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Effect of conditioning horses with an increasing number of high intensity intermittent exercise runs

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Summary: High intensive intermittent exercise (HIIE) is used to condition horses for racing. A study was done to examine the effect of short duration HIIE on the maximal speed ($Speed_{max}$) and v_4 of 6 Thoroughbred race horses (v_4: speed at which under defined conditions the blood lactate concentration [LA] reaches 4 mmol/l). Horses were exercised during 8 weeks with one HIIE session per week on a dirt track. A HIIE session consisted of two runs of 100 m each at near maximal speed separated by 10 minutes walking. After every second week during the conditioning period (CP) the number of runs was increased by one finishing with 5 runs per HIIE session in the last two weeks of CP. Prior to the CP, horses performed a submaximal standardized exercise test ($SET_{submaximal}$) and a maximal speed test ($SET_{speedmax}$) to determine their v_4 and $Speed_{max}$ respectively. $SET_{submaximal}$ was conducted every 2 weeks until the end of CP and $SET_{speedmax}$ after 4 weeks and 8 weeks of CP. The v_4 of horses declined during the first 4 weeks of CP ($p < 0.05$), but returned to initial levels thereafter. $Speed_{max}$ remained equal over time. The results indicate that further studies need to be done to find optimal combinations of exercises to simultaneously increase $Speed_{max}$ and v_4 of horses.

Keywords: duration, high intensity, lactate, stride length, training

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Introduction

High-intensity intermittent training (HIIT) is a form of interval training consisting of short duration bouts of all-out activity separated by rest periods. It is well established that HIIT is effective at improving performance in elite human athletes, but the protocols used vary widely. [1,2] The performance improvement is attributed to changes in maximum oxygen consumption, power output, lactate threshold, time-trial performance and motion economy. [3–8]

The effect of training horses with interval exercise has been studied in horses too. [9–16] The intensity of exercise of the interval training protocols described in these studies was near maximal and the duration of intervals above 30 s. There are few studies on conditioning horses with high intensity intermittent exercise (HIIE) of much shorter duration than 30 s. [17,18] This type of exercise is preferentially used to train race horses in America, especially for horses racing up to 400 m. [17] *Lindner* et al., [18] describe a decrease of v_4 after conditioning horses during 6 weeks using HIIE sessions with two bouts of exercise of 100 m at near-maximal speed one, two and three times a week (v_4: speed run under defined conditions which induces a blood [LA] of 4 mmol/l). This decline of v_4 could impact negatively racing performance because it has been shown that racehorses with a higher v_4 perform better. [19–23] In the current study, the effect of exercising horses during 8 weeks with an increasing number of runs during HIIE sessions once a week on v_4 and the maximal running speed ($Speed_{max}$) was examined. The hypotheses were: 1) $Speed_{max}$ increases; 2) A decline of v_4 can be avoided.

Material and methods

Horses

Six Thoroughbreds (6.67 ± 1.75 years old; 2 mares, 2 geldings, 2 stallions) were used for the study with the consent of their owners. The horses had been racing for 2 to 4 years before entering the study but were not considered by the trainer to be fit for racing. All horses were housed individually in 3×3 m boxes and were given access to sandy paddocks for several hours every day. Horses were fed twice per day (07.00 and 18.00 hrs; grass hay and a 12 % protein concentrate plus minerals) during the conditioning period (CP) according to the individual energy needs based on body weight and workload. Horses were weighed before, during and at the end of CP on a commercial scale. The horses were submitted to HIIE once a week. On the other days, light work (30 min walk and trot in total) was performed. There was not a control group because the exercise tests are stressful and can be painful and risky for the health of horses not conditioned properly. The study design is shown in Table 1.

Exercise

All horses were acclimated to the exercises for 6 to 8 weeks before the CP by subjecting them to one or two fast speed 100 m runs twice a week and once a week up to 30 minutes trot and canter. On the other days, light work (30 min walk and trot in total) was performed.

