the highest EBV, the percentage of coincident animals oscillates between 76.76% (trot) and 62.43% (walk). Meanwhile, the coincident animals within the 10% highest EBV oscillates between 68.36% (trot) and 52.04% (walk).

Table 3
Means ± standard errors of mean, General linear model (GLM) between the gaits (walk, trot and canter) with the different factors analysed and Post-Hoc (Tukey).

Factors	Free movement			Under rider		
	Walk	Trot	Canter	Walk	Trot	Canter
Gender	***	***	***	*	***	n.s.
Male	6.56 ± 0.009^{b}	6.65 ± 0.009^{b}	6.65 ± 0.010^{b}	6.40 ± 0.005^{a}	6.51 ± 0.005^{a}	6.61 ± 0.004
Female	6.42 ± 0.005^{a}	6.51 ± 0.006^{a}	6.22 ± 0.007^{a}	6.45 ± 0.020^{b}	6.59 ± 0.018^{b}	6.61 ± 0.016
Coat color	***	***	***	n.s.	***	***
Bay	6.45 ± 0.008^{b}	6.52 ± 0.009^{b}	6.35 ± 0.009^{b}	6.43 ± 0.008	6.58 ± 0.007^{b}	6.61 ± 0.007^{bc}
Chestnut	6.32 ± 0.019^{a}	6.42 ± 0.022^{a}	6.29 ± 0.023^{ab}	6.47 ± 0.029	6.55 ± 0.027^{ab}	6.67 ± 0.025^{b}
Black	6.38 ± 0.014^{a}	6.45 ± 0.015^{a}	6.28 ± 0.016^{a}	6.38 ± 0.018	6.52 ± 0.015^{a}	6.59 ± 0.015^{ac}
Grey	6.53 ± 0.007^{c}	6.63 ± 0.008^{c}	6.41 ± 0.008^{c}	6.43 ± 0.007	6.54 ± 0.006^{a}	6.56 ± 0.006^{a}
Stud size	***	***	***	**	**	**
1–2 foals per year	6.42 ± 0.008^{a}	6.46 ± 0.009^{a}	6.26 ± 0.010^{a}	6.43 ± 0.011^{ab}	6.57 ± 0.010^{b}	6.63 ± 0.010^{b}
3–6 foals per year	6.50 ± 0.010^{b}	6.60 ± 0.012^{b}	6.40 ± 0.012^{b}	6.46 ± 0.011^{b}	6.56 ± 0.010^{b}	6.62 ± 0.009^{ab}
7–12 foals per year	6.49 ± 0.013^{b}	6.65 ± 0.015^{b}	6.43 ± 0.016^{b}	6.42 ± 0.013^{ab}	6.55 ± 0.013^{ab}	6.62 ± 0.012^{ab}
>13 foals per year	6.55 ± 0.013^{c}	6.73 ± 0.014^{c}	6.55 ± 0.014^{c}	6.40 ± 0.012^{a}	6.54 ± 0.010^{ab}	6.59 ± 0.009^{ab}
Non-breeding livestock	6.40 ± 0.013^{a}	6.44 ± 0.014^{a}	6.31 ± 0.015^{a}	6.43 ± 0.010^{ab}	6.52 ± 0.008^{a}	6.58 ± 0.009^{a}
Age	***	***	***	***	***	***
Rider	–	–	–	***	***	***
Permanent environmental effect	–	–	–	***	***	***

Different superscript letters (a, b, c, d, e) indicate statistically significant difference between means at *** $p<0.001$; ** $p<0.01$; * $p<0.05$.

Table 2
Descriptive statistics analysis of natural gait traits evaluated in free movement during evaluation of basic aptitude in Pura Raza Española horses and under the rider during evaluation of dressage competitions. Comparison of means (Student's *t*-test) between horse gaits.

Trait	Free movement				Under Rider				p
	Mean ± SE	C.V. (%)	Min.	Max.	Mean ± SE	C.V. (%)	Min.	Max.	
Walk	6.46 ± 0.004	14.89	1	9	6.60 ± 0.005	9.26	2	9	***
Trot	6.56 ± 0.005	16.49	1	9	6.68 ± 0.005	8.19	1	9	***
Canter	6.37 ± 0.006	17.62	1	9	6.74 ± 0.004	7.68	1	9	***

C.V. (%) = Coefficient of variation; SE. standard error of the mean; Max= maximum; Min=minimum; *** $p<0.001$.

4. Discussion

In sport horses, gait quality has a considerable influence on their functional performance, especially in a sport discipline such as dressage. Animals that are balanced and elastic are highly sought after, and these qualities score highly at all levels of competition (Becker et al., 2011). However, the PRE horse has its own functional aptitudes and, therefore, certain characteristics of its three natural gaits, which differentiate it from most equine sport breeds.

