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Abstract
In order to find early selection criteria to improve the longevity of show jumping horses in competition, a specific protocol was constructed. Before entering competition, young horses were measured for many traits. These horses were offspring of two groups of sires selected as having the highest and lowest estimated breeding values for functional longevity in jumping competition calculated from progeny. Functional longevity was defined as the time spent in competition corrected for the level of performance. Initial results on subsamples of 346 horses for blood markers and 529 horses for surface temperature from infrared thermography are reported. Key markers of oxidative stress had significant effect on group of sires, especially superoxide dismutase. Surface temperature showed high heritability (up to 0.70) for body and contrast of body with specific locations (fetlocks, hocks, foot, eyes), but only asymmetry in right and left temperature of feet was linked to group of longevity of the sire.

Introduction
Improved longevity is beneficial for the welfare and health of the horse, as well for the satisfaction of a committed rider. To select for this objective is however difficult: heritability is low (0.08 in Ricard and Blouin, 2011) and estimated breeding values (EBV) for longevity are only obtained late in life of breeding animals, as a large number of uncensored phenotypes of relatives are required. This is further compromised as average length of jumping career is about 6 years with maximum over 20 years while horses begin competition at 4 years old. Therefore, possibilities of indirect early selection have been investigated in literature. Selection criteria in these studies were often based on traditional health status, morphological and gait measurements (Jonsson et al., 2014; Seiero et al., 2016; Wallin et al., 2001). That is why a specific protocol was constructed in this study. Two groups of stallions were created (high and low) according to their EBVs for functional longevity in jumping competition calculated from progeny performances. Prior to start of competitive life, young horses (≤4 years) descendants from these stallions were measured for different criteria: welfare, temperament, linear profiling of morphology, physiological parameters, blood biomarkers, body composition through impedance measurements (McKeen and Lindinger, 2004), gait accelerometric measurements, heart rate (during gaits and temperament tests), surface temperatures (from infrared images). Initial results on subsamples of 346 horses for blood markers and 529 horses for surface temperature are reported. The aims of the study are 1) prediction of sire group (high longevity and lower longevity) and 2) heritability estimates for surface temperature measurements.

Materials & Methods
Blood markers. A total of 91 variables were obtained from blood tests on 346 horses. Horses were mainly Selle Français (94%) aged 2 years (9%), 3 years (44%) and 4 years (47%). There were 45% females, 14% geldings and 41% stallions. A proportion of 66% descended from the group of favourable sires for longevity and 34% from the unfavourable. They were measured during 15 events (combination of location and date). Difference between the two groups of sires

for longevity was equal to 0.46 genetic standard deviation, the risk ratio between the two groups was 1.2. Blood variables were divided into eight categories: liver function, kidney function, muscle function, oxidative stress, osteoarticular function, inflammation markers, blood counts and a miscellaneous section. Principal component analysis (PCA) was used to describe relationships between variables. General linear models were used to identify environmental factors. Logistic regression was used to predict the group of sires from blood variables with stepwise selection. Quality of logistic regression was assessed by measuring area under curve (AUC).

Surface temperature. Infrared images from the Trotec IC085LV thermal imaging camera were used to measure surface temperature. For each horse, six images were taken: back, left profile, right profile, front legs, back legs, head. The software IC-IR Report allows to draw geometrical figures on the image and to extract the minimum, average and maximum temperature of a region of interest (ROI). For each image a rectangular reference area was defined to measure the temperature of the whole visible horse. Then specific morphological ROIs were defined. For each horse, the average, maximum and minimum temperatures of six reference areas and 28 ROIs were measured. Data were available for 529 horses, 3,138 images and 17,328 areas. Horses were mainly Selle Français (95%) aged 2 years (18%), 3 years (54%) and 4 years (28%). There were 48% females, 15% geldings and 37% stallions. The horses were sired by 88 sires, 343 by sires classified as favourable for longevity (65%) and 186 (35%) by sires classified as unfavourable. Difference in longevity for the two groups was the same as for the blood variables. The average number of offspring per sire was 6.0, ranging from 1 to 50. Horses were measured at 23 different combinations of location and date between 2018 and 2021 (12 to 34 horses per event). Variables were transformed to better describe the specificity of the temperatures of each horse. We defined six types of variables:

- body, overall images and per image
- differences between body and specific areas: fetlocks, hocks, foot
- differences between areas: fetlock to foot, hock to foot
- differences antero-posterior for foot.
- differences right and left for fetlock, hock, back, foot and eyes
- differences between median and lateral values for back

A univariate animal mixed model was used with the fixed effects of age (3 levels), gender (3 levels), event (23 levels), and a random effect of the genetic value of the horse. Relationship matrix included 5,014 horses (pedigree back over 5 generations). The effect of the group of sires for functional longevity on temperature was tested. We performed a principal component analysis (PCA) of the variables corrected for the effects of age, gender and event estimated by the previous model.

Results

Blood tests. PCA confirmed the categories of blood variables according to functions with higher absolute phenotypic correlations between variables within functions. Heritabilities could not be estimated because of too low sample size, but the random effect of sire was significant for 44 variables, implying that most blood variables were probably heritable. Event effect was significant for 45% of variables, age for 25% and gender for 85%.

