

Effects of 3 different interval training programs on horses used for show jumping. Evaluation based on blood lactate concentration, heart rate, obstacle faults, technique and energy level while jumping.

Summary

Reason for performing study: Studies on training programs to improve the fitness of horses used in show jumping are scarce. Parameters to evaluate the effect of a training program has never been evaluated in show jumping horses.

Objective: The effects of 3 different interval training programs are examined with 3 different standardized exercise test (SET) prescriptions of which SET1 is previously evaluated in the literature and SET2 and SET3 are designed to try to evaluate show jumping specific tasks.

Methods: 20 horses performed the 3 different SET's within 12 days. After this the horses were separated into three groups. Each group would perform a specific interval training method (ITM). Group 1 performed an interval training program that included gallop at an outdoor track at V4 which was calculated for the individual horse (ITM1). Group 2 performed sprint exercise on a 20 x 60 m indoor arena (ITM2), group 3 did "in and out jumping" where each session included 150 jumps. After 6 weeks of training, a total of 8 sessions, the three different SET's were performed again. Parameters including HR, V2, V4, [lactate], number of obstacles down, technique and energy level was evaluated for each group. The practical use of each interval training program and each SET was also evaluated.

Results: In SET1, Group 1 did significantly better than the other groups who showed no improvement. In SET2 there was an overall significant decrease in HR ($P=0,0058$) and a linear correlation between HR and lactate concentration. The effect of training on lactate concentration in SET2 was overall significant ($p=0,0001$). The lactate concentration after 3th interval minus the lactate concentration at rest also showed a significant decrease as a response of training ($P= 0,0001$) and the number of obstacles down decreased after the 6 weeks of training ($p=0,0058$). There were no differences between groups for any parameter. In SET3 there was an effect of training on the lactate concentration ($p=0,034$), an increase in the energy level when jumping assessed by the rider ($p=0,0031$) and an improvement on technique assessed by the rider ($p=0,0073$). There were no differences between groups for any parameter.

Conclusions: All three ITMs have a positive effect on the physical fitness level of show jumpers when the parameters used to evaluate fitness is based on lactate concentration and heart rate. Improving cardiovascular fitness does correlate well with a decrease in obstacles down, jumping technique and energy level during arena jumping Whether this effect can be maximized by increasing intensity (height, speed, number of intervals/session, length of intervals/session), frequency (number of sessions/week) or interval training period (number of weeks or months) is unknown and further research is recommended.

Introduction

The purpose of a structured training program in the athletic horse is to improve performance by inducing physiologic changes. The equine musculature has a large inherent potential to adapt to training pressures; this is significant as correct training improves endurance, strength and speed (Rivero 2007). The limiting factors for strenuous muscular work is the oxygen carrying capacity of the cardiovascular system as well as the efficiency with which oxygen is utilized in the muscles (Engelhardt 1977; Essén-Gustavsson *et al.* 1989).

High performance athletic disciplines demanding regular intensive training carry an increased risk of overtraining and overload injuries. These injuries are the result of an imbalance between the amount of training and the time allowed for physical recovery (Bruin *et al.* 1994; Tyler *et al.* 1996; Hamlin *et al.* 2002). Injuries also arise if regular training fails to adapt the body to competition level work load (Clayton 1990). Extensive research has been done in galloping and trotting race horses in the areas of metabolic demands, physiologic parameters and effects of training in daily work and during racing (Anderson 1975; Bayly *et al.* 1983; Bruin *et al.* 1994; Courouche *et al.* 1997, 1999, 2000, 2002; Davies *et al.* 1983; Evans *et al.* 1993). However, investigations into these parameters remain scarce in non-racing performance horses; both during exercise work and in competitions. Studies are done on endurance horses (Rivero *et al.* 1995, 1996, Hodgeson & Rose 1987, Sloet *et al.* 1991), 3 day eventers (Munoz *et al.* 1998, Williamson *et al.* 1996, Galloux 2002) and Polo ponies (Craigh *et al.* 1985). Very little research exists regarding the physiologic demands and effect of training in show jumpers (Art *et al.* 1990a,b; Rivero & Letelier 2000) .

In horse racing, Standardized Exercise Tests (SETs) are routinely used to evaluate physiologic response to training. SETs are frequently performed on treadmills as this facilitates measurements which would be impossible to perform under field conditions. Field conditions, however, are fairly easy to do and carry the advantage of simulating actual work and racing situations (Persson 1983; Guhl *et al.* 1996; Courouche 1999).

During field SETs several physiologic variables are measured and are of value for the monitoring and planning of conditioning exercise (Courouche 1997, 1999 a,b; Lindner 2009a,b) as well as for the determination of the horses' level of fitness (Persson 1983; Guhl *et al.* 1996; Courouche *et al.* 1997, Courouche 1999a,b). The best indicator of metabolic energy adaptation is the blood lactate concentration. This is not solely due to the lactate changes during aerobic and anaerobic metabolism but also because the blood lactate level reflects the muscle adaptation to the work load over time (Rivero 2000; Lindner 2004). The blood lactate concentration, however, cannot stand alone as a measurement of training efficiency because the fluctuating levels render it difficult to reproduce in a certain time frame (Lindner 1996, 2006). To counteract these fluctuations, lactate measurements are used both over time and at differing speeds. Several parameters define the relationship between blood lactate concentration and speed of work:

The Velocity where the blood Lactate concentration reaches a certain level is defined as **VLa**. The quantitative variable which determines the speed with which the lactate concentration reaches 4 mmol/l is described as **V4** or **VLa4**. Using this variable offers the investigator a reliable way to determine physical fitness and performance in the equine athlete (Courouche 1997; Galloux 1991; Harkins *et al.* 1993; Persson 1997; Lindner 2000). It is well documented that V4 increases with training (Von Witke *et al.* 1994; Eaton *et al.* 1999) and that improving the V4 depends on the intensity, duration and frequency of work-outs (Lindner *et al.* 2000).

Research performed in equine athletes has shown consistent correlation between competitive successes and V4. This is seen in Endurance horses (Demonceau 1989; Erickson *et al.* 1990); 3-day eventing (Galloux 1991); trotters (Courouche 1997; Ronéus 1994,1999); thoroughbred racing (Davie 1999; Harkins *et al.* 1993); and quarterhorse racing (Erickson *et al.* 1991).

A blood lactate concentration of 4 mmol/L is often termed the lactate threshold value, **La4**. This value represents the change from aerobic to anaerobic work. During anaerobic work the lactate concentration will increase more rapidly (Persson 1983; Lindner 2004). The velocity where the lactate concentration is 2 mmol/l is referred to as **V2**. This parameter is generally accepted as the work intensity utilizing aerobic metabolism for energy production (Persson 1983; Harkins *et al.* 1993). A blood plasma concentration of 2 mmol/L is considered a steady-state level of lactate during aerobic work; thus, the velocity at **Vla2** is used for aerobic threshold determination (Rose 1986)

Using HR along with lactate concentration to determine fitness in the horse has proven to be a reliable method (Sloet 2004). The heart rates corresponding to the work intensity of V2 and V4 is **HR2** and **HR4** (Persson 1983; Wilson 1983).

Sloet *et al.* (2006) have shown that jumping over fairly small obstacles requires a higher work intensity compared to running the same distance without any jumps. Both the lactate concentration and heart rate were increased after the jumping exercise. No research has yet been done to correlate height of jumps, number of jumps and work intensity. Studies in show jumpers, however, do show that lactate concentration during midlevel competition hover at or above the anaerobic threshold level (Art *et al.* 1990a,b; Desmecht *et al.* 1996, Barrey & Valette 1992). Considering this observation, the need for exercise at the La4 intensity becomes a key feature in improving fitness as well as durability of the equine athlete.

Training programs or SET's for jumping horses have not been previously evaluated. Prior research shows that the height of the obstacles (Sloet *et al.* 1993) as well as height *and* speed (Munk 2009) will influence the blood lactate concentration in horses. Keeping this in mind, the parameters needed for objective evaluation of fitness in the show jumper must be considered. Additionally, the need for a SET that includes jumping obstacles becomes apparent in order to determine work-specific physical fitness of the show jumper. In riding horses during field conditions, heart rate and lactate concentration have been used to measure the intensity of exercise (Persson 1983, Sloet *et al.* 1987, Sloet and Barneveld 1995).

Research on effect of training in the warmblood includes the use of a treadmill with and without inclines (Hennings *et al.* 2002; Melfsen-Jessen *et al.* 2002; Okonek *et al.* 2002; Shaefer *et al.* 2002), but the effect of a training program that includes jumping has only been investigated by Rivero (2007) and a show jumping specific SET is non-existent .

The purpose of this study is to investigate the effect of three different interval training methods (ITM) to improve fitness in the show jumper. The three different ITM's is flat track galloping, sprint training and in and out jumping (a' tempo). The effect of the 3 training programs are quantified with different measures obtained with 3 different standardized exercise tests (SET). SET1 is galloping on a flat racing track while SET2 and SET3 include jumping work. These interval training methods (ITM) and exercise tests (SET) have been developed with regard to variables such as weather conditions, thus two of the programs can be performed at an indoor arena.

Hypotheses

1. Training programs based on interval type of exercise with and without jumping can improve one or more of the following parameters:
 - [lactate] (at the end of exercise)
 - [lactate2min] (after exercise)
 - max HR and mean HR during Exercise
 - HR 2 min after exercise
 - number of obstacles down,
 - jumping technical ability R (judged by the rider),
 - jumping energy R (judged by the rider),
 - jumping technical ability O (judged by an observer),
 - jumping energy O (judged by an observer)

Methods and Materials

Participant Horses

20 Danish WB show jumpers - 8 mares, 8 geldings and 5 stallions. The horses were 4-12 years old. Average age was 6 years.