The CP lasted for 8 weeks. Exercise was conducted on a 1,600 m dirt racetrack. HIIE consisted of the horses running 100 m at near-maximal speed (12.0–14.0 m/s). In the first two weeks of CP horses run once a week two intervals and the number of intervals in each HIIE session increased by one every two weeks. Before the HIIE horses were warmed-up for 10–15 min at the walk and trot. The horses were then ridden before each run to a distance of approximately 10 m from the starting line. On a visual signal, the run began with the horses crossing the starting line as fast as they could. At the moment of crossing the starting line a person positioned there gave a visual signal for another person positioned at the finishing line to enable the run time to be clocked and the overall speed determined. Between the runs there was a 10 min walking period.

Standardized exercise tests

Horses were subjected to two different standardized exercise tests (SET): a submaximal SET to determine v_4 ($SET_{submaximal}$) and a SET to determine maximal speed over 100 m and stride length over 150 m ($SET_{speedmax}$). $SET_{submaximal}$ was performed prior to the CPs and every 2-weeks during and until the end of CP (table 1) while $SET_{speedmax}$ was conducted at the beginning, at the middle and at the end of CP (table 1).

Table 1 Study design | *Aufbau der Studie*

Study phase	Duration	Procedures
Adaptation	6–8 weeks	Horses vaccinated, wormed and adapted to all procedures: blood sampling, heart rate meter, staff, high-intensity intermittent exercise (HIIE)
Testing	2 days	1st $SET_{speedmax}$
	2 days	1st $SET_{submaximal}$
Conditioning	2 weeks	Once per week HIIE (2 intervals)
Testing	2 days	2nd $SET_{submaximal}$
Conditioning	2 weeks	Once per week HIIE (3 intervals)
Testing	2 days	2nd $SET_{speedmax}$
	2 days	3rd $SET_{submaximal}$
Conditioning	2 weeks	Once per week HIIE (4 intervals)
Testing	2 days	4th $SET_{submaximal}$
Conditioning	2 weeks	Once per week HIIE (5 intervals)
Testing	2 days	3rd $SET_{speedmax}$
	2 days	5th $SET_{submaximal}$

SET: standardized exercise test for submaximal and maximal speed.
HIIE: high-intensity intermittent exercise at near-maximal speed over 100 m.

For $SET_{speedmax}$ horses were handled as for the HIIE runs but speed was measured between 50 and 150 m of the run only with a wireless speed measuring device (GASYS, hs-electronics, Falkensee, Germany). The stride length was measured mechanically in 50 m sections of the 150 m run between the mark where the foot of the lead leg hit the ground and the marks where that foot next stroke the ground. Stride frequency was calculated dividing the last 100 m of the 150 m of $SET_{speedmax}$ with the stride length over that distance.

$SET_{submaximal}$ consisted of several intervals (Table 2). The running speed of horses in interval 1 was 6 m/s with the speed increasing in each consecutive interval allowing for a continuous increase of blood lactate concentration [LA] from basal values up to 4 mmol/l in not less than 3 intervals and not more than 5 intervals. All blood samples were collected from the jugular vein within 20 s of finishing an interval with Na-heparinized evacuated tubes (Vacutainer, Becton Dickinson, Heidelberg, Germany). Blood [LA] was determined immediately (Accusport, Boehringer Mannheim, Germany.[24]) When a horse reached a speed at which its blood [LA] $\geq$ 4 mmol/l, the $SET_{submaximal}$ was terminated. A blood [LA] vs. speed curve was generated using regression analysis to calculate the horse's v_4.[25]

Maximal blood lactate concentration

The maximal blood [LA] [LA_{max}] after $SET_{speedmax}$ was determined from blood collected immediately, 2, 4, 6 and 8 minutes after the test.

