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INTEGRATION OF LINEAR ASSESSMENT OF CONFORMATION TRAITS IN BREEDING PROGRAMS: POTENTIAL AND LIMITATIONS

0

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LINEAR ASSESSMENT IN SPAIN

- Nowadays in Spain: 6 populations with a linear assessment system for conformation control
- Conformation control in studs, morphological shows, test for mares and stallions …

BREED	
Pura Raza Español	PRE
Menorca Purebred Horses	PRMe
Spanish Arab Horses	PRÁ
Spanish Sport Horses	CDE
Pottoka	POTT
Spanish Heavy Horses	SHH

Most advanced

- Evaluation sheets are in constant evolution as the populations

1

CONFORMATION - DRESSAGE PERFORMANCE

- Back et al. (1996) affirmed that **ideal conformation does not exist**, because a conformation trait could be both advantageous for a certain locomotive characteristic and detrimental to other.
- Dressage performance **does not depend solely on conformation**. A long period of learning and training is required for a horse to achieve the greatest level, which entails a major economic investment.
- Favorable conformation is not the only requirement to obtain good movements, but **a minimum level of conformation is needed** to obtain a good horse.
- Searching traits indirectly related to dressage performance would allow early selection of animals. So, **studs can save money** and use it with animals which have morphological athletic skills.
- Selection of horses which display adequate morphological qualities for dressage would **benefit genetic progress** and allows the **screening of animals** before undergoing training (Koenen et al., 1995; Olsson et al., 2008; Ducro et al., 2009).

2

BREEDING PROGRAM OF PURA RAZA ESPAÑOL HORSES

(Resolución del 8 de mayo de 2012 (BOE-A-2012-7035))

- Main aim: the improvement of the morphology, the conformation and the functionality.
  - To obtain healthy animal, without hereditary defects.
  - To improve the morphological characteristics of the breed, according to the standard established for PRE horses.
  - To improve the conformation for sport performance, mainly in Classic Dressage.
  - To improve the functional potential of PRE horses for different sports, mainly in Classic Dressage.
  - To maintain and improve the behaviour characteristics.

3

DESIGNING AN EARLY SELECTION MORPHOLOGICAL LINEAR TRAITS INDEX FOR DRESSAGE IN PRE HORSE


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Designing an early selection morphological linear traits index for dressage in the Pura Raza Español horse

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Making a morphological pre-selection of Pura Raza Español horses (PRE) for dressage is a challenging task within its current breeding program. The aim of our research was to design an early genetic selection morphological linear traits index to improve dressage performance, using 26 morphological linear traits and six dressage traits (walk, trot, canter, submission, general impression – partial scores – and total score) as selection criteria. The data set included morphological linear traits of 10 127 PRE (4159 males and 5968 females) collected between 2008 and 2013 (one record per horse) and 19 095 dressage traits of 1545 PRE (1476 males and 69 females; 12.4 records of average) collected between 2004 and 2014. A univariate animal model was applied to predict the breeding values (PBV). A partial least squares regression analysis was used to select the most predictive morphological linear traits PBV on the dressage traits PBV. According to the Wold Criterion, the 13 morphological linear traits (width of head, head–neck junction, upper neck line, neck–body junction, width of chest, angle of shoulder, lateral angle of knee, frontal angle of knee, cannon bone perimeter, length of croup, angle of croup, ischium–stifle distance and lateral hock angle) most closely related to total score PBV, partial scores PBV and gait scores PBV (walk, trot and canter) were selected. A multivariate genetic analysis was performed among the 13 morphological linear traits selected and the six dressage traits to estimate the genetic parameters. After it, the selection index theory was used to compute the expected genetic response using different strategies. The expected genetic response of total score PBV (0.76), partial scores PBV (0.04) and gait scores PBV (0.03) as selection objectives using morphological linear traits PBV as criteria selection were positive, but lower than that obtained using dressage traits PBV (1.80, 0.16 and 0.14 for total score PBV, partial scores PBV and gait scores PBV) or dressage traits PBV and morphological linear traits PBV (2.97, 0.16 and 0.15 for total score PBV, partial scores PBV and gait scores PBV), as selection criteria. This suggests that it is possible to preselect the PRE without dressage traits PBV using as selection criteria the morphological linear traits PBV, but the expected genetic response will be lower.