In selection programs, it is vital to evaluate the animals at an early stage, which allows animals to be selected for training for later participation in sporting activities (Gómez-Ortiz et al., 2021). Evaluations of young horses in sport competitions have been used successfully in many breeds recognized by the World Breeding Federation of Sport Horses (WBFSH), such as Swedish (Viklund et al., 2008; Jönsson et al., 2014; Viklund and Eriksson, 2018), Dutch (Ducro et al., 2007a, 2009), Belgian (Rustin et al., 2009) Warmbloods and Hanoverian (Schröeder et al., 2010), Polish (Borowska et al., 2011), British sport horses (Stewart et al., 2011) and German horses (Schöpke et al., 2013).

Good scores in gait quality are essential both in the basic aptitude evaluation tests (FM) and in dressage competitions (UR), and for this

Table 4
Genetic parameters for gait traits evaluated during free movement or under rider with all evaluated animals and for coincidence horses (between parentheses).

	σ_u± SE	σ_p ± SE	σ_r ± SE	σ_e ± SE	h^2 ± SE	r_g ± SE
Walk						
Free movement	0.18 ± 0.011 (0.38 ± 0.094)	–	–	0.73 ± 0.010 (0.51 ± 0.083)	0.20 ± 0.011 (0.43 ± 0.099)	(0.49 ± 0.099)
Under rider	0.11 ± 0.016 (0.13 ± 0.034)	0.10 ± 0.013 (0.05 ± 0.028)	0.07 ± 0.007 (0.05 ± 0.009)	0.15 ± 0.002 (0.34 ± 0.001)	0.26 ± 0.036 (0.23 ± 0.047)	
Trot						
Free movement	0.26 ± 0.014 (0.31 ± 0.102)	–	–	0.90 ± 0.012 (0.62 ± 0.098)	0.22 ± 0.011 (0.33 ± 0.106)	(0.61 ± 0.168)
Under rider	0.10 ± 0.012 (0.05 ± 0.018)	0.03 ± 0.009 (0.05 ± 0.015)	0.07± 0.006 (0.04 ± 0.008)	0.12 ± 0.002 (0.31 ± 0.001)	0.31 ± 0.032 (0.11 ± 0.035)	
Canter						
Free movement	0.27 ± 0.016 (0.20 ± 0.091)	–	–	0.94 ± 0.014 (0.70 ± 0.094)	0.22 ± 0.012 (0.22 ± 0.100)	(0.54 ± 0.193)
Under rider	0.10 ± 0.012 (0.04 ± 0.014)	0.03 ± 0.009 (0.04 ± 0.013)	0.07 ± 0.006 (0.02 ± 0.005)	0.11 ± 0.001 (0.30 ± 0.001)	0.33 ± 0.036 (0.10 ± 0.031)	

σ_u=Additive genetic variances, σ_p= permanent environmental effect variances, σ_r= rider variances, σ_e= residual variances, h^2=heritabilities, rg= genetic correlations and SE=standard error.

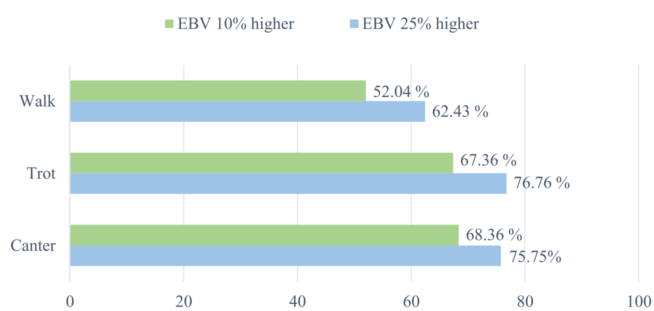

Fig. 1. Percentage of coincident horses in the highest 25 and 10 percentile of the estimated breeding values (EBV), for each gait trait of the Pura Raza Española horse.

reason, these variables are included in the performance controls of the PRE breeding program. In our study, we found gait scores in PRE horses (FM and UR) of between 6 and 7 points, as well as in Swedish Warmblood horses (Viklund et al., 2008, 2010) and Hispano-Arabian horses (Gómez et al., 2016).

Barrey et al. (2002) compared the gaits of walk and trot in German horses (Hanoverian, Oldenburger, and Westfalian), French saddle horses (Selle Français), and PRE horses, to evaluate their aptitude for dressage, with the German horses obtaining higher scores for their gaits. In our study, the gaits traits of the Pura Raza Española horse usually obtained higher scores when the horse was presented UR than for FM. This is probably due to the fact that the horses which participate in dressage have better quality gaits, thanks to their continuous training and because the best animals have been pre-selected to participate in this type of sporting event.

