ABSTRACT: The objective of the study was to examine the validity of $v_4$ [velocity run under the defined conditions inducing 4 mmol/L of blood lactate concentration ([LA])] and $v_{200}$ (velocity run under the defined conditions inducing a heart rate of 200 beats/min) to differentiate performance level among Standardbred racehorses. For this purpose, 19 Standardbred trotting racehorses with differing racing time records in 2 training yards were submitted to a standardized exercise test to determine their $v_4$ and $v_{200}$ (6 horses of one yard only). The test consisted of 4 or more consecutive intervals depending on when the blood [LA] of a horse increased above 4 mmol/L. Speed and time trotted in each interval as well as time between consecutive intervals were the same for horses of a training yard. The blood [LA] measured after each interval was plotted exponentially against running speed to derive $v_4$ from the blood lactate-running speed relationship, and the mean heart rate during the intervals was plotted linearly against running speed to derive $v_{200}$ from the heart rate-running speed relationship. The correlation coefficient between $v_4$ and the racing time record was 0.77 and 0.75 for horses in racing yard A and B, respectively. There was no correlation between $v_{200}$ and the racing time record. Therefore, $v_4$ is a valid indicator of performance level of Standardbred trotting racehorses; however, $v_{200}$ may not be or to a lesser extent.

Key words: blood, exercise, heart rate, horse, lactate, race record

INTRODUCTION

Performance diagnostics should permit identification of horses that are better trained and more capable of performing in sports, as well as assess the effectiveness of training programs. For performance diagnostics, horses can be submitted to standardized exercise tests (SET) to determine their individual blood lactate-running speed (BLRS) and heart rate-running speed (HRRS) relationships. The BLRS curves and HRRS lines themselves can be used to compare horses, but more frequently variables of them are derived for performance diagnostics. The most often derived variable of the BLRS relationship is the $v_4$ [velocity run under the defined conditions inducing a blood lactate concentration ([LA])] of 4 mmol/L; Persson, 1983; Lindner, 2000]. The $v_{200}$ is frequently calculated as the variable representing the HRRS (velocity run under defined conditions inducing a heart rate of 200 beats/min; Persson, 1983; Couroucé, 1997). However, there are few studies published on their validity as performance diagnostics of racing horses.

The hypothesis of this study was that the better the racing time record of Standardbred trotting racehorses, the greater would be their $v_4$ and $v_{200}$ values.

MATERIALS AND METHODS

The results of this study were obtained in the course of providing regular commercial service of performance diagnosis and training guidance to clients in the race industry.

Horses and Study Design

A single study design was applied in 2 training yards. In yard A, 7 healthy Standardbred horses (mean ± SD BW: 460 ± 36 kg; between 3 and 7 yr old; 3 stallions, 4 mares) were included, and in yard B, 12 horses (BW 482 ± 23 kg; between 3 and 5 yr old; 11 stallions and 1 mare) were included.

All horses had a racing time record determined during races of the German Standardbred Trotting Association obtained within the 1 and 6 wk before the SET and had been conditioned for racing for at least 18 mo. All horses were submitted to a SET, but the prescription differed between yards because their oval dirt training tracks had different lengths (in yard A the
track was 1,000 m and in yard B 800 m), and the duration of each interval was aimed to be as close as possible to 5 min, whereas the speed of the SET intervals had to be such that the blood [LA] would increase continuously from concentrations before exercise to 4 or more mmol/L in not less than 4 intervals (Table 1). During the SET, the drivers used a stopwatch constantly to set the prescribed pace. Before each SET, the track was groomed to ensure regular lane conditions. All horses of a yard were tested on the same day between 0730 and 1100 h under similar weather conditions (mean ± SD of environmental temperature at yard A 21.6 ± 2.5°C, relative humidity 70.4 ± 6.0%; at yard B 22.3 ± 2.0°C and 65.2 ± 5.7%, respectively).

