Multivariate analysis of exercise parameters measured during the training of Thoroughbred racehorses

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Summary

The aim of this study was to measure exercise parameters in horses which had performed standardised exercise tests and to verify their use as predictive indexes of horse fitness. Eight horses were tested, on the same track with the same rider. The test consisted of a warm-up followed by three 3 min-steps one cantering and two galloping. The test was followed by a recovery period. The heart rate was recorded during the entire test. Blood samples were taken during the 2 min rest periods following each step, and after the recovery period for the measurement of lactate concentrations. Exercise parameters were defined by the relationship between lactate concentrations, heart rate and velocity.
Results were treated by the multivariate discriminant analysis procedure which indicates that the cardiovascular system seems to be improved during the protocol and that the efficiency score and the cardiac recovery index seem to be good indicators of potential speed.

Keywords: exercise test, fitness indicators, discriminant analysis, efficiency score

Diskriminanzanalyse von Leistungsparametern bei Galopprennpferden anhand von Messungen während des Trainings

Das Ziel dieser Studie war, Leistungsparameter von Pferden bei standardisierten Leistungstests zu messen und ihren Voraussagewert für die Fitness der Pferde zu überprüfen.
Es wurden acht Pferde, fünf Hengste und drei Stuten im Alter von vier bis sechs Jahren, je fünfmal im Abstand von je fünfzehn Tagen getestet. Die Tiere befanden sich seit zwei Monaten im Training für Jagdrennen. Die Tests fanden immer auf derselben Bahn statt und es kam immer derselbe Reiter zum Einsatz.
Der Leistungstest bestand aus einer Aufwärmphase, worauf eine Stufe im Canter bei 450 m/min und zwei Stufen im Galopp bei 600 m/min und 750 m/min folgten. Die Dauer jeder Stufe betrug drei Minuten, zwischen den Stufen wurde eine zweiminütige Pause eingelegt.
Während des gesamten Tests wurde die Herzfrequenz aufgezeichnet, Blutproben zur Messung von Laktat und Hämatokrit wurden in den Pausen nach jeder Stufe und am Ende des Tests nach einer Erholungsphase entnommen. Anhand der Beziehung zwischen Laktatkonzentration, Herzfrequenz und Geschwindigkeit wurden Leistungsparameter definiert.
Mit den Ergebnissen wurde eine Diskriminanzanalyse durchgeführt. Daraus ging hervor, daß in 95 % der Fälle die Pferde dem Test zugeordnet werden konnten, in dem die zugrunde liegenden Leistungsparameter bestimmt worden waren. Es erfolgte eine positive Anpassung des Herz-Kreislauf-Systems über den Versuchszeitraum. Auch die anaerobe Kapazität verbesserte sich. Anhand des Effektivitätskoeffizienten, der Beziehung zwischen den Parametern Herzfrequenz und Laufgeschwindigkeit, und der Erholungsfähigkeit des Herz-Kreislauf-Systems ist eine Beurteilung von Geschwindigkeit und Ausdauerleistungsvermögen der Pferde auch ohne die Entnahme von Blutproben möglich.

Schlüsselwörter: Leistungstest, Indikatoren für Fitness, Diskriminanzanalyse, Effektivitätskoeffizient

Introduction

Physiological data from Thoroughbred racehorses is now well defined by the use of treadmills which allow the investigation of many functions (cardiovascular, respiratory and locomotor systems). It is sometimes difficult to apply these study protocols to the track situation, although this has already been done with Standardbred (*Wilson* et al., 1983; *Demonceau* and *Auvinet,* 1992; *Dubreucq* et al., 1995) and Thoroughbred (*Foreman* et al., 1990; *Harkins* et al., 1993; *Lindner* and *von Wittke*, 1993) racehorses. The aim of this study was to measure exercise parameters in horses which repeatedly performed standardised exercise tests over a period of 3 months, to examine the correlations between them with a multivariate analysis (*Valette* et al., 1991) and to verify their use as predictive indexes of horse fitness.

Materials and methods

Horses

Eight healthy horses (5 stallions and 3 mares) were used in this study. They were 4 to 6 years old and were trained for steeplechase races for 2 months. They were fed a concentrate diet twice daily at levels which provided nutrient requirements for maintenance and work.

Exercise test

Each horse was tested 5 times, every 15 days between November and February, on the same track (1800 meters) with the same rider. The atmospheric conditions were similar during the 5 tests with temperatures between 6 and 9°C and in dry condi-

tions. The test consisted of a 30 min warm-up walking and trotting at 250m/min followed by three 3 min-steps cantering (450 m/min) and galloping (600 and 750 m/min respectively). The test was followed by a recovery period; 10 min trotting at 250 m/min and then 5 min walking. All the exercise tests were performed under accepte conditions of care and welfare for horses.

