Relationships between physiological variables and race performance in French standardbred trotters

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The relationships between V_4 (the velocity for a blood lactate concentration of 4 mmol/litre) and V_{200} (the velocity for a heart rate of 200 bpm) and the performance indices of 223 healthy French trotters were analysed. They were divided into four age groups of three, four, five and six years and over, and into three performance groups (good, intermediate and poor performers) defined by the index of trot (ITR), an annual index of performance calculated by the national stud. V_4 and V_{200} were assessed during the performance of a three-step standardised field exercise test, and four performance indexes (ITR, earnings, best time and the number of starts) were calculated for each group. An analysis of variance showed that V_4 and V_{200} were highly correlated with the horses' age and level of performance ($P<0·05$). The correlation between the physiological variables and ITR was better for the three- and four-year-old horses than for the older horses.

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OVER the past decade there have been several studies of the relationships between physiological factors, in particular blood or plasma lactate concentration, and the racing performance of standardbred trotters or pacers (Rasanen and others 1995, Casini and Greppi 1996, Couroucé and others 1997, Roneus and others 1999, Davie and others 2002). However, their conclusions have not been consistent. Rasanen and others (1995) observed a positive correlation between the blood lactate concentration and an individual horse's performance index after maximal exercise, whereas Roneus and others (1999) concluded that the blood lactate concentration after racing was not a useful tool for predicting an individual horse's performance index. Similarly, Couroucé and others (1997) and Casini and Greppi (1996) observed a relationship between V_4 (the velocity for a blood lactate concentration of 4 mmol/litre) and performance criteria after submaximal exercise, but Roneus and others (1999) and Davie and others (2002) did not. These differences may be due to differences between the methods used in the studies. Differences between the populations of horses in terms of number and breed, between the types of exercise performed (maximal or submaximal, track or treadmill), between the physiological measurements (plasma or blood lactate concentration), and between the indices of performance (best time, earnings or annual index) are the main factors which may explain such variable results. Taking into account the recommendations from previous experiments, the aim of this study was to analyse the relationships between two physiological variables and four performance indices for a large and varied population of French trotters. The influence of the age of the horses on these relationships was also examined.

MATERIALS AND METHODS

Horses

A total of 223 French trotters from three to eight years old were studied. Data were selected from a data bank made up of field exercise tests performed between 1992 and 2002. All the physiological tests satisfied the following six criteria.

Environmental conditions All the tests were performed on six race tracks with similar characteristics in terms of length, design and surface. They were qualified as 'fast tracks' and there was no significant difference between the V_4 and V_{200} values recorded on the six tracks (C. Leleu, unpublished observations). Only the standardised exercise tests performed on a dry track, at a temperature between 10 and 20°C and with little or no wind, were taken into account.

Training state A horse's level of training is known to affect its physiological variables (Persson 1983, Wilson and others 1983, Evans 1985, Couroucé and others 2002); all the horses were in full training, ready to compete, and were clinically sound.

Age A horse's age is also known to affect physiological measurements (Couroucé and others 2002). The horses were divided into four age groups: there were 61 tests on three year olds, 56 tests on four year olds, 59 tests on five year olds and 60 tests on horses six years old or older.

Level of performance The horses in each age group were assigned to three performance categories: good performers, intermediate performers and poor performers, on the basis of the index of trot (ITR) corresponding to the year of the test. The ITR is an official annual index of performance published by the French National Studbook; it is computed annually for each French trotter on the basis of the natural logarithm of its average earnings per race. The mean (sd) ITR of the population is 100 (20). The index has a normal distribution and is linear so that the race performances of all French trotters can be compared. In the present study, the good performers should have an ITR above 120, the intermediate performers an ITR between 100 and 120 and the poor performers an ITR below 100.

Number of starts All the horses had run at least five races each year.

Age of each performance group As earnings have increased greatly over the past 10 years and best time records have improved, the horses in each age and performance group were selected to have similar ages in 2002. As a result, each group had the same number of horses of the same generation, and the groups were comparable.

In total, 236 standardised exercise tests were evaluated because 13 of the horses were tested twice at different ages.