Blood [LA_{max}] was also determined after the first two runs of the HIIE sessions in the 2nd, 4th, 6th, and 8th week of CP, and after the last run of the HIIE sessions in the 4th, 6th and 8th week of CP in addition. Blood after the runs of HIIE sessions was collected at the same times as after $SET_{speedmax}$, and blood [LA] measured as described above.

Statistical analysis

Statistics were conducted using Statview 5.0 (SAS, Cary, NC, USA). Normality of data was confirmed using the Kolmogorov-Smirnov test. All data are expressed as means ± standard deviation (SD). The effect of conditioning on body weight, v_4,

Table 2 Standardised exercise tests (SETs). | *Standardisierte Belastungstests (SETs).*

SETs	Parameters		
	Interval	Length of run (m)	Running speed (m/s)
$SET_{submaximal}$	1	1640	6.00
	2	3280	6.67
	3	3280	8.33
	4	3280	10.00
	5	3280	11.67
SETspeedmax	1	150 [1]	Maximal

[1] The whole distance of 150 m is used to measure the stride length and the last 100 m of it is used to measure the maximal speed

$Speed_{max}$, $[LA_{max}]$ after $SET_{speedmax}$, stride length and stride frequency were examined using repeated measures ANOVA. The relationship between $Speed_{max}$ and stride frequency as well as stride length was examined by means of linear and exponential regression. Significant effects were further analyzed with a means comparison post-hoc test (Fisher-test). A value of $p \leq 0.05$ was considered significant.

Results

Body weight

The body weight of the horses increased during CP (Table 3; $p < 0.01$) (Table 3).

Running speed during and blood [LA_{max}] after exercise

Table 4 shows mean running speeds and $[LA_{max}]$ concentration in blood of horses after HIIE session runs. The speeds achieved during the 100 m runs varied between 12 and 17 m/s, $[LA_{max}]$ was in most cases below 10 mmol/l blood. The time of blood $[LA_{max}]$ differed: 42 % of the values were 2 minutes after exercise, 24 % immediately after, 22 % after 6 minutes and 12 % 6 minutes after exercise (Table 4).

Stride variables during $SET_{speedmax}$

The mean stride length and frequency of horses running the $SET_{speedmax}$ increased significantly among consecutive 50 m intervals (both $p < 0.01$; Table 5) but there was no significant change during CP (Table 5; both $p > 0.05$). $Speed_{max}$ was not related to mean stride length nor mean stride frequency over the last 100 m of the 150 m of $SET_{speedmax}$ (Table 5; $p > 0.05$).

$Speed_{max}$ during and blood [LA_{max}] after $SET_{speedmax}$

$Speed_{max}$ during $SET_{speedmax}$ showed a trend to increase ($p = 0.07$) and blood $[LA_{max}]$ after $SET_{speedmax}$ to decrease (Table 5; $p = 0.09$) during CP. The time of blood $[LA_{max}]$ was 11 % in the sample taken immediately after exercise and 11 %, 22 %, 22 % and 34 % after the 2, 4, 6 and 8 minutes after $SET_{speedmax}$ respectively (Table 5).

v_4

The mean v_4 of the horses decreased between the second and fourth week of conditioning ($p < 0.05$) but returned and remained thereafter at the initial level (Fig. 1).

Table 3 Body weight of horses (n = 6) during the conditioning period. Mean ± SD. | *Körpergewicht der Pferde (n = 6) während der Trainingsperiode. Mittelwert ± Standardabweichung.*

Weighing time of horses during the conditioning period			
Start	3rd week	6th week	8th week
482 ± 42 ^{abc}	480 ± 38 ^{a}	486 ± 38 ^{b}	486 ± 38 ^{abc}

Values are in kilograms (mean ± SD); different superscript letters denote significant differences (at least $p < 0.05$).

Discussion

The first hypothesis of this study was not accepted: The mean $Speed_{max}$ of the horses did not improve significantly. However, there was a strong tendency to increase ($p = 0.07$). Speed is the most important performance parameter in racing. [26] This holds even more for shorter race distances. Speed is a combination of stride frequency and length. [27,28] In this study both stride parameters did not change significantly during the 8 weeks CP, although the mean stride length values increased markedly for every 50 m run.

