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Original article

Comparison of track and treadmill exercise tests in saddle horses: a preliminary report

JP Valette [1], E Barrey [2], B Auvinet [3], P Galloux [4], R Wolter [1]

[1] INRA, Laboratoire de Physiologie Sportive, École Nationale Vétérinaire d'Alfort, F-94704 Maisons Alfort Cedex;
[2] INRA, Station de Génétique Quantitative et Appliquée, F-78352 Jouy-en-Josas;
[3] CHU Laval, Dépt de Médecine Sportive, F-53024 Laval Cedex;
[4] Bureau de Recherche, École Nationale d'Équitation, F-49411 Saumur Cedex, France

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Summary — Several exercise test procedures were compared by measuring cardiovascular, metabolic and locomotor system variables. Six Anglo-arabians and one French saddle horse were tested on the track and on a high-speed treadmill with different slopes (0, 3.5 and 6.3%). Venous blood lactate, heart rate and stride length and frequency were measured at each step of an exercise test consisting of a 10-min warm-up period followed by five 3-min steps at increasing speed: 250, 450, 500, 550 and 600 m/min respectively. Current exercise-related parameters which describe aerobic and anaerobic capacity and cardiovascular and locomotor system responses were studied using the relationships between these measurements and velocity. Results were analyzed by a multivariate procedure: discriminant analysis. It was possible to compare the exercise response of horses during these 4 exercise tests by considering all the data obtained. It was concluded that inclining the treadmill at a 3.5% slope minimized the differences of the physiological response between track and treadmill conditions; however, locomotion on the treadmill remained different.

horses / treadmill / track / discriminant analysis / exercise test

Résumé — Comparaison entre les tests d'effort sur piste et sur tapis roulant chez le cheval de selle : une étude préliminaire. *Plusieurs types de tests d'aptitude à l'effort ont été étudiés en analysant les paramètres cardiovasculaires, métaboliques et locomoteurs. Six chevaux Anglo-arabes et un Selle français, entraînés pour le concours complet d'équitation, ont été testés successivement sur le terrain, puis sur un tapis roulant à grande vitesse avec trois inclinaisons différentes : 0, 3,5 et 6,3%. La fréquence cardiaque, le lactate sanguin, la longueur et la fréquence des foulées sont mesurés à chaque palier d'un test comportant 10 min d'échauffement, puis 5 paliers de 3 min chacun à vitesse croissante : 250, 450, 500, 550 et 600 m/min. Les critères d'effort décrivant les capacités aérobies et anaérobies, ainsi que les adaptations cardiovasculaires et locomotrices sont étudiées en utilisant les relations qui existent entre ces mesures et la vitesse. Les résultats sont analysés par une analyse factorielle discriminante. Il est ainsi possible de comparer les réponses à l'exercice durant les 4 protocoles en considérant toutes les informations obtenues. Il en ressort que l'inclinaison du tapis avec une pente de 3.5% minimise les différences énergétiques entre le terrain et le tapis roulant, mais que la locomotion sur le tapis roulant demeure différente.*

cheval / tapis roulant / piste / analyse discriminante / test d'effort

INTRODUCTION

At the Third International Conference of Equine Exercice Physiology held in Uppsala (1990), there was a general discussion about treadmill *versus* track exercise tests during the exercise tolerance testing workshop. It was concluded that there were significant differences between step exercise tests used in the laboratories all over the world. There was an attempt to standardize measurements and conditions of treadmill tests (speed, slope, step duration, recovery phase). It has been observed that there are differences in physiological responses when speed, slope and duration of the test change (Rose *et al,* 1990; Sexton and Erickson, 1990). Little information is available on the comparison between physiological response during treadmill and overground exercise respectively; however, the treadmill test is becoming a common tool for standard exercise testing.

Exercise fitness depends on adequate functioning and coordination of several body systems such as the cardiovascular, respiratory, haematological, plasma biochemical and muscular systems which have been largely investigated independently (Leach and Dagg, 1983; McMiken, 1983; Persson, 1983; Dalin and Jeffcott, 1985; Thornton, 1985). To obtain a comprehensive picture of the interrelationships between variables from different body systems, classical statistical procedures are insufficient to synthesize all the information obtained during a standard exercise test. Multivariate procedures such as discriminant analysis were therefore used in this study (Valette *et al,* 1991) to describe the information obtained during the test.