Exercise

For a period of six months prior to the study the horses received conditioning as follows: 1 hr turn-out/day, 50 min/day in the horse walker and riding exercise 5xweek. The riding includes general schooling 3x week (10 min warm-up, 25 min trot and slow gallop, 10 min cool-down) and jump training 2 x week. The jumping exercise is 30 min in duration and includes jumping a few fences in a moderate speed with walking exercise in between.

During the interval training and testing period each of the three groups will perform their assigned training program every 5th day for a total of six weeks. This will result in a total of eight interval training sessions. Between the interval sessions the horses will exercise 30 min/day at a submaximal level (HR under 150 bpm). In addition, the horses will be in the horse walker 45 min/day and turned out 1 hr/day. Two of these horses have been previously subjected to interval exercises with a HR over 150 bpm; with the exception of the occasional jumping exercise, none of the others have received training with a known HR over 150 bpm.

Study Set-up

SETs

The 3 SETs were performed at time zero in all 20 horses. The horses were allowed 4 days of rest between performing each test. Subsequently, the horses were assigned to one of three groups based on age-dependent random selection. Each group was provided with a different interval training method (ITM, outlined in fig 5). After completion of the six-week training program all 20 horses re-performed each of the SETs, again with 4 days of rest in between (fig 1).

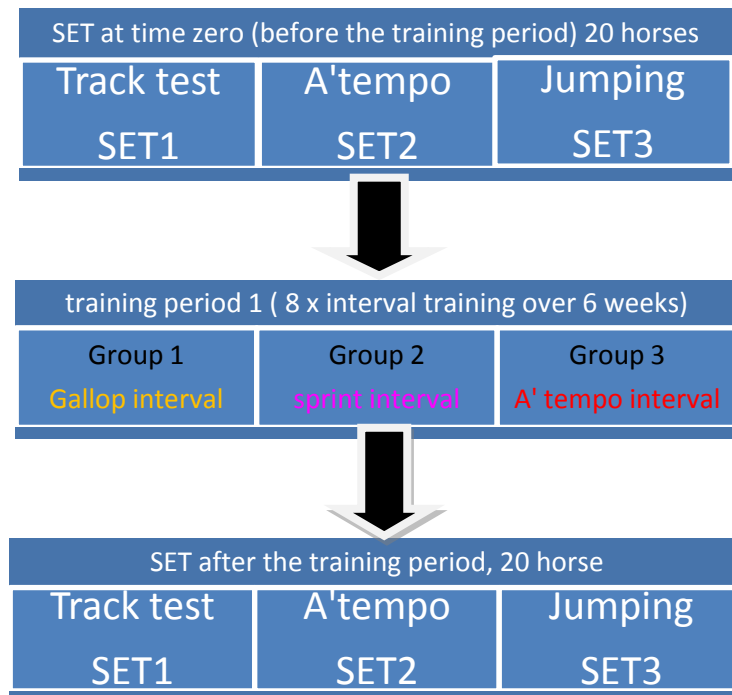


Figure 1. Outline of study set-up. The 20 horses were tested with 3 different SET (standardized exercise test) within 12 days. They were then assigned into 3 groups. Each group had to perform a specific interval training program for 6 weeks, a total of 8 training sessions. The different training methods (ITM) were intervals in gallop, sprint and A' tempo jumping. After the 6 weeks the 20 horses were re-tested in the 3 different SET within 12 days.

Standardized Exercise Tests (SET's) (refer to fig. 4)

1) SET1 – outdoor flat track test

- Elliptical track with a length of 850 m and a turf-on-sand surface.
 - Lap 1; 240 m/min = lap time of 3 min 32 sec. = 14,4 km/t.
 - Lap 2; 320 m/min = lap time of 2 min 39 sec. = 19,2 km/t
 - Lap 3; 400 m/min = lap time of 2 min 08 sec. = 24,0 km/t.
 - Lap 4; 480 m/min = lap time of 1 min 46 sec. = 28,8 km/t

- Lap 5; 560 m/min = lap time of 1 min 31 sec. = 33,6 km/t.
- Blood lactate measurement following each lap and 2 min after completion of the test.
- The speed of work is GPS controlled (Leuleu & Cotrel 2004) in addition to each lap being timed by stop watch to allow correction of velocity prior to V4 calculation.

2) SET 2 – A'tempo (In and out testing) (Refer to fig. 2)

- Elliptical arena with 16 jumps spaced every 3 m.
- Five jumps are placed on each long-side; these are raised in every interval. The jumps on the short-sides remain unchanged throughout.
- Height of jumps: 1st interval is 40 cm, 2nd Interval 65 cm, 3rd interval 85 cm.
- Riding time is 3 x 90 sec. with stops for blood testing after each of the three intervals.
- 90 sec. (1st interval) equals 4.8 laps on the course.
- The number of obstacles down are recorded for each interval.
- Jumping technical ability and degree of fatigue is scored by the rider on a scale of 1-5.
- Lactate is measured after each interval and 2 mins after session completion.



Figure 2. SET2 A'tempo track



Figure 3. SET3 Jumping course

3) SET 3 – Jumping course test (Refer to fig. 3)

- All 20 horses jump a course consisting of 11 obstacles; of these, two are doubles at the level of individually adjusted maximal degrees of difficulty.
- Number of obstacles down and time spent is recorded for each participant.
- The session is filmed; jumping technique and level of fatigue is determined by a third party that is a show jumper but is not familiar with the horse or its group assignment. A scale of 1-5 is used.
- Jumping technique and energy level is also scored on a 1-5 scale by each rider.
- Blood lactate concentration is measured immediately upon completion of the test and two minutes later.

Track test SET 1 (N = 20)	a'tempo jumping SET 2 (N = 20)	Jump course SET 3 (N = 20)
<ul style="list-style-type: none"> • Standard track <ul style="list-style-type: none"> • track length 850 meter • total length 4250 m • outdoor • sand surface • 5 rounds <ul style="list-style-type: none"> • 240 m/min • 320 m/min • 400 m/min • 480 m/min • 560 m/min • Monitoring <ul style="list-style-type: none"> • HRmax, HRavg (Polar 8000) • laptime in seconds • Lactate concentration <ul style="list-style-type: none"> • after each round/ at each speed • 2 min after work; [laktat]2 min • calculation of parameters i Antwert <ul style="list-style-type: none"> • V150 • V200 • V2 • V4 • HF2 • HF4 	<ul style="list-style-type: none"> • Standard track <ul style="list-style-type: none"> • 16 jumps per round • a total of 231 jumps • length of round 72m • total length 1008 m • Speed 225 m/min • indoor/outdoor • fiber surface • 3 x 90 seconds work <ul style="list-style-type: none"> • 90 seconds = one interval <ul style="list-style-type: none"> • consists of 5 rounds • Hight of jumps in 1. interval = 40 cm • Hight of jumps in 2. interval = 65 cm • Hight of jumps in 3. interval = 85 cm • Monitoring <ul style="list-style-type: none"> • HRmax, HRavg (polar 8000) • Number of obstacles down per interval • Lactate concentration <ul style="list-style-type: none"> • after every 90 sec. work ; [laktat] 1,2,3 • 2 min after work; [laktat]2 min • Riders scoring of <ul style="list-style-type: none"> • technique • energy level 	<ul style="list-style-type: none"> • Standard course <ul style="list-style-type: none"> • 11 jumps • track length 380 m • Hight of the jumps according to age <ul style="list-style-type: none"> • 4 year 100 cm • 5 year 120 cm • 6 year 130 cm • 7 year 140 • 8 year 145 • above 8, 150 cm • speed 325 m/min • indoor / outdoor • fiber surface • Monitoring <ul style="list-style-type: none"> • HF (polar 8000) • Number of obstacles down • time • Lactate concentration <ul style="list-style-type: none"> • at finish; [laktat]slut • 2 min after arbejde; [laktat]2min • Riders scoring of <ul style="list-style-type: none"> • technique • energy level • Videorecordings for objectiv scoring <ul style="list-style-type: none"> • technique • energy level

Figure 4. Schematic describing the 3 different SETs. The figure is explained in the text above the figure.

Standard set-ups for SET1, SET2 og SET3.

- Warm-up – 10 minutes of walking followed by 10 minutes of trotting and galloping exercise. In SETs 2 and 3 six small obstacles are used.
- Heart rates are monitored using Polar 8000. Data from Polar 8000 is computer analyzed. The horse is equipped with the Polar 8000 during saddling. The device is removed 15 minutes after completion of the test.
- Between blood sampling for lactate measurements at test finish and 2 minutes afterwards, the horses were being ridden at a walk.

Obstacles down

In SET2 and SET3 the number of obstacles down for each horse was recorded. In SET2 the number was recorded for every interval.

Scoring of jumping technique and energy level

A grading scheme was developed by the rider who scored each horse's technique and energy level immediately upon completion of SET2 and SET3. In SET3, the horses were also graded by an observer who watched video recordings of each horse before and after completion of their 6-week interval training program. The horse and its assigned group were unknown to the observer.

Grade	1	2	3	4	5
Interpretation	Poor	Below average	Average	Good	Optimal

Interval Training Methods (ITM) (refer to fig. 5)

1) Galloping exercise

2) Sprint training

3) A'tempo jumping

1) Galloping exercise.

Performed on an outdoor flat racing track, this one being 850 meters/lap. Each horse is training in a preset speed. The required speed is determined from the individual horses results on the track test SET zero. The required speed is the speed at a lactate concentration of 4 mmol/l, also known as V4.

- 90 secs galop at V4
- 90 secs walking
- Repeated 4 times per session
- 1 training session every 5 days
- A total of 8 training sessions between the SETs

2) Sprint training.

