Monitoring blood lactate and heart rate during two different Standardised Exercise Tests in young Friesian horses

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Abstract

The aim of this study is to generate more in depth information about the exercise physiology of the young Friesian horse and to see how they respond to training. Further aim is to study the accumulation of lactic acid in response to different SET tests (standardized exercise tests) performed throughout a 2 month training period. Our hypothesis is that especially long episodes of continuous cantering cause important blood lactic acid accumulation in young Friesian horses. Our aim was to check whether a SET test that encompasses equal duration of cantering, spread out over shorter but more frequent intervals can prevent this. .

In this study 9 young relatively inexperienced Friesian horses were monitored over a period of two months. Horses performed two different SETs (SET A and SETB) every other week, during which heart rate was monitored and blood lactate was measured at given times. SET A was performed at day 1 of each week, SET B at day 5 of each week. SET A contained episodes of continuous canter whereas SET B alternated short episodes of canter with short episodes of trot and walk in both directions. Total cantering time was the same in both SETs and total workload was even a bit higher in SET B due to the extra trot episodes.

Maximal blood lactic acid concentrations were significantly higher in SET A compared to SET B. Also maximum heart rate (HR) during cantering was significantly higher in SET A than in SET B. When looking at training response, blood lactate levels were significantly lower in week 8 compared to week 0. Heart rate parameters also showed a mild decrease after 8 weeks, however not significant.

Comparison of blood lactate and HR between SETS showed that short intervals of cantering limit lactic acid accumulation, offering interesting information for Friesian horse trainers. All horses showed a significant training response after 8 weeks. Importantly, horses that started the study with the lowest fitness level, displayed the biggest training response.

In conclusion: SET A seems more suitable than SET B for assessing fitness in Friesian horses, whereas SET B provides a good template for training Friesian horses in the aerobic window. Friesian horses reach their anaerobic threshold quicker than warmblood horses.

Based on a decrease in blood lactate concentrations after cantering, the fitness of the young Friesian horses in this study improved significantly as of 8 weeks of training. Mean HR time profile was not a good parameter to assess training response after 8 weeks.

Average heart rate in trot has a strong correlation to blood lactate concentrations after cantering in Friesian horses. This makes it an interesting parameter for further research on fitness assessment. It could be a useful parameter to monitor during daily training of Friesian horses, rather than to focus on HR during cantering which tends to push Friesian horses quickly into their anaerobic threshold.

Horses that started the study with the lowest level of fitness showed the biggest training response, most clearly expressed through lower blood lactic acid concentrations after cantering, emphasizing the importance to be careful with categorizing a Friesian horse as predisposed to poor performance and unfit for a sportive career based upon training parameters assessed at the beginning of training.

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Introduction

The latest few years, there is an increasing interest of horse riders to objectively measure fitness in horses being trained. For this purpose telemetric devices are used, equipped with GPS that enable horse riders to monitor heart rate, velocity and performed distance during training. When, throughout the training period these horses are subjected to a standardized exercise test (SET), one can follow-up training response and adjust the training schedule or format where necessary. However, little is known scientifically at this point concerning appropriate training protocols and applicable SET test protocols, for each individual sport focus the rider has, for example dressage versus jumping. Moreover, it can be expected that a different approach is needed for certain breeds within the same sport focus. Currently, a lot of training is performed on empirical basis.
An appropriate SET test or series of SET test protocols could help to objectively monitor training response in a population of trained horses. It could even help a studbook to identify those individual horses that show great training response or identify those horses that do not.

Wherever we want horses to perform at the maximum of their ability, proper training and conditioning is of great importance. The aim of getting a horse fit is to enable it to perform to a certain level without excessive fatigue and with decreased risk for development of exercise related injuries. The basic principle of training is to expose a horse to a gradually increasing intensity of work. This slow and gradual buildup of workload enables the horse to adapt both physically and mentally and thus maintain a good wellbeing.[1] Aerobic condition training triggers a shift of intermediate muscle fibers towards type 1 fiber function, it increases muscular capillarisation and it increases the amount of mitochondria in the muscles which supports oxidative capacity. A solid aerobic stamina is the basis for all exercise types, whether they are short and explosive or of long and medium grade intensity. Dressage and jumping most probably represent a mix of mainly aerobic and anaerobic exercise episodes. If a horse needs to perform properly in these sports disciplines, excessive and early build-up of lactic acid levels in muscle groups or later on systemically is expected to have a detrimental effect on performance capacity. A solid aerobic stamina can diminish or postpone lactic acid accumulation. Hence the importance of objective follow-up of the training response in a horse.