The aim of this study was to explore cardiac, metabolic and locomotor response of horses successively performing the same exercise test on track and treadmill with different slopes. A multivariate analysis procedure was used to assess which treadmill slope was the most suitable to reproduce the track test results.

MATERIALS AND METHODS

Horses

Six Anglo-Arabians and one French saddle horse were tested. They were 5–8 years old and were involved in a normal training schedule for 3-day-event competitions. All horses were sound. They were tested on the treadmill after 2 habituation sessions.

Exercise test on the track

The standardized test consisted of a 10-min warm-up at a walk followed by five 3 min-steps: a trot at 250 m/min and a canter and gallop at 450, 500, 550 and 600 m/min, respectively. Six experienced riders from the Saumur National Equestrian School were asked to regulate the velocity and cadence of their mounts using linear and temporal markers located along the track. Animals were allowed to rest for 2 min between each step so that a venous blood sample could be taken. This test was repeated twice.

Exercice test on the treadmill

On the treadmill 3 standardized tests consisted of the same increasing speeds as previously with a 0, 3.5 or 6.3% slope, respectively. Animals were allowed to rest for 2 min between each step. During the exercise tests, they were cooled by 2 powerful electric fans. The test with the 3.5% slope was repeated twice.

Measurements

Heart rate

During the entire incremental test, the heart rate (HR) was recorded (Baumann BHL 5000) every heartbeat and the data averaged for each step.

Blood analysis

Blood samples were taken by jugular venipuncture during the rest periods following each step. The samples (0.2 ml) were immediately deproteinized by adding 2 ml of ice-cold 0.6 N perchloric acid and lactate concentration was measured by an automatic analyser (Boerhinger).

Gait analysis

The gait parameters were measured by filming horses with a video camera (Sony CCD F 550 E) for 1 minute at each step. Stride frequency *(SF)* was calculated from the mean stride duration which was determined by counting the number of frames required for 5 successive strides. Velocity *(V)* was measured by counting the number of frames required for the horse to move a distance of 30 m on the track. On the electronically-operated treadmill, velocity was accurately measured by the equipment in question. The stride length *(SL)* was deduced from the relationship: $SL = V / SF$.

Definition of the derived exercise parameters

For each horse, synthetic parameters which described velocity-dependent changes were calculated by means of regression equations. For each horse, 10 derived parameters were calculated and constituted quantitative variables (table I). The relationships of *HR* and *SF versus V* were studied by linear regression. These rela-

Table I. Exercise parameters in the 4 groups of horses.

Exercice parameters	*Track* n = *12*	*Treadmill 0%* n = *7*	*Treadmill 3.5%* n = *10*	*Treadmill 6.3%* n = *2*	*Mean* n = *31*	F *(3/27)*	*Significance* *(%)*
A	117	76	118.5	119.5	108.5	1.90	NS
	41	36	35	39	42		
*VLA*4(m/min)	588	717	580	453	606	13.90	0.00
	32	99	32	30	87		
VdLA(m/min)	512	683	504	449	544	12.50	0.00
	33	122	35	7	100		
LAT(mmol/l)	1.8	2.9	1.8	4.0	2.2	13.60	0.00
	0.3	1.0	0.3	0.4	0.9		
*HR*s (beats/m)	20.30	17.65	21.30	21.60	20.10	2.80	NS
	2.90	2.80	1.80	1.60	2.90		
*HR*4 (beats/min)	188	194	186	185	188	0.90	NS
	9	16	7	8	11		
*SL*s(min)	66.0	71.0	73.5	73.0	70.0	6.40	0.2
	4.5	3.0	4.0	0.2	5.0		
*SL*4(m)	5.00	6.15	5.10	4.30	5.25	15.80	0.00
	0.25	0.70	0.40	0.25	0.65		
*SF*4 (stride/s)	1.97	1.94	1.88	1.75	1.92	5.70	0.4
	0.07	0.10	0.07	0.01	0.09		
*V*200(m/min)	649	755	642	519	662	11.50	0.00
	49	75	40	3	79		

NS: not significant; first line: means; second line: SD.

tionships were entirely described by 2 characteristics, the slope and intercept.

The relationship between blood lactate *(LA)* and velocity was analysed using an exponential model (Demonceau *et al,* 1989, 1991) which was closely correlated to the experimental data:

$$LA = C + \exp(A.V+B)$$

where *A* is a coefficient of curvilinearity and B and C are constant values; *LA* is expressed in mmol/l and *V* in m/min.