Performed in an indoor or outdoor 20 x 60 arena; must mimic the horses acceleration during timed competition.

- 90 secs sprint on the long sides, steady galop at the corners and ends.
- 90 secs walking
- Repeated 4 times per session
- 1 training session every 5 days
- A total of 8 training sessions between the SETs

3) A'tempo jumping training

Performed in an indoor or outdoor 20 x 60 arena; performed as in and out jumping sessions. 6 obstacles on each long-side, none at the ends.

- 90 secs jumping
- 90 secs walking
- Repeated 4 times per session
- Obstacle heights
 - 4 y.o.
 - 1. interval: 50 cm. 2., 3. and 4. interval: 70 cm
 - 5 y.o.
 - 1. interval: 70 cm. 2., 3. and 4. interval: 90 cm
 - 6 y.o. and up
 - 1. interval: 70 cm. 2., 3. and 4. interval: 105 cm
- 1 training session every 5 days
- A total of 8 training sessions between the SETs

Warm-up before all training sessions is 10 minutes of walking followed by 10 minutes of trotting and gallop. The horses doing à tempo training jump 8 warm-up obstacles.

Interval Training Methods (ITM)

Galloping exercise Group 1 ITM 1 (N = 7)	Sprint training Group 2 ITM 2 (N = 7)	A'tempo jumping Group 3 ITM 3 (N = 6)
<ul style="list-style-type: none"> • Standard track <ul style="list-style-type: none"> • 850 meter • outdoor • sand surface • Speed V4. (avg. 490 m/min) • total length 3200 m • HR and V at La4 is determined in SET 1 zero. Training speed is at V4 • Training <ul style="list-style-type: none"> • 90 sec. gallop at V4 • 90 sec. walk • is repeated 4 x per trainingssession • one training session every 5 days • A total of 8 x training sessions between SET zero and SET after the training period • Monitoring <ul style="list-style-type: none"> • HR and V with polar 8000 	<ul style="list-style-type: none"> • Standard track <ul style="list-style-type: none"> • indoor school 20 x 60 m • outdoor school 20 x 60 • Fiber surface • Speed 425 m/min • Total length 2560 m • Sprint (acceleration og deacceleration) at Vmax • Training <ul style="list-style-type: none"> • 90 sec. sprint at the longside og slower at the shortside • 90 sec. walk • is repeated 4 x per training session • one training session every 5 days • A total of 8 x training sessions between SET zero and SET after the training period • Monitoring <ul style="list-style-type: none"> • Polar 8000 	<ul style="list-style-type: none"> • Standard track <ul style="list-style-type: none"> • indoor school 20 x 60 m • outdoor school 20 x 60 • Fiber surface • Speed 325 m/min • Total length (490 m/interval) 2230 m • 6 jumps on each longside <ul style="list-style-type: none"> • jumpheight was dependend on age and interval • 4 year; 50,70,70,70 cm • 5 year; 70,90,90,90 cm • 6 year and older; 70,105,105,105 cm • Training <ul style="list-style-type: none"> • 90 sec. jumping (42 jumps/interval) • 90 sec. walk • is repeated 4 x per training session • one training session every 5 days • A total of 8 x training sessions between SET zero and SET after the training period • Monitoring <ul style="list-style-type: none"> • Polar 8000

Figure 5. Schematic showing the three different ITMs. The figure is explained in the text above the figure.

Data Collection

At all SETs (SET1,2,3) each horse and rider wore Polar 8000 to monitor heart rate and work speed. Blood was drawn from the jugular vein with a 23 g needle for lactate concentration determination. The blood was aspirated into 1 ml heparin coated syringes and the test was performed immediately on a hand-held lactate measuring device¹.

Table 1. Schematic of measured and calculated variables in the three SETs.

	SET1 (Galloping)	SET2 (Á tempo)	SET3 (arena jumping)
Parameters related to HR	HRmax at each speed (round) HR mean at each speed (round) HR 2 min after work finish	HRmax for each interval HR mean for each interval (HRmax for the 3th interval And HR mean for the 3th interval is the used parameter) HR 2min after work finish	HRmax HR mean HR 2 min after work finish
Lactate concentrations	Rest [Lactate] at the end of each speed (round) [lactate] 2min after work	Rest [lactate] after each interval ([Lactate]3 (at the end of jumping interval 3) is the used parameter) [lactate]2 min after work	Rest [lactate]s (at the end of the jump course) [lactate] 2 min after work
HR and lactate related parameters	HR2 = HR at [lactate]2 HR4 = HR at [lactate]4		
V (velocity) related parameters	V2 = Velocity at [lactate]2 V4 = Velocity at [lactate]4		
Other measurable parameters		No. of obstacles down/interval No. of obstacles down, total Jumping technique, rider Jumping energy, rider	No. of obstacles down, total Jumping technique, observer Jumping energy, rider Jumping energy, observer
Summary Measures		(HR mean lap 3 minus HR 2 min) ([lactate] 3th interval minus [lactate]rest) ([lactate]2 min minus [lactate] 3th interval)	(HRmax minus HR 2 min) ([lactate]3th interval minus [lactate]rest) ([lactate]2 min minus [lactate] 3th interval)
Correlations		[lactate] 3th interval and no. obstacles down [lactate]3th interval and HRmean [lactate]3th interval and HRmax	[lactate]jumping and HRmax

1

“ Cobas”, Roche Accutrend Plus GCTL - Lactate, Triglyceride, Glucose and Cholesterol Meter
Evaluated by Evans 1996, Lindner 1996, Williamson 1996 and Delesalle 2007.

Results from SET1 are calculated using the Antwert² program in Excel.

This program calculates the following values: V2, V4, HR2, HR4

Data from SET2 and SET3 were saved in Excel; video recordings of the jumping tests were scored by an observer who is active as a competitive show jumper and professional trainer but has no prior knowledge of these horses.

Statistics

Summary of data used for statistic analysis;

SET 1 (galloping testing), SET 2 (à tempo testing), SET 3 (jumping course testing)

Wilcoxon signed rank test (non-parametric analysis) is chosen as the group sizes are small and are thus assumed to fall outside one standard deviation. This test is used to investigate the horses percentile improvement within each group. That is, whether the different parameters of improvement at the end testing time statistically deviate from 0. In other words, it determines whether the measured parameter is significantly improved. If a parameter shows a statistically significant difference before and after training, the differences between the 3 groups have been analysed with the Kruskal-Wallis test and post-test Dunn's Multiple Comparison test. The purpose here is to determine if one of the ITMs proves to be a superior training method than the others.

The ANOVA test "an analysis of variance for repeated measures" is also used as described for each individual SET. In the case that the ANOVA shows significant effects the Fisher-test is used to do the multiple comparisons.

SET1

Calculations performed as described, no further analysis performed.

2

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SET2.

In addition to the previously described analyses, "summary measures" were performed:

- **Lactate 3minus0:** [lactate] 3th interval minus [lactate] at rest.
 - This represents [lactate] increase in response to work.
- **Lactate 3minus2m:** [lactate] 3th interval minus [lactate] after 2 min.
 - This represents lactate levels returning to normal after work completion.
- **Total number of obstacles down: the sum of obstacles down during all three laps.**

- **HRmean in 3 minus 2m:** HRmean during 3th interval minus HR after 2 mins recovery.
 - Represents HR return to normal after work completion.

Additionally, correlation analysis between [lactate] after 3th interval and the total number of obstacles down.

Lactate levels between the different scores for jumping technique and energy level is compared to the Kruskal-Wallis test. The ANOVA test is utilized to investigate whether the blood lactate, heart rate and total number of obstacles down decreased after the interval training period, taking the training program into consideration. In the case that the ANOVA showed significant effects the Fisher-test was used to do the multiple comparisons.

SET3.

In addition to the previously described analyses, "summary measures" were performed:

- **Lactate Jminus0:** [lactate] after Jumping minus [lactate] at rest.
 - This represents lactate increases in response to work.
- **Lactate Jminus2m:** [lactate] after jumping minus [lactate] after 2 min.
 - This represents lactate levels returning to normal after work completion.
- **HR max-minus 2m:** max HR minus HR measured 2 min after work.
 - Represents HR return to normal after work completion.

The data has been collected in such a way that it has to be examined with an analysis of variance for repeated measures to examine whether the different training programs affected jumping technique (data from a video observer and the rider), energy level (degree of fatigue) of the horse (data from a video observer and rider), blood lactate concentration after the course, HRmax during the course and HR 2 min after the course, time to run the course, and number of obstacles downs. In the case that the ANOVA showed significant effects the Fisher-test was used to do the multiple comparisons.

ANOVA for repeated measures throws out a case from the evaluation if one data point is missing. This is why there is a different number of cases for each variable and training program. And HRmean during exercise was not used as a variable because in the SET starting the whole project too many data were missing.