The aerobic training response is known to be the greatest in the first two months of training.[1, 2] Objective data collection enables trainers to specify workload for individual horses and optimize conditioning results. Heart rate and blood lactate levels are important parameters for monitoring fitness. These parameters were also assessed by Munsters et al. during the performance study executed in cooperation with the Royal Friesian Horse Studbook (KFPS). Munsters et al. developed a standardized exercise test (SET) for young Friesian horses admitted for the ABFP

test organized by the Dutch Royal Friesian Studbook and showed that many young Friesian horses reached their anaerobic lactate threshold (4 mmol/L) during that SET, that actually even represented a lower intensity exercise grade than their daily training routine.[3] Furthermore the fitness response of these horses was assessed over a 6 week training period. Horses were categorized as either low-, moderate-, or non-responder based upon the decrease of maximum HR after 6 weeks of training. The study showed a striking heterogeneity in degree of training response and the authors proposed a genetic background for their findings. A genetic predisposition was proposed for poor athletic capability of certain Friesian breeding lines. The study results actually suggest that young Friesian horses can reach their anaerobic lactate threshold on a daily basis during the ABFP test training and that poor performance seems to have a genetic background in Friesian horses.

Anaerobic training on a daily basis without sufficient recovery time will not have the desired training effect. It is known that a solid aerobic condition is the essential backbone of exercise capacity. In its absence, muscles will not have the opportunity to overcome micro trauma, to develop hyperplasia and hypertrophy and to develop increased cappillarization. Excessive anaerobic training does not fit the definition of basic conditioning mentioned earlier and might cause horses to become overtrained and to underperform[1, 4]. This suggests that the current set-up of the KFPS performance tests for young horses is too heavy and unsuccessful for training and conditioning these horses. Consequently, it is possible that the KFPS underscores the ability of the young horses that even could become overtrained. The study results have led to the question as to whether training during the ABFP test weeks should be adapted or a different SET test should be designed. The KFPS is also in search for early parameters that could help identify poor training responders that are not suitable for an intense sport career. Moreover, horses that are presented for the ABFP test are very diverse when it comes to training history, which makes things even more complicated. Some of them have already been pre-trained at home, whereas others arrive very "fresh" and inexperienced.

When comparing the small amount of available exercise studies in Friesian horses with data available on warmblood horses, it is striking that Friesian horses in general seem to build up lactic acid in a faster and more pronounced way. This might suggest that they require a different and more careful training approach, compared to Dutch warmblood horses to prevent overreaching.[3, 5] Indeed, the research of Munsters et al. suggests that Friesians reach their anaerobic threshold quicker than other horse breeds. Other research encompassing anaerobic lactate threshold showed that most horses do not reach their anaerobic threshold at velocities reached in a standard canter like the one used in the SET test by Munsters et al.[3, 5] Since Friesians have more difficulty cantering, the relatively long four minutes of continuous canter might cause the young horses to reach their anaerobic threshold of 4 mmol/L much earlier. After all, these are young horses that have not been trained for long or are even completely inexperienced at start. In these young inexperienced horses, muscles have not been able to

develop increased aerobic enzyme activity and increased oxidative fiber capacity yet. Therefore muscle fatigue could develop quickly, causing them to reach high lactate levels. Young Friesian horses might exhibit this especially after prolonged cantering because it is not the preferred gait for them.

Aim and Hypothesis

The aim of this research is to monitor the fitness and response to training of young relatively inexperienced Friesian horses over a period of two months.

Our hypothesis is that the SET test applied by Munsters et al., (SET A, Table 1) contains non stop canter episodes that are too long; that an alternative SET protocol (SET B, Table 2) which contains a similar workload but with shorter periods of canter interrupted with periods of trot is less demanding; that there will be an important interindividual difference in training response in the studied group.

The research should show whether young Friesian horses do indeed reach anaerobic threshold in a SET based on a basic training routine from the KFPS performance test like in the research of Munsters et al[3].: SET A (Table 1). Furthermore it should show how lactate levels develop over a period of training. According to current literature the biggest development of training on muscle condition is seen in the first two months[1]. Monitoring heart rate and blood lactate concentration over this period should show a trend in fitness increase expressed through lower mean heart rate and in higher enzyme activity of the aerobic metabolism expressed through lower mean blood lactate levels.[6-9]

Secondly, this study will focus on isolating parameters from the recorded data that might prove useful for the Royal Friesian Horse Studbook in the process of developing a breeding value for selecting fitter horses.

Research Questions

1. Is there a difference in HR and lactic acid time profile for SET A vs SET B?

2. What is the training response in young Friesian horses?

3. Can HR values be correlated with lactic acid levels?

4. How do heart rate parameters and lactic acid concentrations in week 0 relate to training response?

5. Are there heart rate parameters that might prove useful in setting selection criteria for the KFPS?

Materials and Methods

At two training facilities, inexperienced Friesian horses (aged 3-5 years) were subjected to the same training program and monitored during two months. Four horses had been broken just before the start of the study. The other five horses had undergone about one year of low intensity training prior to the study.

Prior to the training period all horses underwent a clinical examination to make sure there were no injuries that might interfere with the research. Horses that showed signs of lameness or systemic illness were excluded from the study.