For each horse, the values of *A*, B and C were found using a solver program (EUREKA, Borland International) by considering all the blood lactate data obtained at each of the 5 steps.The lactate-velocity dependent change was described by the following 4 criteria: the coefficient of curvilinearity *(A),* the velocity which increased blood lactate to 4 mmol/l (*VLA*4), the velocity at which the mean variation in blood lactate was 1.00 mmol/l for an increasing velocity of 1 m/s (or 1.8 mmol/l for 100 m/min) (*VdLA*) and the corresponding blood lactate threshold *(LAT).* The *VLA*4, *VdLA* and *LAT* parameters were markers for the onset of blood lactate accumulation *(OBLA)* (Valette *et al,* 1989).

The relationship between heart rate and velocity was described by the regression coefficients (*HRs*) the velocity at 200 beats/min (*V*200) and heart rate at *VLA*4 (*HR*4).

The relationship between stride length and velocity was described by the regression coefficients (*SLs*), the stride length at *VLA*4 (*SL*4). The stride frequency at *VLA*4 (*SF*4) was also calculated.

Multivariate analysis

In order to demonstrate the influence of the exercise test procedure on the physiological response of the horses, data were ranked in 4 groups: group 1: track test data (n = 12, G1); group 2: treadmill test with a 0% slope (*n* = 7, G2); group 3: treadmill test with a 3.5% slope (n = 10, G2); group 4: treadmill test with a 6.3% slope (n = 2, G3); these were studied by means of the discriminant analysis procedure (STAT–ITCF, Institut des Céréales et des Fourrages, Paris). This statistical method computes various discriminant functions for classifying observations into 4 groups (4 exercise test conditions) on the basis of 10 quantitative variables. In this study the discriminant analysis compared 4 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. The discrimant analysis procedure also provides correlation coefficients between all the variables, means (SD) and a 1-way analysis of variance to test the influence of the exercise test condition.

RESULTS

Table I indicates the means and SD of the 4 groups and the analysis of variance shows that all the variables but *A, HRs* and *HR*4 are relevant to differentiate the physiological response observed in 4 exercise conditions. The mean value of *HR*4 was 188 beats/min, the mean value of *SF*4 was 1.92 strides/s and the mean value of *LAT* was 2.2 mmol/l.

There were many significant correlations between the exercise parameters (table II). There was a good correlation between *VLA*4 and *VdLA* (r = 0.94) which gave the same type of information. These parameters were correlated with *HR*4 and *SL*4. The lactate threshold parameters were negatively correlated (r = 0.56).

First, second and third components explained 66.5, 24.5 and 9.0% respectively of the total variance. The first component had a large loading for the most significant variable: *LAT*. The second component was a contrast of *V*200, *V*4, *SL*4 and *VdLA* (negatively correlated with the second component). The third component axis was negatively correlated with *SLs*.

Plotting the horses of each group relative to the 3 component axes provided a graphic comparison of the physiological responses in the 4 exercise test conditions. The nearer the groups of horses to one an-

Table II. Correlation coefficients between exercise parameters (29 df).

	VLA*4*	V*d*LA	LAT	HR*s*	HR*4*	SL*4*	SF*4*	V*200*
A	0.97	−0.46	−0.56					
*VLA*4		0.96		−0.49	0.53	0.95	0.52	0.79
VdLA			0.46		0.59	0.89	0.48	0.68
HRs						−0.49		−0.51
*HR*4						0.49		
*SL*s							−0.79	
*SL*4								0.75
*SF*4								0.47

other the more similar the exercise response. The Mahalanobis distances between the centres of gravity indicate their degrees of difference (table III). Figure 1 shows the relative location of the centres of gravity of the 4 groups on the first 2 component axes. Groups 1 (track) and 3 (treadmill 3.5%) were the most similar and group 4 (treadmill 6.3%) differed most from the others. Figure 2 shows the relative location of the centres of gravity of 4 groups on axes 1 and 3. Groups 1 and 3 could be distinguished by considering the third component axis, *ie* stride length characteristic (*SL*s).