Results

SET1 Galloping test

Table 2. Summary of the statistical findings using the Wilcoxon signed rank test (non-parametric analysis) and ANOVA for SET1:

Parameter	Results
V2	G1(gallop) is significantly improved after training (P = 0,016). Percentile improvement is (median, min-max) : 18,0-39%
V4	G1(gallop) is significantly improved after training (P = 0,047). Percentile improvement is (median, min-max) : 9, -6-16% G1>G3 ANOVA (Fisher p=0,0039)
HR2	G1(gallop) is significantly improved after (P = 0,031). G2(sprint) approximates significant improvement after training (P = 0,055)
HR4	No change

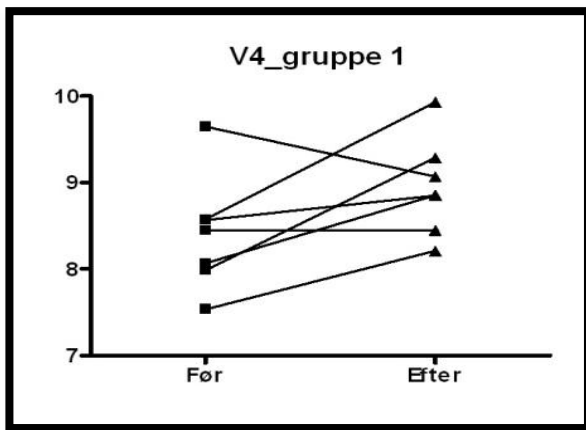
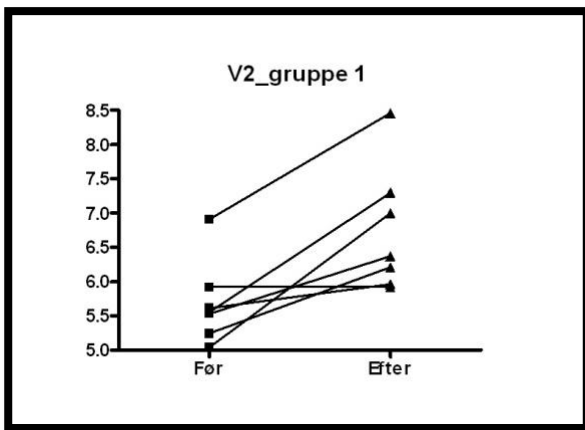


Figure 6. SET1, in group 1(gallop) the increase in V2 for each individual horse is shown. Wilcoxon (P = 0,016). Y- axis is m/s

Figure 7. SET1, in group 1(gallop) the increase in V4 for each individual horse is shown. Wilcoxon (P = 0,047). Y-axis is m/s.

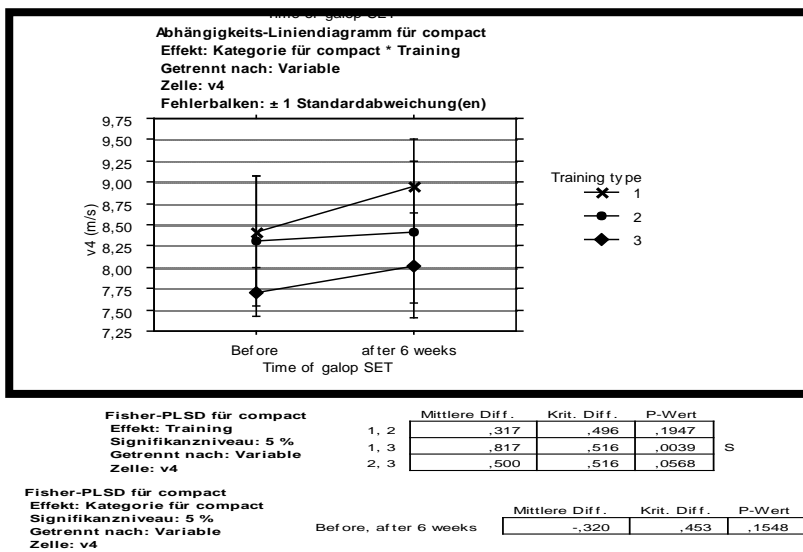


Figure 8. Shows the effect of training on V4. There is no effect of time (ANOVA p = 0,1563), but for training (ANOVA p = 0,0134). The significant difference is between training type 1 and training type 3 (Fisher-test p = 0,039); v₄ increase more after training type 1 than after training type 3. There are no other differences.

SET 2. À tempo test

Table 3. Summary of statistical findings following the Wilcoxon signed rank test (non-parametric analysis) and the ANOVA for SET2. (NI= no improvement; G = group)

Parameter	Results
Correlation between HR max and [lactate] 3th. Interval	Strong statistical relationship between [lactate]3th interval and HRmax before and after the training period. P, before= 0,0047; P, after = 0,0031
Correlation between HR mean and [lactate] 3th. interval	Strong statistical relationship between [lactate]3th interval and HR mean before and after the training period. P, before= 0,0837; P, after = 0,0023
HR	There is an overall decline in HR after training. P = 0,0058. There are no difference between groups.
[lactate] 3th interval in mmol/l	G1(gallop) is significantly improved after training (P = 0,016). Percentile improvement is (median, min-max) : 18, -5 - 36% G2(sprint) is significantly improved after training (P = 0,0078). Percentile improvement is (median, min-max): 36, 7 – 60% G3(atempo) is significantly improved after training (P = 0,065). Percentile improvement is (median, min-max): 40, 25 - 60 % Overall a decrease in lactate concentration (P = 0,043), no difference between groups
[Lactate] 3th interval – [lactate rest] mmol/l Represent the increase as a response to work.	G1(gallop) is significantly improved after training (P = 0,031). Percentile improvement is (median, min-max) : 22, 0- 68% G2(sprint) is significantly improved after training (P = 0,0078). Percentile improvement is (median, min-max) : 51, 28- 177% G3(atempo) is significantly improved after training (P = 0,063). Percentile improvement is (median, min-max) : 34, 26 - 78% Overall a decrease in lactate concentration (P = 0,0001), no difference between groups
[Lactate] after 2 minutes mmol/l	G1(gallop) is significantly improved after training (P = 0,0078). Percentile improvement is (median, min-max) : 27, 17 - 35% G2(sprint) is significantly improved after training (P = 0,0078). Percentile improvement is (median, min-max) : 38, 3 - 80% G3(atempo) is significantly improved after training (P = 0,063). Percentile improvement is (median, min-max) : 42, 14 - 68% Overall a decrease in lactate concentration (P = 0,0001), no difference between groups
[lactate]3th interval minus [lactate] after 2 min.	No change
Obstacles down/faults	No correlation between [lactate]3th interval and total number of faults, neither before nor after the training period The total number of obstacles down is decreased after the training period (P = 0,0058)
Jumping technique, rider	No relationship between [lactate] 3th interval and technical scores
Energy level, rider	No relationship between [lactate] 3th interval and the energy level scores

HR related results are illustrated in figure 9 and 10.

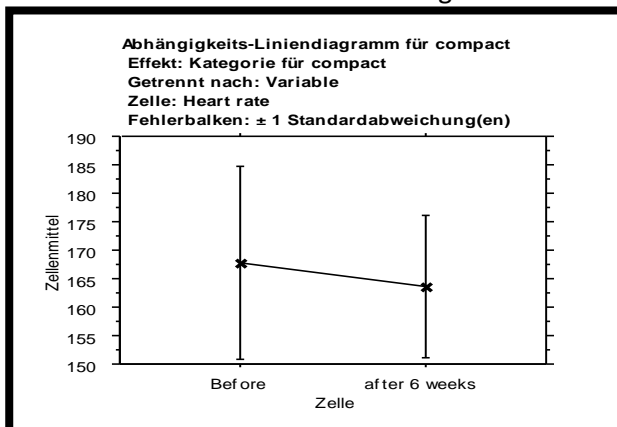


Figure 9. There is an overall decline in HR after training. P = 0,0058. There are no difference between groups Fisher(p>0,05)

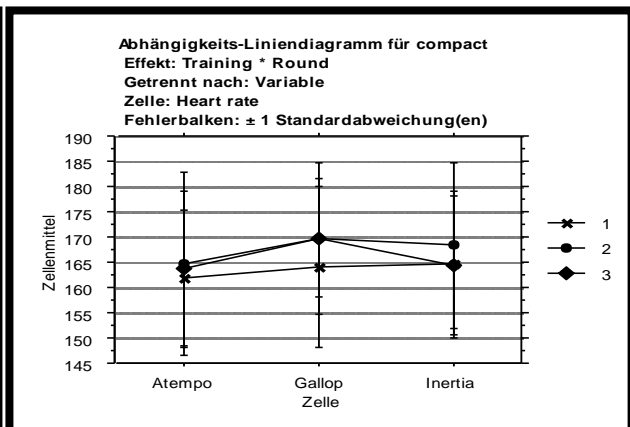


Figure 10. Shows the mean hear rate during each run of each training program. No difference between groups.

Lactate related results for SET2 are illustrated in figure 11, 12, 13, 14.

The overall lactate concentration after 3th interval of a'tempo SET2 shows a statistic significant decrease (ANOVA $P = 0,043$) after 6 weeks of interval training (Figure 11). There are no difference between groups (Fisher $P > 0,05$)(Figure 12).

Figure 13 and 14 illustrates as an example of the calculations with the Wilcoxon test, the effect of the 6 weeks training period on each individual horse in group 2. Group 2 has been doing ITM2 (sprint training).