SET and Blood Sample Collection

Horses were warmed up between 10 and 15 min at a walk and slow trot before starting the SET. The increase of the speed from interval to interval was such that a continuous increase of the blood [LA] from the concentration before exercise but after warm-up to 4 or more mmol/L was obtained in not less than 5 intervals (Table 1). This was done to have at least 4 values to describe the BLRS and v4 from the BLRS relationship. After calculation of the coefficients A, B, and C, v4 could be determined using the equation v = [ln([LA]+C) − B] / A.

Blood samples (5 mL) were collected via jugular venipuncture into Na-heparinized evacuated tubes (Becton Dickinson, Heidelberg, Germany) for measuring blood [LA].

Lactate Analysis

Twenty microliters of each blood sample were transferred immediately after collection to vials containing 200 µL of 0.6 N perchloric acid. Samples were centrifuged at 12,000 × g for 10 min at 20°C, and the supernatant was transferred to empty vials. Samples were stored at 4°C for up to 4 d until analysis, using an enzymatic test kit in a laboratory (Boehringer Mannheim No. 1178750). The intraassay CV for this enzymatic method was 3.2% for a [LA] of 2.15 mmol/L and 4.0% for a concentration of 4.4 mmol/L. These samples were used to calculate the v4 from the BLRS relationship.

Beginning with the third interval, blood [LA] of horses after each interval was measured on site with Accusport. When the blood [LA] was above 4 mmol/L, SET was finished. These values were used to determine when to stop the SET only.

Heart Rate Measurement

Horses of yard A were fitted with heart rate monitors (Polar Sport Tester, Kempele, Finland). The mean heart rate during each interval was plotted linearly against the speed of each interval, and v200 was calculated from this relationship. The monitor recorded the heart rate every 5 s during SET.
Driving Accuracy of Drivers

Two drivers exercised all horses in yard A, 3 drivers in yard B. All were experienced, active Standardbred race drivers. The mean difference between prescribed and driven speed was 0.12 ± 0.12 m/s for drivers in yard A (0.23, 0.05, 0.16, 0.04, 0.05, and 0.10 m/s for the 6 prescribed speeds, respectively), and for drivers in yard B 0.10 ± 0.04 m/s (0.13, 0.15, 0.07, 0.12, 0.13, and 0.05 m/s for the 6 prescribed speeds, respectively).

Statistical Analysis

The relationship between the racing time record of the horses and their $v_4$ and $v_{200}$ (yard A horses only) was examined by means of linear and exponential regression (SPSS/PC, SPSS Inc., Chicago, IL); $P < 0.05$ was accepted as significant. Values are expressed as means ± SD.

RESULTS

After the first 2 to 3 intervals of SET, no clear visual differences of the development of the blood [LA] could be seen among horses, but after the 4th interval, differences could be seen (Figures 1 and 2). The horses with the better racing time records had to trot more intervals to reach a blood [LA] at or above 4 mmol/L. The values shown in the figures are those measured in the laboratory. These values were used to calculate $v_4$ only. The SET of a horse was stopped when its blood [LA] was close to or above 4 mmol/L to reduce the risk of lameness due to running unnecessarily at greater speeds and for more time. These measurements were done on site with Accusport. The blood [LA] values measured with Accusport are greater than those measured in the laboratory (Lindner, 1996). These values are not shown in Figures 1 and 2, and this explains why some of the blood [LA] values shown are under the 4 mmol/L line at the end of the SET.

Between $v_4$ and racing time record of horses in yards A and B were significant linear coefficients of determination ($r^2 = 0.56$ and 0.60, respectively; $P < 0.05$ and $<0.01$, respectively; regression equations of horses in yard A: $v_4 = 688.925 - 5.334 \times$ race record and race record $= 84.385 - 0.111 \times v_4$; regression equations of horses in yard B: $v_4 = 787.768 - 11.347 \times$ race record and race record $= 45.868 - 0.049 \times v_4$). The coefficient of determination in yard B improved slightly to 0.62 when an exponential regression was applied to examine the relationship between racing record and $v_4$ ($P < 0.001$), whereas for horses in yard A, the exponential correlation was not better ($P < 0.01$) than the linear.