Performance indices

Four performance indices were recorded for each horse: its ITR, its cumulative earnings, its number of race starts and its best recorded time. Its ITR was that corresponding to the year of the test; its cumulative earnings (in €), were calculated until December 31 of the year of the test; for example, the earnings

TABLE 1: Speeds (m/minute) of the three, three-minute steps in the exercises undertaken by trotters of different ages

Step	Age (years) Three	Four	Five and over
1	500	500	500
2	560	580	590
3	630	660	680

for a four-year-old horse were the total of its earnings as a two, three and four year old. Similarly, the number of starts for a four-year-old horse was calculated as its total number of starts as a two, three and four year old. The horse's best recorded time was the best time officially recorded during a race (most often a 2100 m race) either during or before the year of the test.

Standardised field exercise test

The testing procedure was the same for all the horses. Each horse started with a 10 minute warm-up at about 350 m/minute, and then did a three-step test at increasing speeds (Demonceau and Auvinet 1992), each step lasting three minutes and with a one minute rest between steps. The speed of each step depended on the age of the horse (Table 1), and the fastest step induced a blood lactate concentration above 4 mmol/l in accordance with the recommendation of Persson (1983).

Measurements and data analysis

Trotting speeds, in m/minute, were measured and recorded with a tachometer (Speed Puls Equus; Baumann and Haldi). The driver used information on the screen to keep the speed as constant as possible during each step. The same device recorded the horse's heart rate. The data from the tachometer and heart-rate meter were downloaded to a laptop computer to determine the horse's mean speed and heart rate during each step. Jugular venous blood samples were collected within one minute of the end of each exercise into tubes containing fluoride and oxalate for the determination of whole blood lactate concentration by the enzymatic method of Boehringer (Bergmeyer 1974). Two physiological variables were calculated for each horse from the information on speed, heart rate and blood lactate concentration during the three steps: V_4, the horse's velocity when its blood lactate concentration reached 4 mmol/litre, and V_{200}, its velocity when its heart rate reached 200 bpm. Technical problems with the heart-rate meters in 10 tests made it impossible to calculate V_{200}. The statistical analyses were therefore made with 236 V_4 and 226 V_{200} values.

Statistical analyses

The results are presented as means (sd). The values of V_4 and V_{200} were calculated for each age group and each performance group, and the influence of age and level of performance on these physiological variables was assessed by a two-factor analysis of variance, followed by Duncan's post hoc test if there were differences.

The relationships between the physiological variables and the performance indices were investigated by regression analyses, taking all the horses, and each age group separately, into account. The lines of best fit and coefficients of determination (r^2) were calculated. Finally, a correlation matrix was calculated. A level of significance of $P<0·05$ was used in all the tests.

TABLE 2: Numbers of tests applied to trotters of different ages and performance categories and their mean (sd) age in 2002, index of trot (ITR) and number of starts

Age and performance	Number	Age in 2002 (years)	ITR	Number of starts
Three year old				
Good performers	20	5·6 (2·5)	133 (12)	13 (6)
Intermediate performers	20	5·3 (2·5)	107 (7)	9 (4)
Poor performers	21	5·6 (2·3)	80 (15)	7 (2)
Four year old				
Good performers	19	7·4 (3·1)	140 (14)	19 (7)
Intermediate performers	19	7·7 (2·7)	107 (7)	20 (9)
Poor performers	18	7·7 (3)	83 (14)	18 (10)
Five year old				
Good performers	20	9·3 (2·9)	137 (8)	33 (13)
Intermediate performers	20	9·4 (2·7)	107 (11)	39 (11)
Poor performers	19	9·2 (3·2)	87 (15)	31 (15)
Six year old and older				
Good performers	19	10·2 (2·8)	139 (9)	53 (15)
Intermediate performers	23	10·7 (3·2)	103 (14)	58 (25)
Poor performers	18	10·6 (3·1)	84 (20)	53 (11)

RESULTS

Characteristics of the population of horses

The criterion 'mean age of the performance groups in 2002' was similar in the three performance groups in each age group, so that the earnings and best times of each group can be compared.

Similarly, the mean ITRs for the good, intermediate and poor performers were not significantly different in the four age groups, indicating that the three levels of performance were the same in the four age groups. Finally, there was no significant difference between the number of starts in each performance group. The mean (sd) results are shown in Table 2.

