

COMPARISON OF THE METABOLIC RESPONSES OF TRAINED ARABIAN AND THOROUGHBRED HORSES DURING HIGH AND LOW INTENSITY EXERCISE

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Summary

The metabolic responses to low and high intensity exercise were compared in 5 Arabian (AR) and 5 Thoroughbred (Tb) horses. For 2 months before the study, horses were fed an identical diet and undertook a similar exercise training program. Horses then completed 3 treadmill (3° incline) trials: 1) an incremental test (MAX) for determination of aerobic capacity, V_{LA4} , and lactate threshold (LT; the percentage of VO_{2max} when plasma lactate = 4 mM); 2) a single high-speed exercise test (SPR) for estimation of maximal accumulated oxygen deficit (MAOD) in which horses ran at 115% VO_{2max} until no longer willing to maintain position on the treadmill; and 3) a 90 min test at 35% VO_{2max} (LO). VO_{2max} ($P < 0.001$) and running speed ($P < 0.05$) at VO_{2max} were higher in Tb (154 ± 3 ml/kg/min at 12.9 ± 0.5 m/s) than in AR (129 ± 2.5 ml/kg/min at 11.8 ± 0.2 m/s). Total run time during MAX was greater ($P < 0.05$) in Tb (10.5 ± 0.5 min) than in AR (9.3 ± 0.3 min). However, V_{LA4} and LT were not different between groups. Run time during SPR (Tb 149 ± 16 ; AR 109 ± 11 s) and MAOD (Tb 88 ± 4 ; AR 70 ± 6 ml O_2 /kg) were higher ($P < 0.05$) in the Tb group. During LO, FFA were higher ($P < 0.05$) in AR than in TB between 60 and 90 min, while respiratory exchange ratio (RER) was lower ($P < 0.05$) from 60 to 90 min of exercise, indicating a greater use of fat for energy. The higher aerobic and anaerobic capacity of the Tb horses likely contributed to their superior high intensity exercise performance. Conversely, the AR may be better adapted for endurance exercise as evidenced by the greater use of fat. These metabolic differences may reflect breed variation in muscle fiber types.

Introduction

Few studies have formally compared indices of athletic performance in different breeds of horses. Rose and colleagues (Rose et al. 1995) described indices of exercise capacity in Thoroughbred and Standardbred racehorses that were examined because of poor performance. These researchers reported that aerobic capacity and total run time, measured during an incremental exercise test, were significantly greater in the Thoroughbreds compared to the Standardbreds. However, as these horses were examined for performance problems, it is difficult to apply the findings to normal racehorses.

In this study, we examined selected measures of exercise capacity and metabolism in a small group of Thoroughbred and Arab horses of similar age, training background, and diet. Both breeds of horses are used for several athletic disciplines, ranging from sprint racing to endurance events. However, anecdotal evidence indicates that Thoroughbreds have superior high intensity exercise capacity, whereas Arabian horses are regarded as superior performers during endurance exercise. We hypothesized that the facility of Thoroughbred horses for high intensity exercise would be reflected in greater aerobic and

anaerobic capacities when compared to the Arabian horses. We also hypothesized that respiratory exchange ratio (RER) would be lower in the Arab horses during low intensity exercise, reflecting a greater use of fat for energy.

Materials and Methods

Five Thoroughbred (Tb) geldings (8-12yrs, body weight 515 ± 13 kg) and 5 Arabian (AR) geldings (8-10yrs, body weight 432 ± 9 kg) were studied over a 3-week period. During the 2 months adaptation period prior to testing, all horses were fed an identical diet and undertook a similar exercise program. All exercise, before and during the study, involved a combination of treadmill exercise and walking on a mechanical walker (treadmill 3-days and walker 4-days a week). All the horses were acclimatized to the equine treadmill and walker and had participated in several treadmill exercise studies during the previous two year period. The horses were housed in box stalls, with a minimum of 5-hours paddock turnout per day. Muzzles were worn to prevent grazing. The diet consisted of unfortified sweet feed (45% cracked corn, 45% whole oats, 10% molasses), alfalfa cubes, bluegrass orchard hay, loose salt (50g per day) and a mineral supplement Microphase (60g per day). The amounts fed were adjusted for body weight. Horses had unlimited availability of fresh water at all times.

Exercise tests

Following the adaptation period horses completed 3 treadmill (3° incline) trials. 1) an incremental exercise test (MAX) for determination of the maximal rate of oxygen consumption (VO_{2max}) and several other indices of exercise capacity; 2) a single high-speed exercise test (SPR) for estimation of maximal accumulated oxygen deficit (MAOD) in which horses ran until fatigue at 115% VO_{2max} ; and 3) a 90 min test at 35% VO_{2max} (LO). During all exercise tests, oxygen consumption (VO_2), carbon dioxide production (VCO_2), and RER were measured by indirect calorimetry. There was a minimum of 7 days between tests and the order of the SPR and LO trials were randomized.