The heart rate (HR) was recorded (Baumann BHL 5000) during the entire test and the data were averaged during the last minute. Blood samples were taken during the 2 min rest periods following each step and after the recovery period for the measurement of haematocrit (PCV) and lactate concentrations (LA) after deproteinisation in perchloric acid. Blood samples were taken at rest (for clinical examination), 3 hours later for CK (creatine kinase) and 24 hours later for AST (aspartate aminotransferase) which are indicators of muscle damage.

Definition of the derived exercise parameters

For each horse, 12 parameters were calculated and constituted quantitative variables.

The linear relationship between HR and velocity (V) was described by V200; the slope of the relationship (HRs); EC, an efficiency score which is the velocity during the last step of the test divided by the heart rate (*Ivers*, 1989) and CRI (cardiac recovery index) which is the HR at the end of the test divided by the HR after 1 min of recovery (*Valette* and *Sablon,* 1992). The relationship between LA and velocity was studied using an exponential model (*Demonceau* et al., 1991; *Valette* et al., 1991);

$$LA = \exp(Acurv^*V + b) + c$$

where Acurv is a coefficient of curvilinearity and b and c are constant values and analysed with a solver program (Eureka, Borland international). The lactate dependant change was described by the following criteria: VLa4; Acurv; Vs, the velocity at which blood lactate dramatically increased and LAT, the corresponding blood lactate threshold. In addition, other pa-

Tab. 1: Exercise parameters obtained after 5 standardized tests on 8 horses

	Test 1	Test 2	Test 3	Test 4	Test 5	Mean	F value	Proba
							4/35 df	%
V200 (m/mn)	714	722	702	721	734	719	0.20	ns
	41	73	103	59	59	71		
HRs	21.45	25.55	19.15	16.30	19.75	20.45	1.65	ns
	5.10	5.85	11.80	4.40	5.65	7.70		
HR4 (beats/mn)	185	186	189	187	182	186	0.45	ns
	5	15	14	4	7	11		
EC	3.50	3.57	3.50	3.57	3.66	3.56	0.55	ns
	0.21	0.30	0.30	0.18	0.19	0.25		
CRI	1.71	1.65	1.60	1.60	1.68	1.65	1.20	ns
	0.13	0.16	0.10	0.07	0.12	0.13		
SL	87.3	97.8	114.9	110.6	85.4	99.2	2.55	ns
	32.1	18.1	19.6	12.0	24.1	25.2		
LRI	1.35	1.36	1.86	1.33	1.69	1.52	2.00	ns
	0.61	0.18	0.47	0.42	0.49	0.50		
Vla4 (m/mn)	674	706	666	672	650	674	1.95	ns
	36	18	55	26	47	43		
Vs (m/mn)	638	668	636	631	625	640	1.25	ns
	35	12	62	25	39	41		
Acurv	1.15	1.94	1.71	1.49	1.09	1.48	2.55	ns
	0.28	0.61	0.85	0.67	0.41	0.68		
LAT (mmol/l)	2.88	2.48	2.92	2.57	3.17	2.80	1.75	ns
	0.31	0.47	0.63	0.56	0.72	0.61		
PCV (%)	50.65	52.40	56.50	54.65	52.70	53.40	4.40	0.60
	5.05	2.75	3.20	2.00	1.85	3.50		

ns : not significant; first line : means; second line : SD

rameters were measured: HR4, which is the HR at VLa4; LRI (lactate recovery index) which is the LA at the end of the test divided by the LA after 15 min of recovery; and SL, a lactate index which is the velocity divided by the blood lactate concentration, during the last step. Acurv, Vs and LAT may be indicators of the onset of blood lactate accumulation (*Valette* et al., 1989).

Statistical analysis

In order to study the improvement of the fitness of horses during the training period, data were ranked in 5 groups (the 5 exercise tests). Data were treated by the multivariate discriminant analysis procedure (DA) which takes into account all the

tre of the graph are not clearly explained by the first and second components which represented 64.3 and 17.3% respectively of the total variance.