Mean heart rate during the intervals of SET is shown in Table 2. The heart rate of 1 horse was not recorded by the heart rate monitor. There was no correlation between the racing time record and $v_{200}$ of horses in yard A ($P > 0.05$; Figure 3).

DISCUSSION

The $v_4$ of the Standardbred racehorses examined was linearly correlated with their individual racing time record as the measure of their performance. This re-
relationship was built on individual data, and this approach has not been used often (Casini and Greppi, 1996). One reason is that horses competing in other sport disciplines do not have such an objective measure of their competitive performance like the racing record of Standardbreds. However, there have been good relationships described between v4 and other variables of performance, such as earnings, placings, and winnings. This involves endurance riding (Demonceau, 1989; Erickson et al., 1990), 3-d-eventing (Galloux, 1991), Standardbred racing (Couroucé, 1997; Ponchard, 1998), Thoroughbred racing (Ponchard, 1998; Davie, 1999), and Quarterhorse racing (Erickson et al., 1991). No other variable has shown as frequently a good relationship with variables of sports performance.

In contrast, there was no correlation between the racing time record of horses and their v200 in yard A. Leleu et al. (2004) observed the same with their Standardbreds. It is not uncommon that, compared with v4, the v200 or other variables of the HRRS relationship do not react as much to conditioning (Sloet van Oldruitenborgh-Oosterbaan, 1990; Trilk et al., 2002). Thus, this seems to be the case for performance diagnostics too. Evans (1994) stated in his review on the cardiovascular system of horses that heart rate during submaximal exercise is an unreliable index of fitness in horses. This may be because of the smaller range of adaptation to conditioning than blood [LA].

Data analysis for the correlation of racing time records and v4 had to be performed separately for the 2 yards because the prescriptions of the SET differed in the speed at which the horses run the intervals. This

Table 2. Heart rates of Standardbred trotting racehorses of yard A during intervals of the standardized exercise test (mean ± SD)

<table>
<thead>
<tr>
<th>Interval</th>
<th>Number of horses that run the interval</th>
<th>Heart rate, beats/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>131 ± 13</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>142 ± 13</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>156 ± 12</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>175 ± 15</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>195 ± 12</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>216 ± 9</td>
</tr>
</tbody>
</table>

Figure 2. Blood lactate-running speed curves of 12 Standardbred racehorses with racing time records for 1 km in yard B.

Figure 3. Correlation between v200 and racing time records of 6 Standardbred racehorses in yard A.
was because of the different length of the training tracks and that the duration of each interval was prescribed to be close to 5 min. Thus, with horses starting and finishing an interval at the same place of the track, the duration of each interval depended on the speed of the horses in the interval and the number of laps that they had to run to be close to the 5-min mark. In addition, the speed of the initial interval and the increase of the speed in each interval had to be such that at least 4 intervals had to be run by the horses before a blood [LA] of 4 mmol/L or more was measurable. These requirements were in place because of the v₄ concept adopted from sport science in humans (Mader et al., 1976). Mader et al. (1976) postulated that the v₄ is the value on the lactate power curve that best reflects the aerobic/anaerobic threshold in running man and therefore the maximal lactate steady state. This was confirmed experimentally by Heck et al. (1985). In both studies, the athletes were submitted to SET with steps of 5-min duration and to speeds that increased gradually the blood [LA] to above 4 mmol/L during 4 or more steps. These requirements allow for a good repeatability of the results also (Guhl et al., 1996; Köster, 1996) and are the basis for the research on guiding the exercise speed of conditioning programs with blood [LA] (Werkmann et al., 1996; Gansen et al., 1999; Trilk et al., 2002; Rivero et al., 2007; Lindner et al., 2009). In addition, they allow for the final speed at which horses have to run to achieve a blood [LA] of 4 or more mmol/L to be less than when the same speeds are run in steps of shorter duration (Köster, 1996). This reduces the risk of lameness under field conditions. In conclusion, these results show that v₄ can be considered a valid variable to estimate the competitive performance of Standardbred racehorses, whereas v₂₀₀ does not.

**LITERATURE CITED**