For MAX, horses ran for 90 s at 4 and 6 m/s, with subsequent increases of 1 m/s every 60 s until the horses were unable to maintain their position on the treadmill. VO_{2max} was determined when oxygen consumption increased by $<4\text{ml/kg/min}$ despite a 1 m/s increase in running speed. The speed: VO_2 relationship for each horse was determined by linear regression of oxygen consumption and speed during the incremental exercise test. Heart rate was recorded throughout exercise (Polar HR meter). Blood samples for measurement of hematocrit and plasma lactate concentrations were obtained during the last 10 s of each speed increment and at the end of the test.

Anaerobic capacity was estimated by the measurement of MAOD during SPR. The SPR consisted of a 5 min warm-up at 4 m/s, followed by running at a speed calculated to require an oxygen consumption 115% of VO_{2max} until the horses were unable to maintain their position on the treadmill, and a 5 min cool down at 4 m/s. Total run time and actual running speed were recorded for each horse. Oxygen deficit was calculated by subtracting the actual VO_2 , measured during the SPR, from estimated O_2 demand (Eaton et al. 1995). Oxygen demand was calculated from the speed- VO_2 relationship, determined

by measuring VO_2 at each speed during the incremental exercise test. The regression equation describing the VO_2 -speed relationship was used to estimate oxygen demand at higher running speeds. Blood samples for measurements of plasma lactate concentrations were collected before exercise, at the end of the sprint protocol, and after 5 and 10 min of recovery. In LO, blood samples for measurement of plasma glucose and free fatty acids (FFA) were obtained at 0, 5, 15, 30, 45, 60, 75, and 90 min of exercise. VO_2 and VCO_2 were measured at 5-min intervals throughout exercise from which RER (VCO_2/VO_2) was calculated.

Analyses and calculations

Hematocrit was measured in triplicate by the microhematocrit method. Plasma glucose and lactate concentrations were measured in duplicate using an automated analyzer (YSI 2300 analyzer). Plasma FFA concentrations were determined using a commercial kit that employs an enzymatic colorimetric method (NEFA test kit; Wako Chemicals). From data collected during MAX, the following measurements were made or values determined by linear regression: $\text{VO}_{2\text{max}}$, peak hematocrit, maximum oxygen pulse ($\text{VO}_{2\text{max}}/\text{HR}_{\text{max}}$), speed at a heart rate of 200 (V_{200}), running speed that elicited a plasma lactate concentration of 4 mM ($V_{\text{LA}4}$), lactate threshold (LT; the percentage of $\text{VO}_{2\text{max}}$ when plasma lactate reached 4 mM), end-exercise plasma lactate, peak running speed, and running speed at $\text{VO}_{2\text{max}}$. All metabolic computations were expressed on a mass-specific basis. The data were analyzed using an unpaired Students *t* test (variables during the MAX and SPR tests) or, for the LO test, by a 2-way repeated measures ANOVA (breed and time as independent variables). Significance was taken at $P < 0.05$.

Results

There were significant differences for a number of variables measured during MAX when the Thoroughbred and Arabian horses were compared. $\text{VO}_{2\text{max}}$, running speed at $\text{VO}_{2\text{max}}$, peak speed, total run time, maximum oxygen pulse, and peak hematocrit were significantly higher in Tb than in AR (Table 1).

Table 1. Metabolic indices in Thoroughbred and Arab horses during an incremental treadmill exercise test.

Variable	Thoroughbreds	Arabs
$\text{VO}_{2\text{max}}$ (ml/kg/min)	$154 \pm 3^*$	129 ± 2.5
Maximum oxygen pulse	$0.639 \pm 0.009^*$	0.603 ± 0.006
Peak hematocrit (l/l)	$0.628 \pm 0.01^*$	0.56 ± 0.009
V_{200} (m/s)	9.76 ± 0.21	9.51 ± 0.16
$V_{\text{LA}4}$ (m/s)	8.44 ± 0.27	8.27 ± 0.46
LT (% $\text{VO}_{2\text{max}}$)	71.9 ± 2.5	72.7 ± 2.7
End exercise lactate (mmol/l)	21.9 ± 2.1	18.1 ± 0.9
Peak speed (m/s)	$13.6 \pm 0.9^*$	12.5 ± 0.2
Speed at $\text{VO}_{2\text{max}}$ (m/s)	$12.9 \pm 2.5^*$	11.8 ± 0.2
Run time (s)	$630 \pm 30^*$	558 ± 20

Values are mean \pm SE for 5 horses. *Significant difference from Arabian horses.