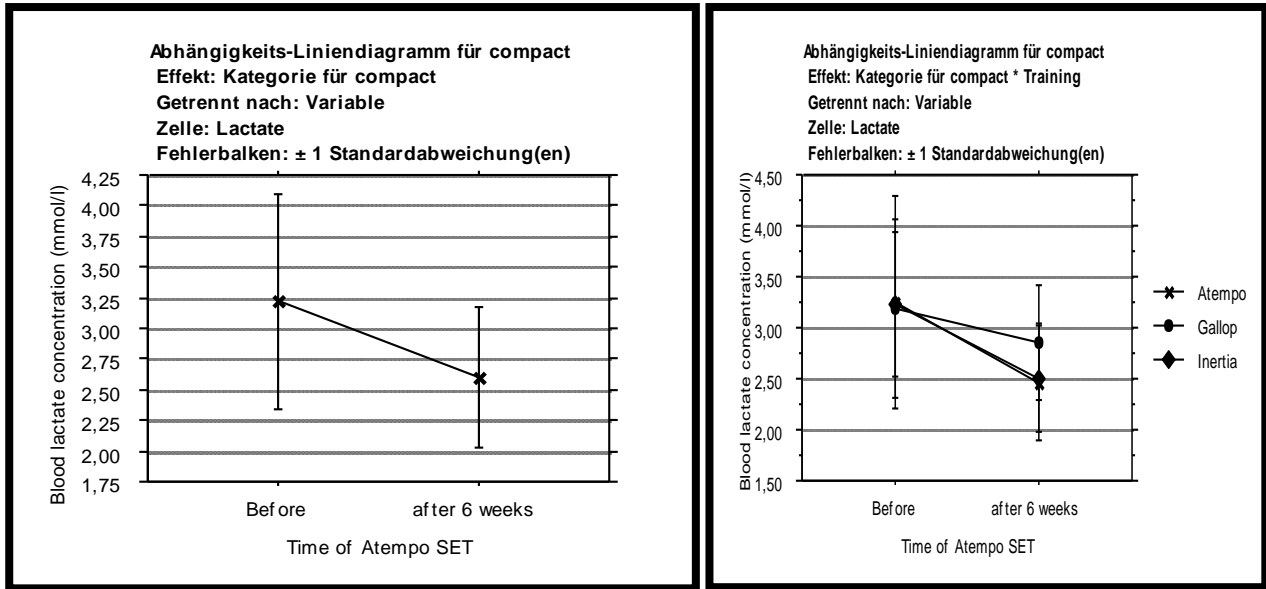


Figure 11

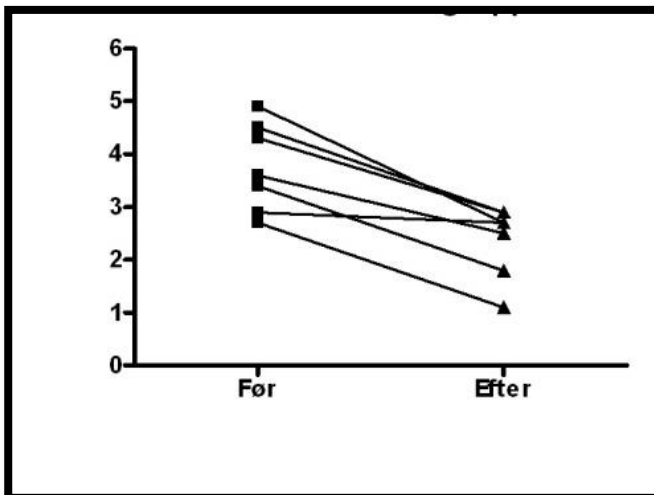


Figure 13. In SET2, there is a decrease in [lactate] for each individual horse in response to training in group 2 ($P = 0,0078$)
 On the Y-axis is m/s.

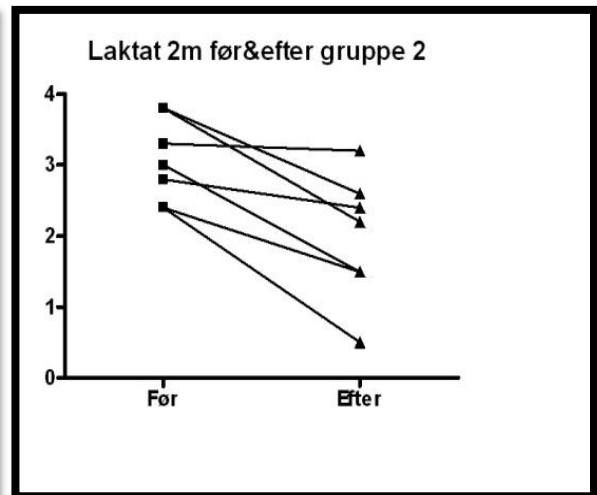


Figure 14. SET2, a decrease in [lactate] is shown for each individual horse in group 2, 2 min after training ($P = 0,0078$)
 in response to training. On the Y-axis is m/s.

Obstacles down, Energy level and technique results for SET2 are shown in figure 15, 16, 17, 18.

There is no correlation between obstacles down and lactate concentration. The mean number of obstacles down increases with interval (figure 15 and 16), there are no differences between groups. The total number of obstacles down is decreased after the 6 weeks training period (ANOVA $P = 0,0058$), there are no differences between groups.

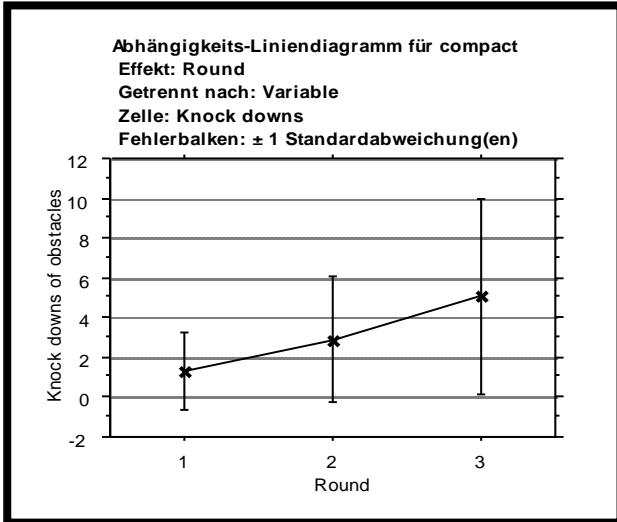


Figure 15. The total number of obstacles down increases with with interval.

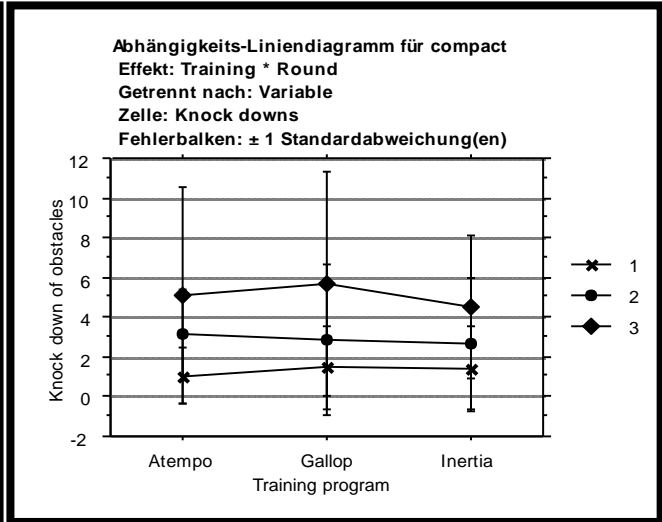


Figure 16. The total number of obstacles down increases With interval, there are no differences between groups.

The results for energy level and technique score assessed by the rider in SET2 is shown in figure 17 and 18. There are no statistic significant effect of the 6 weeks training period.

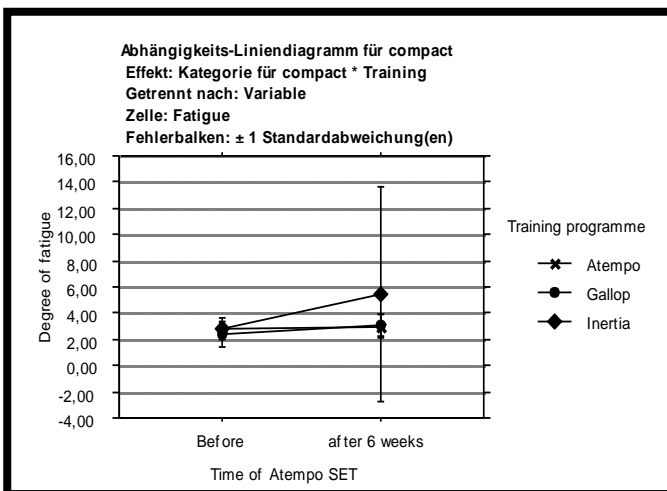


Figure 17. The mean score of energy level (fatigue) assessed by the rider, before and after 6 weeks of training with the different ITM ($P > 0,05$)

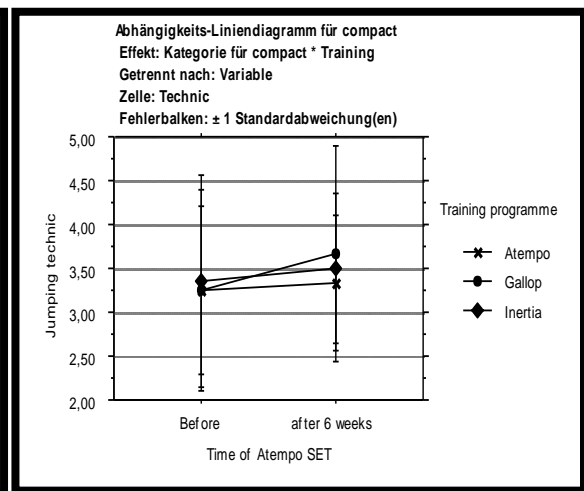


Figure 18. The mean score for jumping technique assessed by the rider, before and after 6 weeks of training with different ITM ($P > 0,05$)

SET3. Arena jumping test

Table 4. Summary of the statistical findings using the Wilcoxon signed rank test (non-parametric analysis) and ANOVA for SET3.

Parameter	Results
HR	HRmax no change HR2 min no change Statistically significant relationship between HRmax and [lactate]J
[lactate]	An overall decrease in lactate concentration (P = 0.0340)
[Lactate after 2 min]	No change
No. obstacles down	No change
Jumping technique, rider	An overall increase in technique score assessed by the rider (P = 0.0073).
Jumping technique, observer	No change
Energy level, rider	An overall increase in energy level score assessed by the rider (P = 0.0031)
Energy level, observer	No change

Lactate related results for SET3 are illustrated in figure 19 and 20.

There is an overall decrease in lactate concentration after the 6 weeks training period (P = 0,034) but there are no difference between groups.