Other performance indexes

Earnings Fig 1 shows the distribution of earnings in each age group and each performance group. Both the horses' age and their level of performance had an effect on their earnings, and there was also an interaction between the two factors. The six year olds and older had significantly higher earnings than

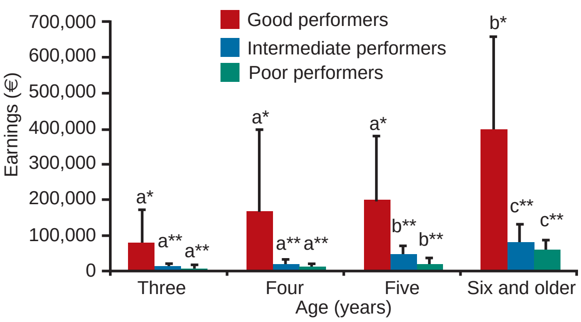

FIG 1: Earnings in each group of age and performance. Different subscripts mean significant difference (P<0·05), *, **, *, Difference between performance groups, a, b, c, Difference between age groups**

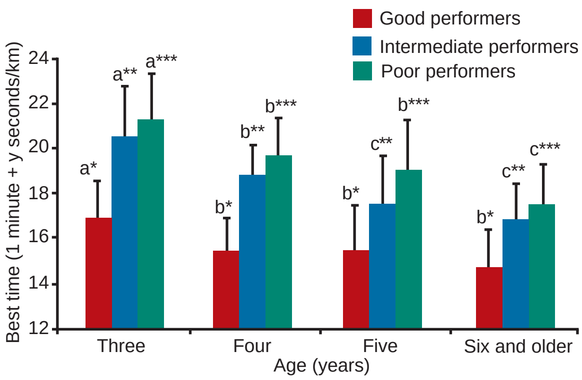

FIG 2: Best times in each group of age and performance. Different subscripts mean significant difference (P<0·05), *, **, *, Difference between performance groups, a, b, c, Difference between age groups**

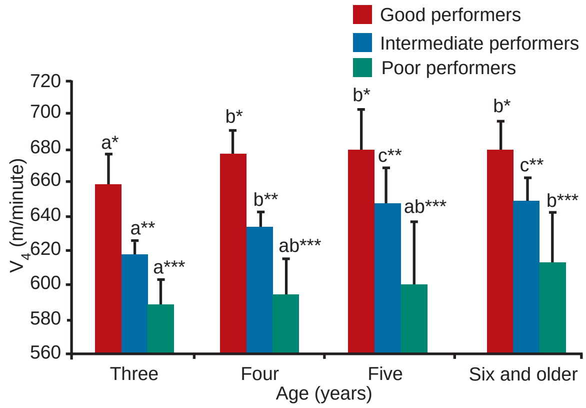

FIG 3: Repartition of V_4 in each age and performance groups. Different subscripts mean significant difference (P<0·05), *, **, *, Difference between performance groups, a, b, c, Difference between age groups**

younger horses, and five year olds earned more than three year olds. Good performers also earned more than the horses in the two other groups (P<0·05), whose earnings were not significantly different.

Best record time The mean values for best time are shown in Fig 2. The horses' age and level of performance both influenced their best time, but there was no interaction between the two. Three year olds were significantly slower than horses aged four and over. Similarly, the six year olds were significantly faster than the younger horses. There was no significant difference between the four and five year olds. There were significant differences between each performance group (P<0·05).

Physiological variables The mean values of V_4 for each age group and performance group are shown in Fig 3. The analysis of variance indicated that both the age of the horses and their level of performance had a significant effect. V_4 was significantly higher in four year olds than three year olds, and higher in five year olds than four year olds, but it then stabilised. V_4 values were significantly different between the good, intermediate and poor performers, with the best performers having the highest values. There were significant positive coefficients of correlation between V_4 and the ITR (r=0·72), between V_4 and earnings (r=0·45) and between V_4 and best time (r=0·60).