Keywords: Andalusian horse, conformation, equine, genetic evaluation, linear scoring system

Implications

The Spanish horse industry moves an increasing amount of money being estimated at 0.5% of Spanish Gross National Product. Within this industry, Pura Raza Español horses (PRE) is the most important breed in terms of census and impact on international trade. The growing demand for dressage PRE contrasts with the difficulties in obtaining reliable genetic evaluations. This work aims the selection of the morphological traits more related to functionality, allowing an increase in the reliability of the genetic evaluations, as well as a pre-selection of animals which will be trained for dressage, resulting in savings costs and increasing the genetic progress of the breed.

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Introduction

Selecting animals with conformation characteristics which make them excel in sport performance is a major aim of horse breeding programs for the different functional traits (Belloy and Bathe, 1996). In the PRE breeding program, there is an increased interest for horses which demonstrate high performance in sport competitions, especially dressage (Sánchez *et al.*, 2014). Consequently, PRE with superior dressage performances have a greater economic value than other PRE. The main goal of the PRE breeding program is to improve not only the functionality, but also its conformation for sport performance (Sánchez *et al.*, 2016). To accomplish these objectives and obtain data for the genetic evaluations, the PRE were tested in morphological and performance tests.

948

- Main interest: to assess the possibility of obtaining an indirect selection criterion that allows a pre-selection of horses to take part in dressage, creating **an early morphological selection index** which includes conformation and / or dressage traits.

4

DESIGNING AN EARLY SELECTION MORPHOLOGICAL LINEAR TRAITS INDEX FOR DRESSAGE IN PRE HORSE

- **WHY??**
  - **Increased interest** for horses with higher performance in competitions
  - **Greater economic value** of animals with superior dressage performances
  - The selection of animals which display adequate morphological qualities for dressage performance would benefit the **genetic progress**
  - The screening of the animals before undergoing training for dressage (pre-selection of animals with more adequate conformation) **saves time and money**

5

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❖ AVAILABLE DATA

19,095 PERFORMANCE records

Collected between 2004-2014 at 469 official dressage test for young horses in Spain

1,545 horses
(1,476 males and 69 females)
Average 12.4 records/animal

Aged between 4-6 years old

6 Dressage Traits (average of 3 individual judges):
walk, trot, canter, submission, general impression and total score

687 horses with PERFORMANCE and CONFORMATION data with 5,359 common ancestors

10,127 linear CONFORMATION records

Collected between 2008-2013

10,127 horses
(4,159 males and 5,968 females)
1 record/animal (average of 2 appraisers)

≥ 3 years-old

26 Linear Traits (20 appraisers, previously trained and tested, in a scale of 9 classes):
18 primary traits and 8 secondary traits

6

DESIGNING AN EARLY SELECTION MORPHOLOGICAL LINEAR TRAITS INDEX FOR DRESSAGE IN PRE HORSE

STEP 1: ESTIMATION OF PRELIMINARY VARIANCES AND BREEDING VALUES

An univariate animal model was applied for the **6** Dressage and **26** Linear Traits

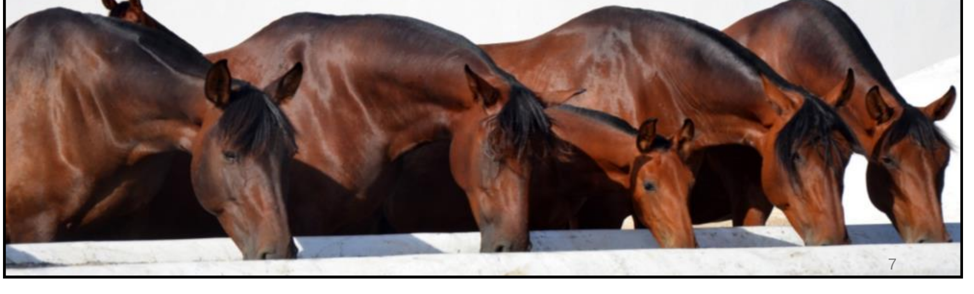
Genetic Model for the 6 Dressage traits - DT (Sánchez et al., 2014)