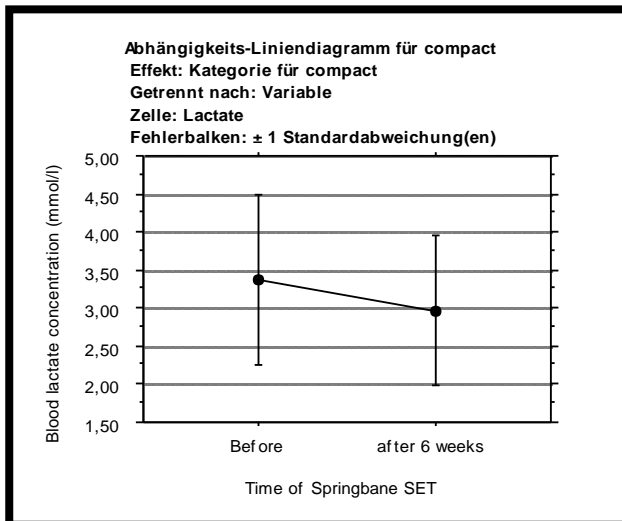


Figure 19. There is an overall decrease in [lactate] after 6 weeks.

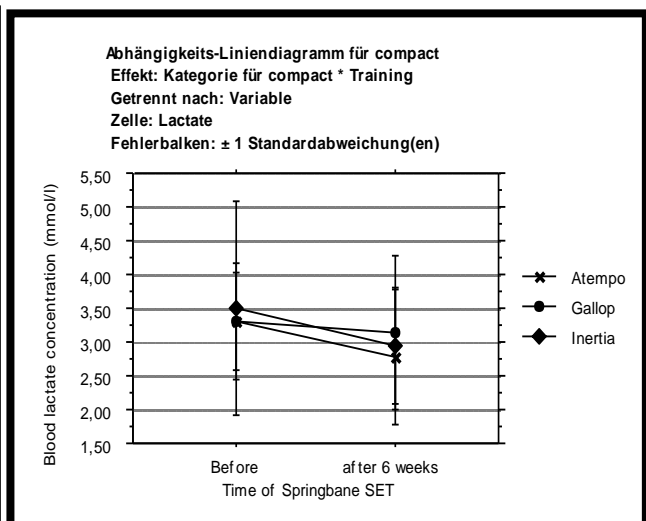


Figure 20. The [lactate] decreased after 6 weeks of training but there were no differences between groups.

Energy level and technique scores assessed by rider and observer, results for SET3 are shown in figure 21, 22, 23, 24.

There is a statistical significant increase in energy level assessed by the rider after the 6 weeks training period ($P = 0.0031$), there are no difference between groups (figure 21 and 22).

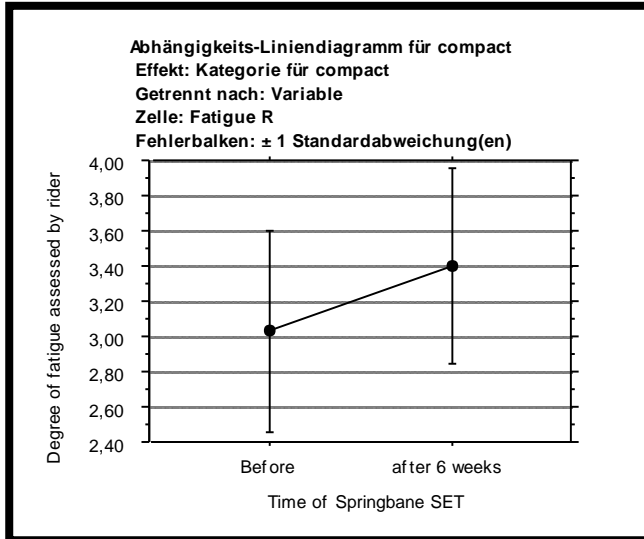


Figure 21. For energy level (fatigue) assessed by the rider there was a change during time ($p=0.0031$).

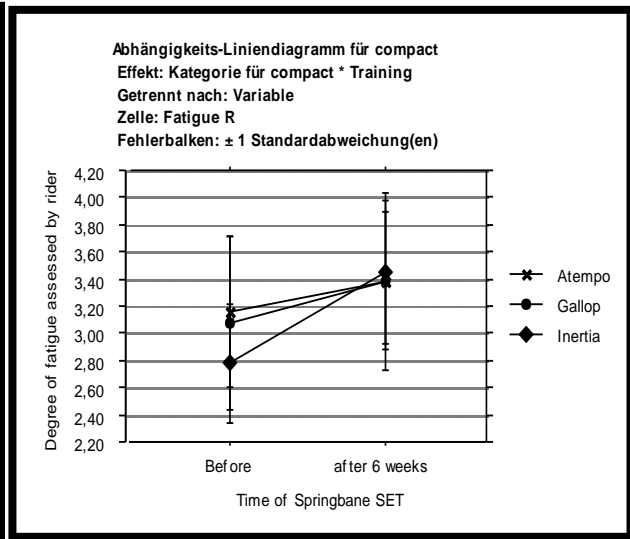


Figure 22. For energy level assessed by the rider there was an overall effect of training but no difference between ITM ($p>0,05$)

There is a statistical significant increase in technique score assessed by the rider after the 6 weeks training period ($P = 0.021$), there are no difference between groups (figure 23 and 24).

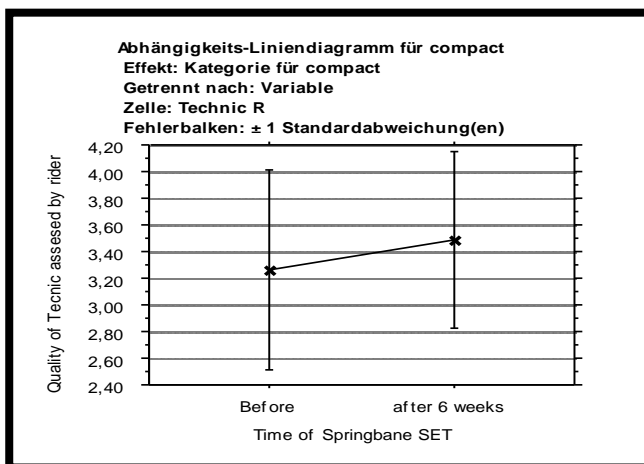


Figure 23. There were a significant effects for time($p=0.0211$) jumping technique as assessed by rider

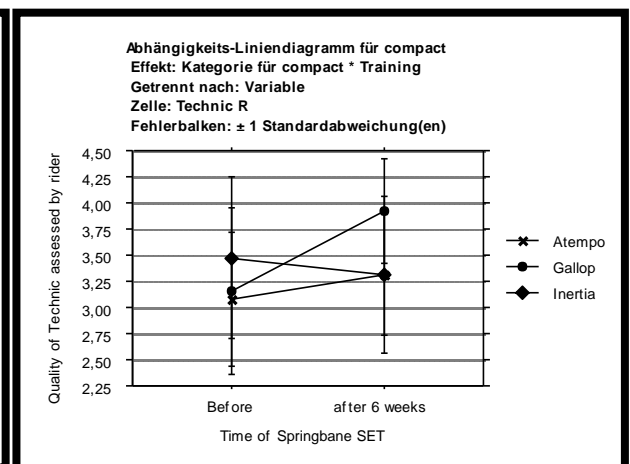


Figure 24. Results indicated that there was an effect of ITM on quality of jumping technique as assessed by rider where ITM1 was superior to ITM2 ($p=0.0073$).

There were no statistical significant improvement in energy level or technique score assessed by the observer.

Test	Parameters	ITM 1 (gallop)	ITM 2 (sprint)	ITM 3 (Atempo)	ITM 1 + 2 + 3
SET 1	V2	Increased P = 0,016	No change	No change	<p>Statistical Significant difference in improvement after training (anova)P = 0,0134. The significant difference is between ITM 1 and ITM 3. (Fisher) P = 0,039</p> <p>Overall decrease. P = 0,0089 no difference between ITM</p>
	V4	Increased P = 0,047	No change	No change	
	HR2	Increased P = 0,031	Increased P = 0,055	No change	
SET 2	HR				<p>There is an overall decline in HR after training P = 0,0058.</p> <p>There are no difference between ITM</p>
	[la]3 interval	Decrease in [la] P = 0,016. Improvement -5 - 36 %.	Decrease in [la] P = 0,0078. Improvement 37 - 60 %.	Decrease in [la] P = 0,065. Improvement -25 - 60 %.	<p>Overall decrease in [la] after 6 weeks of training P = 0,043</p> <p>There are no difference between ITM</p>
	[la]3 - [la]rest	Decrease in [la] P = 0,031. Improvement 22 - 68 %.	Decrease in [la] P = 0,0078. Improvement 51 - 177 %.	Decrease in [la] P = 0,063. Improvement 26 - 78 %.	<p>Obstacles down increased with interval (jump height) there were no difference between ITM. Obstacles down decreased after training (P = 0,0058)</p>
	[la]2 min	Decrease in [la] P = 0,0078. Improvement 17 - 35 %	Decrease in [la] P = 0,0078. Improvement 3 - 80 %	Decrease in [la] P = 0,063. Improvement 14 - 68 %	<p>There are no effect of training on jumping technique and energy level (p>0,05)</p>
	Obstacles down				
	Technic Rider				
	Energy level Rider				
SET 3	[la]jumping				<p>Overall decrease in [la] p = 0,034. There were no difference between ITM.</p>
	Energy level R				<p>Overall increase in energy level assessed by the rider p= 0,0031. No improvement detected by Observer</p>
	Energy level O				
	Technique R				
	Technique O				<p>There are a significant effect for 6 weeks of training on technique R. P = 0,0073. No improvement detected by O</p>

Table 5. Summeryzed results for the individual ITM on each parameter in SET1,2,3

Discussion

General notes on each investigated parameter

HR (Heart Rate)

A correlation between fitness level, resting heart rate (Foreman *et al.* 1990) and/or HRmax (Evans and Rose 1988) has never been shown. HRmax is therefore not considered a useful tool in the determination of physical fitness in the horse (Evans & Rose 1988; Foreman *et al.* 1990). During this study HRmax refers to the maximum heart rate each horse has reached during the SETs and the value has been used to individually determine the horse's work intensity. The mean HR is considered a more reliable parameter for the determination of physical fitness and effect of training (Evans & Rose 1988; Foreman *et al.* 1990). Previously, studies have shown that exercise reduces HR levels in response to work performed at sub-maximal intensity. Likewise, HR at any given (sub-maximal) work level may be used to indicate cardiovascular adaptation to this work (Von Engelhardt 1977; Bayly *et al.* 1983; Persson *et al.* 1983; Thornton *et al.* 1985; Evans and Rose 1988; Foreman *et al.* 1990; Seeherman and Morris 1991). Hennings (2002) showed that training based on specific heart rates may be used to improve endurance, i.e. over time a reduction in HR is seen at a given speed. Hennings (2000) showed that the degree of improvement of HR at certain speeds did not depend on the horse's pre-study performance level.