Table 4 Running speed and maximal blood lactate concentration $[LA_{max}]$ of horses (n = 6) after diverse runs of high-intensity intermittent exercise (HIIE). Mean ± SD. | *Laufgeschwindigkeit und maximale Blutlaktatkonzentration [LA_{max}] von Pferden (n = 6) nach den verschiedenen Läufen einer hochintensiven intermittierenden Belastungseinheit (HIIE). Mittelwert ± Standardabweichung.*

HIIE session during the conditioning period	Run	Running speed (m/s)	$[LA_{max}]$ (mmol/l)
1st week	1	15.1 ± 0.73	–1
	2	15.2 ± 1.02	–1
2nd week	1	14.2 ± 1.24	5.32 ± 1.21
	2	14.5 ± 0.61	7.08 ± 1.96
3rd week	1	13.8 ± 1.97	–1
	2	15.1 ± 1.65	–1
	3	15.4 ± 1.52	–1
4th week	1	13.6 ± 1.08	4.98 ± 1.33
	2	14.2 ± 0.98	7.34 ± 2.88
	3	15.0 ± 1.20	8.60 ± 3.88
5th week	1	14.7 ± 1.46	–1
	2	14.9 ± 1.36	–1
	3	15.2 ± 0.86	–1
	4	15.4 ± 0.83	–1
6th week	1	16.3 ± 1.60	5.52 ± 1.86
	2	15.4 ± 0.78	6.45 ± 2.58
	3	15.6 ± 1.12	–1
	4	16.5 ± 0.82	7.80 ± 3.08
7th week	1	14.5 ± 0.90	–1
	2	14.21 ± 0.54	–1
	3	14.8 ± 0.81	–1
	4	14.7 ± 0.79	–1
	5	15.0 ± 0.86	–1
8th week	1	14.1 ± 0.83	5.42 ± 0.91
	2	15.2 ± 0.47	7.02 ± 1.70
	3	15.4 ± 0.65	–1
	4	15.8 ± 0.93	–1
	5	15.1 ± 0.91	8.77 ± 2.15

–1 Not measured.

Significant was the increase of the mean stride length of horses running the $SET_{speedmax}$. This locomotion strategy to run faster under field conditions has been described before. [29–31]

The second hypothesis of this study was accepted: Mean v_4 of horses was the same at the end as at the start of CP albeit there was a significant decrease towards the first half of CP. *Lindner* et al. [18] describe a decrease of the v_4 of horses conditioned during 6 weeks using HIIE sessions with two bouts of exercise of 100 m at near-maximal speed one, two and three times a week.

The results of these studies indicate that a decline of v_4 may be avoided when horses are asked to run more than 3 times over 100 m during a HIIE session in a week.

Elite racehorses can maintain maximum speed over a specific distance. [32] Endurance plays an important role to achieve this. Since long, v_4 has been used to examine the effect of training on endurance, [33–35] and it has been shown that racehorses with a higher v_4 have faster speed records and earn more. [19–23] In humans it is proposed that sprinters benefit from endurance training because the resynthesis of their muscle PCr stores is more rapid. [36–38]

Mean blood $[LA_{max}]$ after $SET_{speedmax}$ tended to decrease ($p = 0.09$). In the other two studies on the effects of conditioning with HIIE over the same distance as in this study, the decrease of plasma NH_{3max} and blood $[LA_{max}]$ after exercise during CP provided the basis for a discussion on possible beneficial effects on performance. [17,18] These significant changes may have been missed if the concept of the maximal value after exercise would not have been applied. [39–41] In the actual study, it was shown that blood [LA] changed at least until 8 minutes after HIIE runs and $SET_{speedmax}$, the last time a blood sample was collected. Blood [LA] values obtained once or several times but separated by more than 2 minutes after exercise may not represent sufficiently well the metabolic demand of horses working at high intensity.