Discussion

Analysis of variance indicated that none of the variables except for PCV (Tab. 1) was improved with time in response to the 5 tests. The first component included the parameters CRI, HRs, PCV and SL while the second component was a contrast of VLa4, VS, Acurv, LAT and EC. V200, HR4 and LRI were on the two components
The position of test 1, situated closed to the intersection of axes 1 and 2 indicated that horses were not well prepared for

Tab. 2: Correlation coefficients between exercise parameters (38 df)

	V200	HRs	HR4	EC	CRI	SL	VLa4	Acurv
HRs	-0.58°°°							
HR4	-0.41°°							
EC	0.91°°°	-0.61°°°	-0.36°					
SL					0,34°			
LRI						0,43°°°		
VLa4			0.33°	0,42°°	0,36°	0,57°°°		
Vs	0.33°		0.40°°	0,47°°°	0,39°°	0,59°°°	0.94°°°	
LAT							-0.34°	-0.79°°°
PCV		-0.33°		0,42°°		0,42°°		

°p<0,05, °°p<0,01, °°°p<0,001

information given by the 12 quantitative variables (*Valette* et al., 1992). This statistical method compared the 5 groups by determining a set of new uncorrelated variables (1st, 2nd and 3rd components) defined by a linear combination of the variables with the maximum within-group variance. This analysis also provides correlation coefficients between all the variables, means (SD) and a 1-way analysis of variance.

Results

All horses performed the tests without showing any signs of exhaustion, plasma concentrations of CK and AST remained within the normal range. Table 1 indicates the means and SD obtained after the tests. Horses finished the tests with a mean HR value of 212 beats/min and a mean LA value of 9.2 mmol/l. The mean V200 was 719 m/min (12 m/s) and the mean VLa4 value was 674 m/min (11.2 m/s). There were good correlations (Tab. 2) between V200 and EC (0.91) and between VLa4 and Vs (0.94) which gave the same type of information. The lactate threshold parameters Acurv and LAT were negatively correlated (-0.79). We observed no correlation between V200 and VLa4, nor between EC and CRI. EC and SL were not correlated but were correlated with VLa4 and Vs. Figure 1 shows the location of the centres of gravity of the 5 groups on axes 1 and 2 of the DA procedure. The closer the parameters are to the periphery, the more correlated they are. Parameters or groups situated close to the cen-
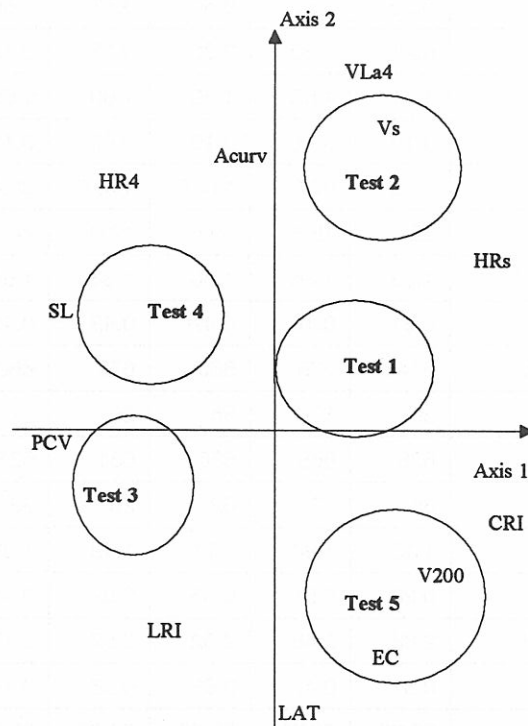

Fig. 1: Location of the centres of gravity of the 5 tests on axes 1 and 2 of the DA procedure (exercise parameters and tests are defined in the text)

races at the beginning of the study. During the protocol, aerobic capacity was improved as noted by increases, firstly in VLa4 and Vs during tests 2 and 3 and then in oxygen transport capacity or PCV. The cardiovascular system was improved during the protocol as noted by the position of Test 5 on the component defined by V200, CRI and EC. Test 5 was characterised by decreases in VLa4 and Vs values and also by a lower value for Acurv and a higher value for LAT, indicating an improvement in anaerobic capacity (*Valette* et al., 1989). The DA procedure also calculated the probability of misclassification of a horse in another group (another test) by taking into account all the exercise parameter values. It was found that 95% of the values were correctly assigned to the group they were initially assigned to.

Thorougbbred racehorses have higher V200 and VLa4 values than have Standardbred horses (*Dubreucq* et al., 1995) which may be explained in part by the lower energetic cost of gallop. The efficiency score was closely correlated with V200, an indicator of anaerobic fitness. The efficiency score and the cardiac recovery index are easy to measure during a training schedule when heart rate can be recorded but blood samples are not available. They are not correlated and therefore give complementary information. They seem to be good indicators of potential speed and of the aptitude to sustain prolonged work, when examined at velocities where HR is over 200 beats/min.

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