During this research, HR is not used directly as a parameter during SET1; rather it is used through HR2 and HR4. These parameters are velocity dependant, thus are only used during SET1.

In agreement with before mentioned studies, SET2 shows a significant decrease in mean HRs during 3th interval for all groups ($P=0.0058$) (figure 9). The data are similar between groups (figure 10). Likewise, SET2 shows a linear correlation between mean HR and lactate concentration after 3th interval; both before and after the training period. Unfortunately, in SET3 missing data caused mean HR calculations to be impossible. No improvement in HRmax was shown, but a relationship between HRmax and lactate concentration after work was seen.

Using these SETs, **HR after 2 min** did not change after the interval training sessions.

An average HR2 of 150 bpm during this study shows each horse to be at their expected level of fitness, while an average HR4 of 180 bpm shows their heavy work intensity. These results approximate findings in thoroughbreds. Lindner *et al.* (2000) saw a HR4 of 170 bpm in trained horses. In the current study, HR2 was statistically higher in group 1 (gallop training) after training, while no HR increases were shown at HR4. It is not possible to correlate age and fitness level with HR2 or HR4.

Blood lactate concentration

The average resting concentration of lactate in this study is determined at 1,46 mmol/L, and thus within accepted reference values (Lumsden *et al.* 1980; Moore *et al.* 1976; Latson *et al.* 2005).

Maximum lactate concentrations at SET1 before and after the training period are between 3 and 9 mmol/L. These values are comparable to values determined in WB horses at similar speeds during SETs on tread mills (Hennings *et al.* 2002; Melfsen-Jessen *et al.* 2002; Okonek *et al.* 2002; Shaefer *et al.* 2002). Courouce

et al. (1999), Persson (1983) and Courouce (1999) showed in trotters that both HR and lactate responses were more pronounced during outdoor track testing than under horizontal tread mill conditions. This has also been determined to be true in ridden horses (Valette *et al.* 1993; Barrey *et al.* 1993) and in the dutch WB breed (Sloet & Barneveld 1995). It is the interaction of the rider, mechanics of motion, environmental conditions and psychological factors that determine the differing values seen during tread mill and track testing.

In a SET containing à tempo jumping, the usual parameters are useless as they relate to velocity of work (V). In SET2, velocity can be minimally altered as the distance between the jumps is short. Lactate concentration that is measured after each 90 seconds interval is used as an expression of the increasing intensity of work one expects to see as the obstacles get higher.

There are no published values with which to compare the lactate concentrations found during SET2. The mean blood lactate concentration after last jumping interval is 3,8 mmol/L before training and 2 mmol/L after training. Thus, the training effect on the lactate concentration in SET2 is statistically significant ($p=0,043$). The lactate level shows that all horses improved their aerobic capacity during the interval training period (figure 11). The improvement varied between 18 – 40 % in the different groups and suggested that groups 2 (figure 13) and 3 improved the most, but there were no statistical significant difference between groups (figure 12). When calculating the rise in lactate concentration seen in response to work, a general lowering of this level is apparent after the training period ($P= 0,0001$). All groups are significantly improved from 22-51 percent, with group 2 showing the largest effect also for lactate concentration 2 min after test (figure 14). The fact that the biggest improvement is seen after the sprint exercise may suggest this training method to be superior, but it may merely be a reflection of normal variance caused by the small group sizes. One might have expected group 3 (ITM with á tempo) to show the most effect of training due to a training induced improvement in technique.

In SET3 it is also not possible to use V-related parameters of measurement. Published lactate concentration values after show jumping exercise provide alternative means of analysis (Art *et al.* 1999a,b; Barrey & Valette 1992; Covalsky *et al.* 1992; Desmecht *et al.* 1996; Rietbroek *et al.* 2007; Sloet *et al.* 2006). Unfortunately, it is difficult to compare these values as variables include height of obstacles, number of obstacles, arena size and speed. In the present study, all horses jumped the same course, used the same time but the height of the obstacles varied depending on the age of horse. The obstacle height neared maximum capacity for each participant horse. Lactate concentration before exercise was measured at 3,4 mmol/l, and 3,1 mmol/l after the training period. The overall decrease in lactate concentration was significant ($p = 0,034$) (figure 19) but there were no difference between ITM (figure 20).

In spite of the challenges when making comparisons with published research, the lactate concentration is seen to be low after completion of the arena jumping test, especially considering its individually tailored level of difficulty. In Covalskys (1992) research, he shows that experienced show jumpers have a higher lactate concentration in competitions in unknown surroundings as compared to delivering the same performance in familiar surroundings. This finding may be applicable to this study as SET3 took place in the horses regular training facility. The lactate concentration at SET3 is found to be higher the older the horse, and the higher it jumps. Average lactate concentrations grouped by age is as follows: 4 y.o. 2,2 mmol/l, 5 y.o. 3,1 mmol/l, 6 y.o. 3,6 mmol/l; older horses 4,6 mmol/l. As each age group is equally split between the

ITMs, these values may be compared. This finding agrees with a previous one (Munk, 2009) showing that lactate concentration is directly related to the degree of difficulty (obstacle heights and speed).

In SET1, the lactate concentration is related to velocity and time. This is defined as parameters V2 and V4. In the literature, V2 and V4 are the most frequently used entities for evaluation of equine performance during a SET (Lindner 2000). In the present study, group 1 participants showed a statistically significant improvement at the V2 and V4 parameters (figures 6,7,8). V2 median was improved by 18 percent and in one horse as much as 40 percent. V4 in group 1 is improved by 9 percent with a maximum improvement of 16 percent. Lindner (2004) measured an improvement of V4 in racehorses of 17 percent during a 6-week span. Other research in the racehorse have shown an improvement of 24 percent in 8 weeks, 31 percent in 9 weeks, 22 percent in 32 weeks and 35 percent in 10 weeks (Eaton *et al.* 1999; Rivero & Serrano 1999; Hinchcliff *et al.* 2002). In trotters in race training, a rise of only 4 percent is seen (Bayly *et al.* 1987; Roneus *et al.* 1994; Courouche *et al.* 2002). The opposing results may be explained by the fact that racing horses have an existing fitness level which may only be improved marginally regardless of training method; therefore V4 can only be pushed a little. The average velocity at V4 before training is 490 m/min and after training has increased to 510 m/min. For group 1, having shown a statistically significant training response, the increase is from 500 m/min to 540 m/min. A better effect of training could have been expected but this may be explained by the fact that group 1, that was exposed to galloping intervals, did not receive continual speed adjustments according to individual increases of V4. Lindner (2002) states the importance of re-evaluating V4 every other week to adjust the speed of training for maximum beneficial response.

To finish the discussion about the lactate concentrations reached at the different SETs, one needs to consider the intensity of work in the three SETs. In SET1, a lactate concentration of 4 mmol/L is seen at a speed of 500 m/min. At the time of this measurement, the horses have already run 3400 meters with an average HRmax of 197 bpm and a HR mean of 185 bpm.

In SET2, the speed is 225 m/min, a lap is 1008 meters and the number of small jumps is 240. The average maximum lactate concentration is 3,8 mmol/L before the training period and 2,8 mmol/L after training. HRmax at a lactate level of 3,8 mmol/L is 180 bpm. Mean HR is 170 bpm.

In SET3, the speed is 325 m/min, lap length is 380 m and number of larger jumps is 11. The average maximum lactate concentration is 3,4 mmol/L before the training period and 3,1 mmol/L after training. HRmax at lactate 3,4 mmol/L is 180 bpm. Mean HRs cannot be calculated due to missing data.

If a HR of 180 bpm is suggestive of the intensity of work as described by Hennings (2000), Evans & Rose (1988) and Foreman (1990), then the work level in SETs 2 and 3 were very similar in spite of differences in speed, number of jumps and height of jumps. This may be explained by the assumption that a large number of small jumps in SET2 equal the smaller number of large jumps in SET3. The study by Munk (2009) shows higher lactate concentrations at timed competitions than during non-timed events of same degree of difficulty. Therefore, the differences in speed in SET 2 (225 m/min) and SET3 (325 m/min) should be considered. In SET1, the speed, HRmax and mean HR exceed those in SETs 2 and 3 and explains the corresponding elevations in lactate concentrations.

In SET 2, the lactate concentration 2 minutes after finished work shows a statistically significant improvement in all groups of between 27 and 42 % (figure 14). If, however, the resting lactate

concentration is subtracted from the lactate concentration after 3th interval, this improvement is non-existent. Hyypa (2000) concluded that decreased concentrations of lactate after finished work is a poor indicator of physical fitness as it cannot be improved by training. Practically, though, it is important for the planning of training sessions.