However, there were no significant differences between breeds for V_{LA4} , LT, V_{200} and plasma lactate concentration at the end of the test. Running speed during SPR was 14.5 ± 0.2 m/s and 13.4 ± 0.2 m/s for the Tb and AR horses, respectively. Total run time during SPR was 27% longer in the Tb (149 ± 16) than in the AR (109 ± 11 s). Similarly, MAOD and peak plasma lactate concentrations were significantly higher in the Tb group (Fig. 1).

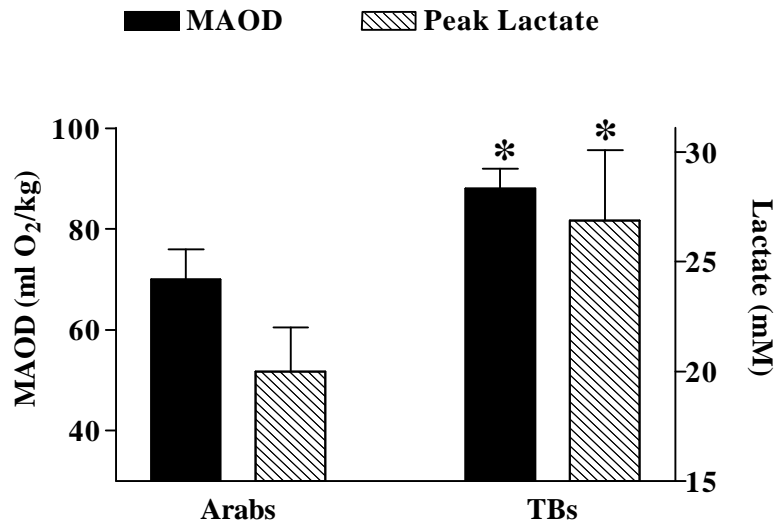


Figure 1. Maximum accumulated oxygen deficit and peak lactate concentrations for the Arabian and Thoroughbred horses during a single high speed exercise test at 115% of maximum oxygen uptake.

During LO, running speeds for the Tb and AR horses were 5.2 ± 0.1 m/s and 4.7 ± 0.1 m/s, respectively, corresponding to a relative workload of $35 \pm 1\%$ of VO_{2max} . Plasma FFA were higher ($P < 0.05$) in AR than in Tb between 60 and 90 min, while RER was lower ($P < 0.05$) in the AR horses from 60 to 90 min of exercise (Table 2). Plasma glucose concentrations were significantly higher in the Tb than in the AR horses at several time points during exercise, but there were no breed differences for plasma lactate concentrations (Table 2).

Discussion

The main findings from the present study were (1) a higher VO_{2max} , maximum O_2 pulse and run time in the Tb compared to AR horses during the incremental exercise test (MAX); (2) an apparently greater anaerobic capacity in the Tb horses, as evidenced by higher values for MAOD during SPR; and (3) lower RER in the AR horses during LO, indicating breed differences in substrate selection during low intensity exercise. Among other factors, diet and training history, can markedly influence the metabolic response to exercise. An advantage of the present study was the ability to control for these factors. For the 2-month period prior to the study, the horses were fed an identical diet and the level of conditioning undertaken by both groups of horses was similar. However, it is

possible that previous training history contributed, at least in part, to the observed between breed differences in metabolic responses. For the 2-year period before the study, the AR horses had been used for endurance exercise studies and their conditioning primarily comprised low intensity exercise. On the other hand, conditioning of the Tb horses involved a combination of low and high intensity exercise during the same time frame.

On average, the AR ran for approximately 70 s less than the Tb horses during MAX and had significantly lower values for several of the metabolic indices. In a previous study of racing Standardbreds and Thoroughbreds, metabolic indices that indicated a high capacity for oxygen transport were predictive of treadmill run time during incremental exercise (Rose et al. 1995). Similarly, in the present study, the higher $\text{VO}_{2\text{max}}$, maximum O_2 pulse, an index of stroke volume, and peak hematocrit in the Tb horses were factors that likely contributed to the longer exercise time during MAX. The Tb horses also demonstrated higher work capability during supramaximal exercise as demonstrated by the longer run time in SPR. This greater work capability may be attributable to higher $\text{VO}_{2\text{max}}$ and MAOD, the latter an indirect measure of maximal anaerobic metabolism (Eaton et al. 1995). This apparent breed difference in anaerobic capacity may reflect variation in muscle fiber types and the muscle concentrations and activities of enzymes involved in glycolysis, such as lactate dehydrogenase and phosphofructokinase.