Regardless of the breed, most sport horse breeders aim to breed horses that excel in sport competitions, mainly dressage or show jumping, and different methods have been adopted across Europe to evaluate the functional performances of these horses (Bruns, 2001). To achieve good genetic progress of the horse in the dressage discipline, the intensity of selection must be high, as well as the heritability of the traits evaluated in competition (Hellsten et al., 2006). In this regard, a reliable estimation of genetic parameters (heritability and correlations) is essential to plan and carry out any selection programme.

There are many factors that influence horse gaits (Sánchez et al., 2014). The study of the environmental factors (Table 3) has shown that males are more successful in basic aptitude scores, while females score higher in dressage. In contrast, with Swedish Warmblood horses, males score higher in dressage tests (Viklund et al., 2008, 2010). However, most of the articles that study horse gaits do not differentiate the score by sex (Albertsdóttir et al., 2008; Becker et al., 2011; Sánchez-Guerrero et al., 2017a). Another effect that has been found to be significant is the coat, coinciding with Sánchez-Guerrero et al. (2019), who found significant differences in numerous conformation variables as a function of coat colour in the PRE horse or with the study by Perdomo-González et al. (2022) in the Pura Raza Menorquina horse. An association has also been found in the PRE between coat colour and certain conformational defects such as cresty neck (Sánchez et al., 2017b) or deep neck (Ripollés et al., 2020). The genetic correlations between conformation and gaits are usually reported to be positive and moderate to high (Ducro et al., 2007b; Vicente et al., 2014; Sanchez-Guerrero et al., 2017a). In this study, horses with a grey coat obtained higher scores for gaits in FM, compared to horses with other coats, although chestnut and bay horses showed the best scores in UR. According to Sánchez-Guerrero et al. (2019), PRE bay horses showed the greatest height at withers. This variable is perhaps one of the most studied, because of its relationship with the functionality of the horse, showing a positive relationship with the horse's sport performance (Magnusson and Thafvelin, 1985; Sánchez-Guerrero et al., 2017a, 2019) or the scores obtained in morphological contests (Holmström and Philipsson, 1993). Galisteo et al. (1998) estimated significant and high correlations with stride length and length of overtracking and a moderate influence with angular parameters. In this context, Sánchez et al. (2013b) showed that withers height had a significant relationship with most of the biokinematic variables (14 variables: 6 temporal, 4 linear and 4 angular), with a 0.55 relationship with hindlimb length.

Stud size is extremely important, because it influences the size of the farm and the type of management carried out. As observed in this study, horses from large studs, preferably dedicated to breeding and reproduction, showed higher FM gait scores, probably because these horses are under extensive management and have enough land to move about freely. On the other hand, horses from smaller studs obtained higher gait scores for dressage, possibly because they are from stud farms dedicated to training horses to participate in dressage.

In addition, the rider factor has a great influence on the gaits of the PRE horse, as shown in work carried out by other authors in different equine breeds, such as British sport horses (Kearsley et al., 2008). In functional studies carried out in the PRE breed (Sánchez et al., 2014), the rider factor and the rider-horse interaction are always included in the models for estimating genetic parameters in variables related to the functionality of the PRE in dressage. A good rider tends to stabilize the horse's locomotor pattern (Peham et al., 2004). We therefore decided to include the rider as a factor in the genetic parameter estimation model, following the indications of previous studies carried out in different equine breeds such as Anglo-Arabian (García-Ballesteros et al., 2018);

PRE (Sánchez et al., 2014, 2017a Solé et al., 2017; García-Ballesteros et al., 2018); Spanish Sport Horses (Bartolomé and Cockram, 2016, 2018), and Arabian horses (García-Ballesteros et al., 2018).

In the last decade, numerous studies have focused on analysing functionality in horse breeds, as is the case of the Royal Dutch Sport horse (KWPN) (Ducro et al., 2009), Warmblood sport Horses (Koenen et al., 2004), Swedish Warmblood horse (Gelinder et al., 2002; Wallin et al., 2003), Menorca horses (Solé et al., 2013), PRE horse (Valera et al., 2017; Sanchez et al., 2016a) and jumping horses (Ricard et al., 2020). Most studies on functional improvement in horses have focused on estimating the heritabilities of the horse's gaits in sporting events (Olsson et al., 2000; Wallin et al., 2003; Ducro et al., 2007a, 2007b; Viklund et al., 2008; Medeiros et al., 2020). Studies that have estimated heritabilities for variables related to sport performance have produced relatively low values, which can be attributed to the high influence of environmental effects on functional traits (Barrey et al., 2002; Wallin et al., 2003), such as Hispano-Arab horses, whose heritability for the three gaits, walk, trot and canter, were 0.10, 0.13, 0.13, respectively (Gómez et al., 2016).