Blood test: logistic regression to predict sire group. The AUC of the logistic regression was 0.76, not fully satisfactory. Table 1 shows the significant variables (p value ≤ 0.1). Horses descending from sires with favourable longevity had a higher level of erythrocyte superoxide dismutase (SOD in U/g Hb) as well as lower haemoglobin and bile acid levels than horses descending from sires with unfavourable longevity.

Table 1. Blood test variables selected in logistic regression used to differentiate between the longevity group of sires: mean, standard deviation, P value, Estimate

	Mean	SD	P value	Estimate
Bile acids (µmol / l)	5.426	2.428	0.0130	0.24
Bilirubin (mg / l)	13.62	5.72	0.0068	-0.113
Total Protein (g/l)	64.49	7.00	0.0410	-0.086
Globulin beta 1 (g/l)	9.882	3.480	0.0850	0.15
SOD (U / g Hg)	1959	525	0.0006	-0.00148
Copper (mg / l)	0.9741	0.1807	0.0682	-2.3
Leucocyte (/ mm3)	8.754	1.946	0.0028	-0.69
Small lymphocytes (/ mm3)	3626	948	0.0111	0.00081
Monocytes (/ mm3)	375.7	130.3	0.0582	0.0039
Haemoglobin (g /dL)	12.55	1.29	0.0030	1.104

Surface temperature: environmental factors and heritability. Event effect was significant for all variables except for some left versus right asymmetry variables. Gender was rarely significant, especially when measuring asymmetry. Age was significant for almost half of the variables. Two years olds and three-years olds were cooler overall than four years olds. The temperature of the fetlocks, feet and eyes was higher relative to the body in 2- and 3-year-olds than in 4-year-olds. Youngest horses were more asymmetrical (fetlock, back, eyes). Females had warmer feet and fetlocks relative to the body than geldings and stallions. Eyes were coolest relative to the body in stallions, followed by females and then geldings. Table 2 shows heritabilities for variables with estimates significantly different from zero for average and/or maximum temperature.

Table 2. Heritabilities (SE) of variables derived from measured surface temperatures on 6 images: back, left profile, right profile, front legs, back legs, head

		Temperature	
Measurement	Region of interest	Average	Maximum
Reference	Overall mean	0.68 (0.19)	-
	Head – overall mean	0.31 (0.14)	-
Specific relative to Reference	Fetlocks	0.58 (0.17)	0.58 (0.16)
	Hocks	0.26 (0.15)	0.27 (0.16)
	Feet	0.64 (0.18)	0.64 (0.17)
	Eyes	0.09 (0.12)	0.70 (0.18)
Specific	Hocks relative to Fetlocks	0.25 (0.13)	0.29 (0.14)
Asymmetry antero-posterior	Feet	0.15 (0.11)	0.13 (0.10)
Asymmetry right-left	Hocks	0.22 (0.13)	0.11 (0.10)
Asymmetry median-lateral	Back polygons	0.70 (0.18)	0.00

Surface temperature: PCA. The first principal component explained only 17% of the variance. Twenty-three variables were needed to explain 80% of the variance, according to the deliberate choice to avoid redundant variables by using temperature differences. The first axis discriminated between horses that had a rather cold whole body and warm eyes, hocks, fetlocks and feet relative to the body and the opposite (warm body, cold extremities and joints relative to the body). The former had accordingly greater temperature contrasts. These horses also had warm feet relative to the hocks and fetlocks. The second axis gathered the right/left asymmetry variables for fetlocks and feet. The variables calculated from the average or maximum temperatures were on the same axes and indicated the same. The third axis discriminated horses that had warmer hocks than feet, warmer fetlocks than feet and asymmetry in hock temperatures. The fourth axis highlighted the antero-posterior asymmetries of foot temperatures.

Surface temperature: effect of longevity group of sires. Only one variable showed significant difference for EBV-based sire group for longevity (p-value 0.03): right and left asymmetry in posterior feet. Asymmetry was lower for the group of favourable sires.

Discussion

Results highlighted the first steps to find early selection criteria for longevity. Oxidative stress and asymmetry of feet temperature were the first interesting criteria. It is possible to relate the amount of SOD to longevity in two ways: either this antioxidant protects against the deterioration of cellular components and thus helps to maintain the cellular integrity necessary for intense exercise; or a decrease in SOD in horses with poor longevity is linked to certain diseases (muscular / respiratory) that may cause the horse to stop competing. Asymmetry in temperature may indicate inflammatory, vascular, or neurological disorder (Soroko and Howell, 2018). Even if surface temperature is highly influenced by environmental factors (Jansson et al., 2021), high heritability of infrared temperatures has already been found in horses. Heritability was 0.26 (0.16) for differences in eyes temperature during effort phase and 0.52 (0.07) during recovery phase in a jumping test (Bartolome et al., 2021). Heritability of eye temperature was 0.38 (0.17) before and 0.50 (0.22) just after dressage competition (Sanchez et al., 2016). Eyes temperature may be related to the level of stress (Cook et al., 2001). When the study protocol will be completed, and 1,000 horses measured, more reliable results regarding potential early indicators for longevity can be produced.

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