Other parameters; obstacles down, technique and jumping energy.

In SETs 2 and 3, the number of obstacles down is used to assess the effect of the three ITMs. In SET2, a positive statistically significant correlation is seen between the number of obstacles down during interval 1,2 and 3 ($p=0,0001$)(figure 15 and 16). This result is not surprising, as the obstacles were elevated at the same time the horses became fatigued. However, the total number of obstacles down showed a statistically significant decrease after the training period ($p=0.0058$). This effect was general, neither ITM being superior, discarding the possibility that it was merely due to better technical abilities within group 3 (à tempo interval training). No relation is seen between lactate concentration after 3th interval and the number of obstacles down.

In SET3, the number of fault/obstacles down both before and after the interval training period is so low that no improvement can be determined.

The additional parameters in SETs 2 and 3 aim to determine whether the ITMs had an effect on the horses' technical abilities as well as energy level while jumping. In SET2 this is judged by the rider, while in SET3 this is judged by both the rider and an observer watching the tests on video. In SET2, no effect of training is seen on either parameter (figure 17 and 18). Likewise, no relationship is shown between the lactate concentration after 3th interval and the technical scores. Since technique and jumping energy are based on subjective evaluations, the validity of the riders score is debatable. The number of obstacles down before and after training is a more objective way of evaluating both technique and energy. In SET3, energy level (figure 21 and 22) and jumping technique (figure 23 and 24) shows a statistically significant improvement especially for ITM 1 as scored by the rider but not by the observer, bringing the validity of the parameter further into question. No relationship is seen between the lactate concentration after jumping work as compared to the energy level- and technical scores.

Research in humans have determined that the speed at set-off in a maximum jump test is improved significantly with training. Testing at sub-maximum levels (50 percent of the max jump test) the amount of energy required diminished significantly with training. The muscle enzyme activity of *m. gastrocnemius* increased and a general rise in performance of 8 percent was seen after 15 weeks of jump training (2 x week) along with a decrease in energy expenditure of 24 percent (Kyrolainen *et al.* 2004). Pereira (2008) showed that the fatigue arising from jumping repetitively may decrease the speed of jumping though the jump height is unaltered. The same author found that volley ball players jump optimally with 14 s of rest between each effort.

Human jump training and à tempo jumping in horses may be similar and this would explain why lactate concentration and number of obstacles down both improved with training. Why group 3 (à tempo) does not show a significant improvement in SET3 as compared to the other two groups may be due to the arena jumping test requiring too little intensity of work. If this was the case, the arena jumping training, while

showing improved aerobic condition, would fail to show improvement in muscle strength and explosive capacity at set-off.

Another human study in volleyball players has determined that running and jumping together result in higher lactate concentrations and higher HRs (i.e. is of higher work intensity) than jumping alone. The height of jumps will decrease sooner after running and jumping than after just jumping (Hertogh *et al.* 2005). Should one compare this study to similar exercises in the equine athlete, one might assume arena jumping (higher jumps) to be of higher work intensity than á tempo training (lower jumps). Caution, however, should be exercised when correlating SET 2 and 3 since the number of jumps differ greatly between the two. Muscle biopsies would have been of value in the current study as the earliest measurable adaptation in muscle is a rise in enzymes used for aerobic energy metabolism. This change is associated with increased density of mitochondria and capillaries (Rivero 2007).

Whether the ITMs used in this study were of meaningful and comparable intensity, duration and frequency is difficult to determine. No doubt, SET1 showed the galloping exercise to be the training type that improved V4. Undoubtedly, this effect could have been maximized if continual training adjustments had been in performed. Group 1, that was exposed to galloping intervals (ITM1), did not receive continual speed adjustments according to individual increases of V4. Lindner (2002) states the importance of re-evaluating V4 every other week to adjust the speed of training for maximum beneficial response.

Gottlieb-Vedi (1995) and Courouce (1999) recount how the majority of the training in the racing trotting horse is done between V2 (HR2) and V4 (HR4). This improves aerobic energy metabolism and provide adequate effect of training. The horses doing the ITM sprint and ITM á tempo have shown lactate concentration values between La2 and La4 as well as heart rates between HR2 and HR4. In view of this, perhaps an even greater improvement on V2 should have been expected in these groups during the post-training SET1. The intensity of speed work during ITMs 2 and 3 was too low to expect improvement of V4.

When evaluating fitness based on SET2, all three ITMs had a positive effect. A statistically significant decrease in HR, lactate concentration and a smaller number of obstacles down is seen in all groups.

When evaluating fitness based on SET3, each ITM showed some effect. The lactate concentration after jumping the course decreased after 6 weeks of training and there were no difference between ITM. Both energy level and technique judged by the Rider was overall improved and for the technique scores it seemed like ITM1 was superior to the others.

That the improvement in the measured parameters in SET 3 is modest may be caused by a too low work intensity required by the ITMs. This explanation, however, is contradicted by the results of SETs 1 and 2. SET3 itself, then, becomes a more likely cause of the non-convincing results. It is entirely possible that the intensity required to perform SET3 was too low to provide strong fitness evaluation data. Whether the flaw lies in degree of technical difficulty, obstacle height, lap length, or speed is unknown and offers material for future studies.

Concerning the practical aspects of performing the SETs and the ITMs

SET1 and ITM1; with the exception of inclement weather, it is practically easy to perform this training and testing. The challenge of this type of training and testing is to keep a steady lap pace, especially as deceleration and acceleration are required for blood sample collection. In addition the GPS monitor may be slowish to react, especially at directional changes. This flaw may be compensated for by timing each lap and calculating the speed. The riders were satisfied with the training and testing method and the horses really seemed to enjoy it.

SET2 and ITM3; this A'tempo training and test can be conducted in an indoor arena. However, it requires multiple persons for quick obstacle adjustments between laps. The horses tolerate this test very differently; some give up and barrel through the course while others are too careful. Generally, the horses seem as tired after SET2 as they were after SET1. Respiration is elevated and the horses seem to be working at max during the last interval. They do not, though, sweat as much in SET2 as in SET1. The riders were satisfied with the test but stated that with this method of training and testing, horse and rider need to be fairly experienced at jumping to allow the height increases needed to perform at max. It seems unlikely that the jump heights used in this trial could be further elevated as the horses were working extremely hard by 3th interval.

SET3 and ITM2; this training and test was easy to perform.

Conclusion

Evaluating the ITMs

This research shows that all three interval training methods had an effect on the energy metabolism, (measured as the lactate concentration), in show jumpers. This response to training, however, cannot be measured using a field SET as is typically done in race horses. Improving the aerobic metabolism has an effect on the show jumpers' energy level and technical ability as evaluated by the rider. The training methods also showed an effect on the number of obstacles down in SET2.

As expected, an effect of galloping intervals (ITM1) was seen during the SET1. For group one, a decrease in the lactate concentration was also seen during SET2 and SET3.

Using a SET1 no training effect could be shown from neither ITM2 (sprint interval training) nor ITM3 (á tempo interval training). In comparison, in SET2 and SET3 an effect of training was noted on the lactate concentration for both the sprint and á tempo interval training methods.

In conclusion, all three ITMs have a positive effect on the physical fitness level of show jumpers. Improving cardiovascular fitness does correlate well with a decrease in obstacles down, jumping technique and energy level during arena jumping. Whether this effect can be maximized by increasing intensity (height, speed, number of intervals/session, length of intervals/session), frequency (number of sessions/week) or interval training period (number of weeks or months) is unknown and further research is recommended.

Evaluation of SETs

A field SET (SET1), as is used on the race track, is useful in the evaluation of physical fitness level and training effect from galloping intervals in show jumping horses. The effect of training seen in jumpers that have undergone jumping specific interval training with sprints or á tempo, cannot be measured with SET1, but becomes apparent as a statistically significant decrease in lactate concentration during SET2 and SET3. SETs 2 could be promising with respect to the development of a specific SET method for the evaluation of fitness level and effect of training in the show jumper. SET3 has a lack of repeated lactate measurements and is therefore of very little value. Testing methods are in need of further work to determine work intensity as determined by obstacle height, number of jumps, lap size and speed.

The relationship between lactate concentration and HR is well known in racing horses. This study shows this to be the case, as well, in show jumping disciplines.

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List of abbreviations

SET	Standardized exercise test
SET1	Standard Exercise test field track
SET2	Standard Exercise test a' tempo
SET3	Standard Exercise test jumping course

ITM	interval training method
ITM1	interval training method gallop
ITM2	interval training method sprint
ITM3	interval training method a' tempo

A' tempo = in and out jumping; obstacles standing so close that the horse does not take a stride in between

HR heart Rate

V velocity (speed)

V2 The velocity where the lactate concentration is 2 mmol/l is referred to as **V2**

V4 The quantitative variable which determines the speed with which the lactate concentration reaches 4 mmol/l is described as **V4** or **Vla4**

HR2 The heart rates corresponding to the work intensity of V2 and V4 is **HR2**

HR4 The heart rates corresponding to the work intensity of V2 and V4 is **HR4**

[Ia] lactate concentration

La4 A blood lactate concentration of 4 mmol/L is often termed the lactate threshold value, **La4**

VLa The Velocity where the blood Lactate concentration reaches a certain level is defined as **VLa**

VLa2 A blood plasma concentration of 2 mmol/L is considered a steady-state level of lactate during aerobic work; thus, the velocity at **VLa2** is used for aerobic threshold determination

VLa4 The quantitative variable which determines the speed with which the lactate concentration reaches 4 mmol/l is described as **V4** or **Vla4**

[Lactate] J lactate concentration at the end of show jumping course

[lactate]3th interval lactate concentration after finishing the final interval in SET2