Considering all the animals evaluated in our study, the heritability was higher when the horse was evaluated during UR. This may be due to the fact that the UR population is smaller, with fewer animals participating, and that these animals are pre-selected by breeders to participate in this discipline. In addition, the animals participating in dressage competitions are usually related to each other, and it is very common for descendants of animals with good results in dressage to participate in these competitions. Therefore, the coancestry between them is usually greater. According to Becker et al. (2011), the values for the heritability of Oldenburger horse gaits in UR were 0.33, 0.39, and 0.34, for gait, trot, and canter, respectively. The heritability values in gaits for the PRE are slightly lower than those obtained in Oldenburger. This may be due to the greater specialization that German horses have had over time in the sport of dressage, in contrast to the PRE. However, these differences could also be attributed to the fact that the Oldengurger population analysed is more homogeneous, as the study only considered one sex (all the animals evaluated were mares).

In the case of the coincidence animals in our study, the heritability was higher when the horse was evaluated during FM. The horse performed the movements in freedom and were therefore not influenced by external factors. These gaits are natural and are therefore more homogeneous and more heritable. The heritability values for FM obtained in this study were similar to the heritability of natural gaits studied in the KWPN horse by Ducro et al. (2007a), where values of 0.35 were obtained for walk, 0.50 for trot, and 0.25 for canter; in the Brazilian Horses (Medeiros et al., 2020), where values of 0.36 were obtained for walk, 0.54 for trot, and 0.35 for canter; and in Oldenburger horses, where values of 0.38 were obtained for walk, 0.49 for trot, and 0.34 for canter. In the genetic model of UR, certain external factors cannot be included, such as the type and hours of training, length of preparation of the horse, feeding, whether the rider who trains is the same rider who participates in the dressage competition, etc. The heritability values for UR were lower than those obtained in PRE competition horses (Sánchez-Guerrero et al., 2017a), where the heritability for walk was 0.21, for trot 0.27, and 0.33 for canter. This may be due to the fact that in our study, a wider range of criteria was used to select the horses. By using criteria to select coincident animals (horses participating in FM and UR, horses ridden by more than one rider, horses having at least three dressage participations, age between 4 and 6 years), improved heritabilities were obtained.

The value of genetic correlations is fundamental for building selection indices or for predicting correlated responses to selection (Sánchez-Guerrero et al., 2017a). The genetic correlations obtained in this study between the same gaits were considerably high, with trot being the gait with the highest genetic correlation, which when analysed for FM, best reflects the trot scores in UR (Solé et al., 2013). The high genetic correlations found between FM and UR gaits imply a very good predictability in dressage results for young horses. However, the correlations obtained by Becker et al. (2011) in Oldenburger horses were considerably higher, namely 0.84 (walk), 0.71 (trot), and 0.9 (canter). This may be due to the fact that in German breeds, selective efforts have achieved a significant superiority of horses in dressage competitions (Barrey et al., 2002). These results are in line with different studies in other breeds, such as Dutch Warmblood (Ducro et al., 2007a), Swedish Warmblood (Wallin et al., 2003; Viklund et al., 2008) and PRE horse (Sánchez-Guerrero et al., 2017a), all of which have obtained positive and high genetic correlations between FM and dressage competitions.

Finally, Fig. 1 shows the importance of considering the evaluation of the young horse's natural gaits in the basic aptitude tests. In this way, breeders can to carry out an early pre-selection of PRE horses destined to participate in dressage competitions, in order to ensure a good selection response. It should be noted that, if the intensity of selection in this breed is high, the percentage of animals with the best evaluations for trot and canter, with or without rider, would be over 67%, and for walk, would be over 52%.

5. Conclusion

The estimated heritability for the three natural gaits of the PRE horse, whether in *free movements* (FM) or *under rider* (UR), can be considered suitable for genetic selection of breeding stock based on genetic values. In the same way, the high genetic correlations found between the same gaits according to the type of presentation of the young horse (FM or UR) allow us to carry out an early pre-selection of animals that can participate in dressage competitions. This pre-selection entails an important economic advantage and time saving for the breeder and, indirectly, greater genetic progress in the improvement of the range of functions of the PRE horse.

Author contributions

Conceptualization, Valera, M; data curation and preparation, Ripollés M., Sánchez-Guerrero, M.J.; methodology, Ripollés M., Sánchez-Guerrero, M.J., Bartolomé, E.; formal analysis, Ripollés M.; Perdomo-González, D.I.; genetic parameters estimation, Ripollés M., Perdomo-González, D.I., results validation, Ripollés M., Valera, M., Bartolomé, E.; discussion, Ripollés M., Perdomo-González, D.I., Valera, M.; writing—original draft preparation, Ripollés M.; writing—review and editing, Ripollés M.; supervision, Valera, M.; funding acquisition, Valera, M. All authors have read and agreed to the published version of the manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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