The discriminant analysis procedure calculated the probability of misclassification analysis of a horse in another group by taking into account all its exercise parameter values. It was found that 87.1% of the horses were correctly classified in the group they were initially assigned to. The misclassification occurred only between groups 1 (track) and 3 (treadmill 3.5%).

Table III. Mahalanobis distances between the 4 groups.

Groups	*1*	*2*	*3*
2	2.27		
3	1.76	2.39	
4	3.93	4.02	3.99

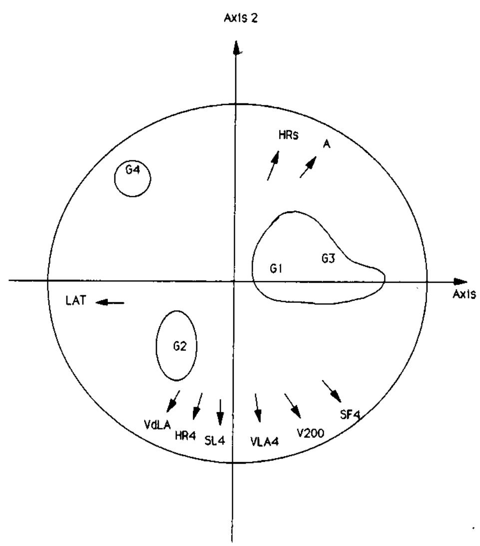

Fig 1. Location of the centre of gravity of the 4 groups on axes 1 and 2 (parameters and groups are defined in the text).

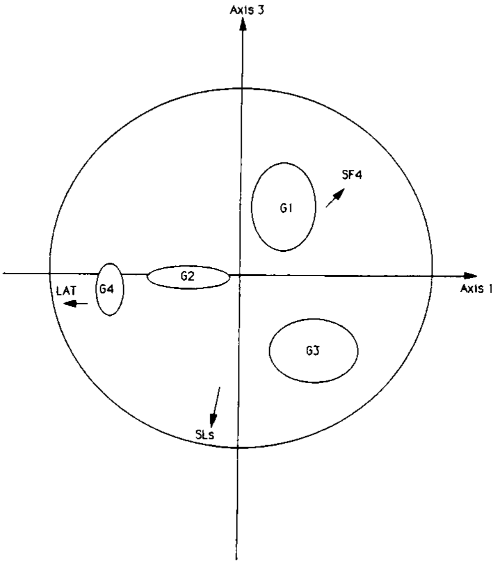

Fig 2. Location of the centres of gravity of the 4 groups on axes 1 and 3 (parameters and groups are defined in the text).

DISCUSSION

According to the present results and to those from previous studies (Barrey *et al*, 1989; Valette *et al*, 1991) a multivariate procedure such as the discriminant analysis is a valuable tool for comparing the physiological response of exercising horses. Multivariate analysis takes into account all the information available in a table of quantitative data and aims at synthesizing the results in a set of diagrams which allows the influence of the exercise test procedure to be distinguished. Exercise tests on an inclined treadmill are often used to simulate overground work of competition horses but little information is available on the comparison of stride parameters and energy expenditure in overground *versus* treadmill condition (Straub and Hoppeler, 1989). This study compared different groups of horses performing different exercise tests and revealed that treadmill locomotion seems to require less muscular effort than overground locomotion.

The Mahalanobis distances between the groups revealed that the track test results were approximately reproduced by the 3.5% treadmill test. More precisely, the velocity-dependent changes in characteristics remained different. The only difference between track and 3.5% treadmill tests was the increase in stride length (*SLs* = 66 *versus* 73.5, table I). The stride length was longer during treadmill locomotion as indicated by the third axis of the discriminant analysis.

The track and 3.5% treadmill test favoured higher blood lactate concentration and heart rate increase than the 0% treadmill test. This observation was indicated by the higher *HR*s and *A* values (fig 1). During the 0% treadmill test, horses produced a light work. On the other hand, the 6.3% test required heavy muscular effort.

The influence of the exercise test procedure (overground *versus* flat or inclined treadmill) on the measured parameters could be attributed to 5 types of factors:

- the mass action of the rider (Thornton *et al*, 1987);
- the speed control on track;
- the treadmill locomotion (Barrey *et al*, 1991);
- the meteorological conditions;
- the psychological adaptation to the treadmill.

It was concluded that inclining the treadmill with a 3.5% slope minimized the differences in the physiological responses between overground and treadmill conditions, but the treadmill locomotion remained different.

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