$Y_{ijklmnopq}$ = Age_i + Sex_j + Stress $level_k$ + Training $level_l$ + Stud of $birth_m$ + $Event_n$ + $Rider_o$ + Rider-Horse $inter_p$ + permanent $environment_q$ + $Anim_r$ + $e_{ijklmnoqr}$

Genetic Model for the 26 Linear traits - LT (Sánchez et al., 2013)

Y_{ijklm} = Age_i+Sex_j+Geographical $Region_k$+Appraiser*$event_l$+$Anim_m$+e_{ijklm}

PEDIGREE: at least 4 generations of all the animals in control = 37,231 animals



7

DESIGNING AN EARLY SELECTION MORPHOLOGICAL LINEAR TRAITS INDEX FOR DRESSAGE IN PRE HORSE

STEP 2: SELECTION OF LT MOST CLOSELY RELATED WITH DT

A partial least square procedure using the reduced rank regression factorial extraction method was implemented to investigate the relationship between the 26 LT (as model effects) and the 6 DT (as dependent variable)

Wold criterion > 1 was applied to select the variables with a greater importance for projection statistic

3 STRATEGIES based on different dependent variables

Total Score = *Final score in the reprise*	Partial Scores = *walk, trot, canter, submission and general impression*	Gait Scores = *walk, trot and canter*
6 *neck-body junction, width of chest, angle of shoulder, cannon bone perimeter, length of croup and angle of croup.*	4 *width of head, head-neck junction, neck-body junction* and *lateral angle of knee.*	3 *width of head, head-neck junction* and *lateral angle of knee.*

4 *upper neck line, frontal angle of knee, ischium-stifle distance and lateral hock angle*

A total of 13 LT selected

8

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STEP 3: ESTIMATION OF GENETIC PARAMETERS TO GUARANTEE THAT GENETIC AND PHENOTYPIC CORRELATIONS ARE CONSISTENT AND COVARIANCE MATRIX IS POSITIVE

A multivariate animal model was applied for the **6** DT and the **13** LT selected
Only animals with DT and LT were included in the analysis

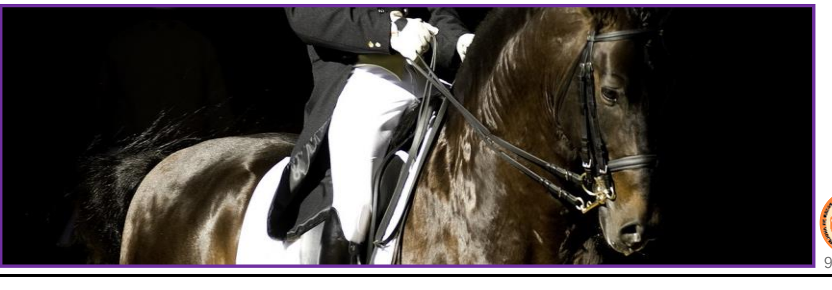
Genetic Model for the 6 Dressage traits (Sánchez et al., 2014)

$$Y_{ijklmnopq} = Ag_i + Sex_j + Str_k + Tr_l + St_m + Ev_n + Ri_o + RiAn_p + pe_q + An_r + e_{ijklmnoqr}$$

Genetic Model for the 13 Linear traits (Sánchez et al., 2013)

$$Y_{ijklm} = Ag_i + Sex_j + Reg_k + App_l + a_m + e_{ijklm}$$

PEDIGREE: at least 4 generations of all the animals in control = **5,359 animals**



9

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Genetic parameters (heritabilities and genetic correlations) for 6 DT and 13 LT