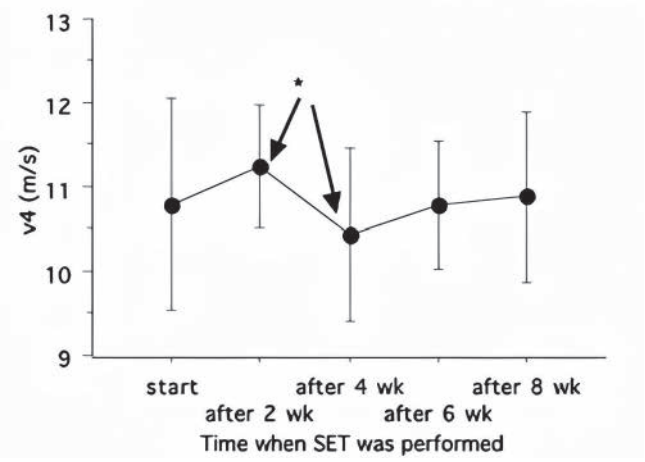

Fig. 1 Development of v_4 (speed run under defined conditions that induces a blood lactate concentration of 4 mmol/l) of horses ($n = 6$) over 8 weeks of conditioning. Mean ± SD and * $p < 0.05$. | *Entwicklung der v_4 (Geschwindigkeit, die unter definierten Bedingungen gerannt, eine Blutlaktatkonzentration von 4 mmol/l induziert) von Pferden ($n = 6$) während einer Trainingsperiode von 8 Wochen. Mittelwert ± Standardabweichung und * $p < 0,05$.*

The limitation of this study is of course the low number of horses. With more horses some of the results might have been significant. Two more horses were involved but failed to complete the CP due to musculoskeletal weakness which did not allow them to recover in time to go on with the experiment.

In conclusion, the examined conditioning program allowed to maintain the v_4, but without increasing significantly $Speed_{max}$ of horses. Further studies are needed on the effect of exercising horses. Considering the results of this study, it would be interesting to condition horses with a combination of HIIE and long slow exercise one or two times per week.

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Equine welfare statement

All procedures were approved by the Bioethical Committee of the University Nacional del Litoral, Esperanza, Argentine

Conflict of interest statement

All authors declare that no competing interests exist.

Authors contributions

AL and RS designed the study, RS, NL, LB and JG executed the study, AL analyzed the data and wrote the manuscript. All authors reviewed and approved the final version.

Table 5 Stride length of running horses ($n = 6$) during consecutive 50-m segments of a 150-m run, speed run between 50 and 150 m and maximal blood lactate concentration [LAmax] after a maximal speed exercise test (SETspeedmax). Mean ± SD. | *Schrittlänge laufender Pferde ($n = 6$) bei aufeinanderfolgenden 50-m-Abschnitten eines 150-m-Laufs, Geschwindigkeit zwischen 50 und 150 m des 150-m Laufs und maximale Blutlaktatkonzentration [LAmax] nach einem mit maximaler Geschwindigkeit gelaufenen Belastungstest (SETspeedmax). Mittelwert ± Standardabweichung.*

$SET_{speedmax}$	Stride length (m)			Speed (m/s)	$[LA_{max}]$ (mmol/l)
	0–50	51–100	101–150		
Before start of CP	5.92 ± 0.54	6.05 ± 0.57	6.18 ± 0.43	17.0 ± 0.68	8.32 ± 2.36
4 weeks after	6.18 ± 0.32	6.21 ± 0.33	6.48 ± 0.39	16.8 ± 0.43	7.48 ± 1.23
8 weeks after	6.30 ± 0.77	6.37 ± 0.25	6.58 ± 0.38	17.4 ± 0.83	6.70 ± 0.99

Values are the mean ± SD. CP = conditioning period.

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