There was a linear relationship between V_4 and ITR in the whole population of horses: ITR = $0{\cdot}486V_4 - 200$ (r^2=0·52) (Fig 4). Considering each age group separately, this linear relationship was stronger in the younger horses: r^2 was 0·67 for the three year olds, 0·70 for the four year olds, 0·55 for the five year olds, and 0·35 for the six year olds and above.

The mean values of V_{200} for each age group and performance group are shown in Fig 5. The analysis of variance indicated that both the age of the horses and their level of performance had a significant effect. V_{200} increased significantly between the three year olds and four year olds and then more

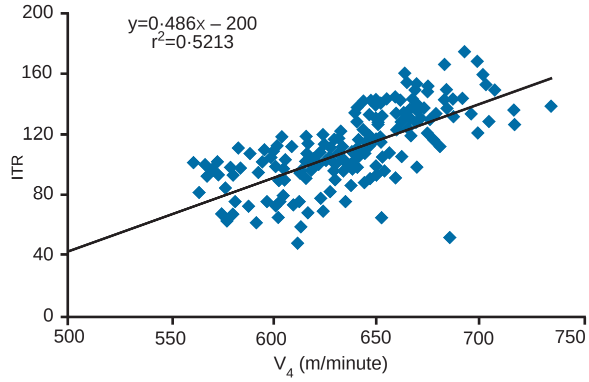

FIG 4: Linear regression equation describing the relationship between V_4 and index of trot (ITR) derived from 236 tests on 223 healthy French trotters

slowly between the four year olds and six year olds. V_{200} was significantly different in each of the performance groups, the best performers having the highest V_{200} values. Lower coefficients of correlation than those observed with V_4, were observed between V_{200} and ITR (r=0·47), between V_{200} and earnings (r=0·33), and V_{200} and between V_{200} and best time (r=–0·43).

There was a linear relationship between V_{200} and ITR (Fig 6) for the whole population: ITR = $0{\cdot}252V_{200} - 49$ (r^2=0·21). For each age group separately, the linear relationships between V_{200} and ITR were poorer than for V_4; r^2 was 0·16 for the three year olds, 0·33 for the four year olds, 0·28 for the five year olds and 0·20 for the six year olds and older.

DISCUSSION

The 223 horses studied had a wide range of athletic abilities. A lack of variation has often been used to explain the difficulty in establishing relationships between physiological measurements and performance indices (Roneus and others 1999, Davie and others 2002). Two of the criteria used to select the population, the ITR and the similar number of races run by the good, intermediate and poor performers in each age class, provided a wide range of athletic abilities. Particular care was taken to control the factors influencing V_4 and V_{200}. Environmental factors may interfere, and field tests are said to be less reliable than treadmill tests for physiological evaluations (Casini and Greppi 1996, Sloet Van Oldruitenborgh Oosterbaan and Clayton 1999). To limit the influence of external factors, only tests performed under excellent condi-

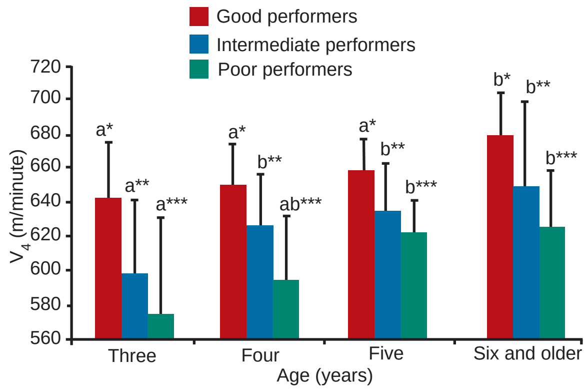

FIG 5: Repartition of V_{200} in each age and performance groups. Different subscripts mean significant difference (P<0·05), *, **, *, Difference between performance groups, a, b, c, Difference between age groups**