Another interesting finding was the lower values for RER in the AR horses during exercise at 35% $\text{VO}_{2\text{max}}$. Furthermore, FFA concentrations were higher in the AR between 60 and 90 min of exercise. As FFA utilization is considered proportional to blood concentration, the data for RER and FFA concentrations support the hypothesis that the AR horses are better adapted for fat metabolism during low intensity exercise. Carbohydrate supply can be a performance limiting factor during prolonged exercise, therefore a greater use of fat for energy may delay carbohydrate depletion and extend performance during such exercise. As for the metabolic responses to high intensity exercise, further studies are required to determine the mechanisms underlying this apparent breed difference in energy metabolism during low intensity exercise.

References

Eaton MD, Rose RJ, Evans DL, Hodgson DR. Assessment of anaerobic capacity using maximal accumulated oxygen deficit in fit Thoroughbreds. *Equine Vet J Suppl.* 18 (1995) 29-32.

Rose RJ, King CM, Evans DL, Tyler CM, Hodgson DR. Indices of exercise capacity in horses presented for poor racing performance. *Equine Vet J Suppl.* 18 (1995) 418-421.

TABLE 2. Plasma FFA, glucose and lactate concentrations and respiratory exchange ratio in Thoroughbred (TB) and Arabian (AR) horses during 90min of exercise at 35% of maximal oxygen uptake.

	<u>Time, min</u>						
	<u>0</u>	<u>15</u>	<u>30</u>	<u>45</u>	<u>60</u>	<u>75</u>	<u>90</u>
<u>Glucose, mmol/l</u>							
<u>Tb</u>	<u>5.23 ± 0.10</u>	<u>7.24 ± 0.5*</u>	<u>7.30 ± 0.61</u>	<u>7.45 ± 0.58*</u>	<u>7.65 ± 0.71</u>	<u>8.05 ± 0.84</u>	<u>8.67 ± 0.80*</u>
<u>AR</u>	<u>5.44 ± 0.12</u>	<u>6.36 ± 0.27</u>	<u>6.67 ± 0.26</u>	<u>6.70 ± 0.30</u>	<u>7.04 ± 0.33</u>	<u>7.44 ± 0.39</u>	<u>7.50 ± 0.41</u>
<u>FFA, mmol/l</u>							
<u>Tb</u>	<u>0.36 ± 0.09</u>	<u>0.49 ± 0.111</u>	<u>0.67 ± 0.11</u>	<u>0.79 ± 0.13</u>	<u>0.78 ± 0.12*</u>	<u>0.82 ± 0.09*</u>	<u>0.80 ± 0.10*</u>
<u>AR</u>	<u>0.33 ± 0.04</u>	<u>0.59 ± 0.09</u>	<u>0.76 ± 0.10</u>	<u>0.87 ± 0.07</u>	<u>0.99 ± 0.10</u>	<u>1.04 ± 0.08</u>	<u>1.11 ± 0.12</u>
<u>Lactate, mmol/l</u>							
<u>Tb</u>	<u>0.810 ± 0.06</u>	<u>1.41 ± 0.60</u>	<u>1.23 ± 0.36</u>	<u>1.15 ± 0.27</u>	<u>1.09 ± 0.34</u>	<u>1.04 ± 0.29</u>	<u>0.90 ± 0.31</u>
<u>AR</u>	<u>0.74 ± 0.09</u>	<u>0.99 ± 0.31</u>	<u>0.94 ± 0.22</u>	<u>0.80 ± 0.19</u>	<u>0.75 ± 0.21</u>	<u>0.70 ± 0.18</u>	<u>0.65 ± 0.17</u>
<u>RER</u>							
<u>Tb</u>	<u>ND</u>	<u>0.95 ± 0.02</u>	<u>0.91 ± 0.02</u>	<u>0.90 ± 0.03</u>	<u>0.89 ± 0.02*</u>	<u>0.86 ± 0.01*</u>	<u>0.85 ± 0.02*</u>
<u>AR</u>	<u>ND</u>	<u>0.91 ± 0.02</u>	<u>0.88 ± 0.01</u>	<u>0.84 ± 0.02</u>	<u>0.83 ± 0.01</u>	<u>0.80 ± 0.02</u>	<u>0.80 ± 0.02</u>

Values are mean ± SE for 5 horses.

FFA, free fatty acids; RER, respiratory exchange ratio; ND not done

*Significant difference from AR