Heritability		Walk	Trot	Canter	Submission	General impression	Total score
		0.21	0.27	0.33	0.31	0.30	0.30
Width of head	0.15	0.00	-0.20	-0.21	-0.11	-0.18	-0.16
Head-neck junction	0.44	-0.12	-0.13	-0.13	-0.13	-0.12	-0.13
Upper neck line	0.36	0.24	0.06	0.06	0.16	0.12	0.15
Neck-body junction	0.14	-0.22	-0.17	-0.20	-0.29	-0.23	-0.25
Width of chest	0.31	-0.20	-0.30	-0.22	-0.10	-0.20	-0.21
Angle of shoulder	0.29	0.20	0.41	0.46	0.39	0.40	0.41
Lateral angle of knee	0.22	0.44	0.20	0.18	0.16	0.24	0.26
Frontal angle of knee	0.16	0.10	0.22	0.08	0.12	0.12	0.13
Cannon bone perimeter	0.53	0.21	0.12	0.13	0.24	0.19	0.20
Length of croup	0.15	0.07	-0.01	0.10	0.09	0.07	0.08
Angle of croup	0.25	0.14	0.01	0.03	0.18	0.10	0.11
Ischium-stifle distance	0.12	0.22	-0.21	-0.31	-0.15	-0.15	-0.12
Lateral hock angle	0.35	0.05	-0.04	-0.01	0.10	0.01	0.02

Heritabilities ranged 0.12-0.53 for LT and 0.21-0.33 for DT, suitable for genetic selection

Genetic Correlations between LT and DT ranged 0-0.46 (moderate-low magnitude)

10

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STEP 4: ESTIMATION OF GENETIC RESPONSE TO DIFFERENT INDICES

Selection index **provided a natural connection between the net merit of an animal's genotype and its relationship to profitability.**

Classic selection indices theory of Hazel and Lush (1943), and its reformulation for the use of breeding values of Gutiérrez et al. (2014)

Type 1: Selection Criteria based only on breeding values for dressage traits

Type 2: Selection Criteria based only on breeding values for linear traits

Type 3: Selection Criteria based on breeding values for linear and dressage traits

Each DT was given the same economic weight in the index, to study relative genetic responses starting with genetic parameters.

For the comparison of computed responses:

- ***A selection intensity of 1 was assumed (as a constant)***
- ***The global genetic expected response was calculated when 3-5 objectives were included in the same indices (as the average)***

11

DESIGNING AN EARLY SELECTION MORPHOLOGICAL LINEAR TRAITS INDEX FOR DRESSAGE IN PRE HORSE

Expected Genetic Responses for the morphological selection indices related to dressage aptitude in the Pura Raza Español Horse

Objective	Index	Criteria	Walk	Trot	Canter	Submission	General impression	Toral Score	Mean
		Genetic Response							
Total Score	Type 1_{TS}	PS						1.80	1.80
	Type 2_{TS}	10 LT						0.76	0.76
	Type 3_{TS}	10 LT+PS						2.97	2.97
Partial Score	Type 1_{PS}	PS	0.12	0.15	0.17	0.18	0.17		0.16
	Type 2_{PS}	8 LT	0.04	0.04	0.03	0.04	0.04		0.04
	Type 3_{PS}	8 LT+TS	0.13	0.16	0.18	0.18	0.17		0.16
Gait Scores	Type 1_{GS}	GS	0.10	0.15	0.16				0.14
	Type 2_{GS}	7 LT	0.04	0.03	0.03				0.03
	Type 3_{GS}	7 LT+TS	0.12	0.15	0.17				0.15

TS= Total scores; PS =Partial Scores; walk + trot + canter + submission+ general impression, GS= Gait Score; walk+ trot + canter, 10 LT= upper neck line + neck-body junction + width of chest + angle of shoulder + frontal angle of knee + cannon bone perimeter + length of croup + angle of croup + ischium-stifle distance +lateral hock angle; 8 LT= width of head +head-neck junction + upper neck line,+ neck-body junction + lateral angle of knee + frontal angle of knee + ischium-stifle distance + lateral hock angle.7 LT= width of head +head-neck junction + upper neck line,+ lateral angle of knee + frontal angle of knee + ischium-stifle distance + lateral hock angle.