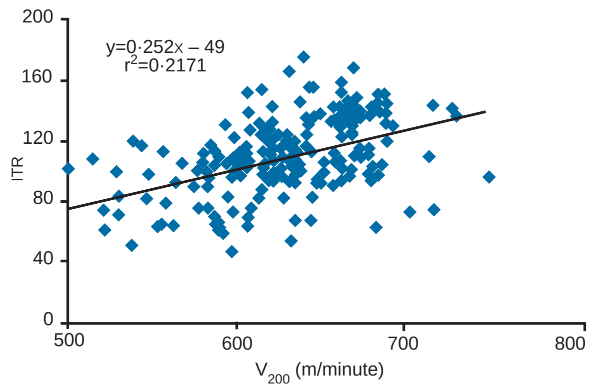

FIG 6: Linear regression equation describing the relationship between V_{200} and index of trot (ITR) derived from 226 tests on 223 healthy French trotters

tions of track and weather were included. Special attention was paid to the standardisation of the tests, in order to get accurate and comparable measurements, and the reproducibility of the tests has been verified (Dubreucq and others 1995). Finally, fitness has a great influence (Persson 1983, Wilson and others 1983, Evans 1985, Couroucé 1999, Couroucé and others 2002), and only horses in optimal physical condition were included in the analysis.

The physiological variables measured in this study were similar to those described by Casini and Greppi (1996) and Couroucé (1999). Although the mean values were similar, their sds were much larger owing to the heterogenitity of the population.

The relationships between V_4 and some performance indices have been measured by using submaximal exercise tests. Couroucé and others (1997) used the same exercise test on a race track and found that, among 100 French trotters, 96 per cent of those with low V_4 values were poor performers, but 89 per cent of those with high V_4 values were good performers. They defined a horse as a good performer if it finished in the first five in a race during the two months after the exercise test and as a poor performer if it finished lower in the placings. The different performance criteria make it difficult to make precise comparisons between the two studies. Casini and Greppi (1996) studied 20 standardbred trotters in a field exercise test and compared 10 good performers with 10 poor performers, categorised on the basis of their best time. The good performers had significantly higher V_4 values and there was a negative correlation between the V_4 values and the best time (–0·61), which is very close to that observed in the present study (–0·60). Finally, Davie and others (2002) used a two-step exercise test to study the relationship between the V_4 values and earnings of 16 pacers. They found a significant correlation between V_4 and log earnings (r=0·51, P=0·053) and log earnings per start (r=0·54, P=0·036). These correlations were slightly better than that observed in the present study (0·45), in which the strongest link between the physiological variables and the performance indices was that between V_4 and ITR (0·72). Roneus and others (1999) used the same criteria to study 10 trotters and found no significant relationship; the difference may be due to the narrower range of the IPI (the Finnish equivalent of the French ITR) which was studied (100 to 116) than the range of ITR used here (64 to 156).

In addition to differences in methodology, another factor influencing the capacity to demonstrate a relationship between V_4 and performance is the type of competition in which the horses are involved. The metabolic pathways that provide the energy for racing is mainly distance dependent (Hogdson and Rose 1994). In France, trotting races range from 2000 to 4400 m in length, with most being either 2800 or 3200 m. Clearly, the aerobic capacity demanded of a French trotter running 3200 m is not the same as that demanded of American standardbred running a mile. The variability and the length of trotter races are typically French, and this type of exercise may lead to the selection of horses with a large aerobic capacity. The significant relationships between V_4 and performance observed here, compared with other studies, may be due to the greater aerobic capacity needed by French trotters, compared with trotters running shorter distances.

The relationship between V_4 and ITR was closer in the young horses than in the older horses. Roneus and others (1999) also observed that individual differences related to performance were more pronounced in two year olds than in very similar mature horses. During the first two years of competition, registration for most races is based on age and sex alone, without regard to athletic ability, but older horses are selected for races on the basis of their previous performance, quantified by earnings. As the selection of individual horses continues, the relative importance of aerobic capacity as a factor limiting performance may decrease, but other factors, such as locomotor integrity or psychological factors may increase.

The relationships between performance indices and the physiological exercise variables V_4 and V_{200} have been investigated in a large population of trotters with a wide range of athletic abilities, and the relationships have been examined in four age groups. For horses of all ages, V_4 and V_{200} were closely related to the performance of the horse during the year of the test. The physiological parameters were significantly better for elite horses than for intermediate performers, and for intermediate performers than for poor performers. The physiological variables, and particularly V_4, were good predictors of the level of performance of a horse in the year of the test, and they were better predictors for young horses aged three to four years than for older horses, possibly because there was more variation in the athletic ability of the younger horses.

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