Genetic response using LT PBV as selection criteria is positive, but lower than that obtained using DT PBV

Pre-selection of animals using LT PBV as selection criteria is possible, but expected genetic response is lower

Maximum expected genetic response for total score is achieved by type 3, but nowadays most of the young animals do not have DT

12

POTENTIAL OF LT

1. **Rapid, simple and cheap** performance control. It does not require previous preparation of animals. Therefore, all population can be controlled.
2. **Objective** system (mainly for primary traits). The appraiser does not compare the animal with the ideal individual.
3. **Descriptive** system which includes all variability of the population for each trait. Therefore, all the differences between the animals are controlled.
4. **Positive** system which determinates the characteristics that an individual can transmit to the next generations. Therefore, it is interesting for breeders to obtain a general improvement of conformation and to correct punctual defects.
5. **Informative** system. It evidences the sense of deviation. Therefore, it can be used for the evaluation of each trait and for the genetic evaluations.
6. **Flexible system in time and space**. Breeding evaluations can be useful also if breeding objectives or conformation changes in time.

13

POTENTIAL OF LT

7. These characteristics ensure **higher heritability values** than other conformation evaluation systems.
8. Although the use of LT index had a relatively lower response, it is essential for the **early pre-selection of young horses without DT** but with an adequate conformation to be trained for specific disciplines with high costs of preparation and training in terms time and money (fe. Classic Dressage).
9. The use of linear assessment also allows the increase of reliability of traits related with other performance controls and the increase of the number of animals available for selection with an acceptable genetic response, which **optimize the breeding program in terms of time and money**.
10. The inclusion of **negative characteristics and defects**, with interest for the breeders, allows the knowledge of their incidence and the selection to avoid them:

    Fe. In the PRE horses: cresty neck, invert neck, melanoma, vitiligo and white leg marks are included.

    In Menorca Horses: quality of coat color, white marks and leg defects are included.

14

LIMITATIONS OF LT

In the designing of the sheet

1. Previous analysis of phenotypic data are needed (to control limits, distributions, variability, relationships...) Although the **correct pre-selection of traits** related with performance from the beginning is very difficult (impossible?).
2. Some conformation traits are not suitable to be included as primary traits (low variability, difficult to be objectively measured…), because sometimes characteristics with interest for breeders are **complex**. Therefore, an objective evaluation is more difficult.
3. A **clear definition of traits** is needed to ensure correct collection of data, mainly for secondary traits and the **number of classes has to be adjusted** to obtain major discrimination with most accurate evaluations to obtain adequate repeatability.
4. The **teaching and training of appraisers** is compulsory to ensure adequate information from the beginning.
5. The use of linear assessment for **pre-selection of young horses** has to be supported by other evidences (fe. adequate results of the ancestors in control).

15

LIMITATIONS OF LT

In the data collection

1. An **excessive number of traits** makes difficult the data collection and processing.
2. The **correct classification** of some traits is difficult if the range of classes is large (fe. angles).
3. The evaluation of traits related with **bone references** is more difficult in animals selected for meat production, because bone references are difficult to detect.
4. The maximum homogenization of presentation conditions is needed to **reduce environmental effects**.
5. The system can not be used during all life of animals (against molecular systems). Therefore, it is necessary to determine the range of age and other conditions for the animals to **homogenize the evaluation** (if they are very young, maturity is not reached; if they are very old, conformation could be modified by "life conditions")

16

LIMITATIONS OF LT

In the use of the data

1. Appraisers have to be **periodically tested** to verify that information is adequate and system is correct.
2. If traits have a **low number of useful classes** (used by appraisers), they have to be analyzed as categorical traits, which difficults their application in selection.
3. Populations are alive elements. Therefore the **periodical review of traits and ranges** is needed to adapt system to the changes in the population because of selection and other needs.
4. To ensure the adequate use of available data for the selection of general conformation, the creation of indixes is needed. But if animals are **selected for different performances,** the use of adequate indexes for each performance is needed. And the indices have to be periodically re-evaluated.
5. If a high number of criteria are included in the evaluation system without testing relationships between them, there is a **risk of obtaining a poor global response**.

17


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