Throughout the training period, the riders were asked to keep a logbook recording whether the horse showed signs of disease, lameness or reluctance to work. This was recorded because research shows that horses with an injury show higher mean heart rate and increased plasma lactate levels.[12] During the research one horse got injured during a trailer ride and therefore could not complete the last week of the study.

At both facilities horses were subjected to a similar training protocol, comprising of 30-45 minutes of basic dressage training comparable to the workload in SET B, three times per week. The horses performed two different SETs once every two weeks. SET A on day 1 of the week (Monday) and SET B on day 5 (Friday) of the week. Heart rate was measured throughout the SETs by means of a Polar RC 3 GPS system. The electrodes were placed under the girth behind the left elbow and under the saddle on the left side behind the withers. Velocity was recorded simultaneously with a GPS. Blood was collected by briefly stopping the horses during the SET and collecting a blood sample from the jugular vein. Blood was collected at the start of training $[Lactate]_{start}$, directly after the left canter $[Lactate]_{canter1}$ and right canter $[Lactate]_{canter2}$ and at the end $[Lactate]_{end}$ during SET A and B. Moments of blood collection are marked [Lactate] in Tables 1 and 2.

Table 1: SET A

Time (min)	Exercise	Description
$[Lactate]_{start}$ 00:00-03:00	Walk	± 2m/s
03:00-05:00	Left trot	On the left hand ±3.5m/s
05:00-07:00	Right trot	On the right hand ±3.5m/s
07:00-09:00$[Lactate]_{canter1}$	Left canter	On the left hand ±5m/s
09:00-11:00$[Lactate]_{canter2}$	Right canter	On the right hand ±5m/s
11:00-21:00$[Lactate]_{end}$	Walk	Recovery ±2m/s

This set up was suitable to monitor the build-up of lactate levels throughout the SETs and especially study the effects of the canter phase in young Friesian horses. Plasma lactate concentrations were measured with a portable measurement device: Akray Lactate pro. Lactate concentrations <0,8 mmol/L were below the detection limit and were set at 0,8. Ambient temperature and humidity can affect the response to exercise and were therefore recorded during the measurements. [10, 11]

The horse rider was equipped with a polar watch to enable him/her to control speed during SET tests.

Table 2: SET B

Time (min)	Exercise	Description
[Lactate]$_{start}$ 00:00-03:00	Walk	± 2m/s
03:00-05:00	Left trot	On the left hand ±3.5m/s
05:00-06:00	Left canter	On the left hand ±5m/s
06:00-07:00	Left trot	
07:00-08:00[Lactate]$_{canter1}$	Left canter	
08:00-09:00	Walk	
09:00-11:00	Right trot	On the right hand ±3.5m/s
11:00-12:00	Right canter	On the right hand ±5m/s
12:00-13:00	Right trot	
13:00-14:00[Lactate]$_{canter2}$	Right canter	Recovery ±2m/s
14:00-24:00[Lactate]$_{end}$	Walk	

Data processing and statistical analysis

The following heart rate parameters were isolated from the Polar heart rate curves: average heart rate during trot (HR$_{trot}$), maximal heart rate during left canter (HR$_{maxLC}$) and maximal heart rate during right canter (HR$_{maxRC}$), average heart rate during left canter (HR$_{LC}$) and right canter (HR$_{RC}$). Since cantering episodes are only 1 minute in SET B, the heart will not reach a steady state to calculate a reliable average. Therefore HR$_{LC}$ and HR$_{RC}$ were only determined in SET A. Lactate at the beginning of the set was recorded as [Lactate]$_{start}$, after left canter as [Lactate]$_{canter1}$, after right canter as [Lacate]$_{canter2}$ and at the end of the SET as [Lactate]$_{end}$.

Statistical evaluation included difference in lactate concentrations between SET A and SET B, training response expressed in HR decrease and [Lactate] decrease from 8 weeks of training. Furthermore correlations of the heart rate parameters and lactate concentrations after cantering were analyzed to find valuable parameters for determining fitness in young Friesian horses. Looking into the predictive value of heart rate parameters for lactate concentrations will help to develop non-invasive techniques for assessing fitness and choosing selection criteria for the KFPS.

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Heart rate and lactic acid parameters were also correlated to the training response expressed by the decrease in blood lactic acid concentration between week 0 and week 8, to look for predictive parameters for training response in this study.

Difference in mean lactate concentration and heart rate between SET A and SET B was analyzed with a paired two-sample T-test, with heart rate or lactate concentration as the dependent variable and SET as independent variable. Training response was determined by comparing mean lactate concentrations and mean heart rate of week 0 to those of week 8. Data were analyzed with a paired two-sample T-test with heart rate or lactate concentration as the dependent variable and week number as independent variable.

Results

All nine horses were evaluated for lameness or illness at the beginning of the study. Vital signs were normal in all horses compared to the accepted veterinary references. [13] All horses were found healthy and not lame. During the study one horse got injured on a trailer ride during the last week of the study and could therefore not complete it. Ambient temperature during the study ranged between 10 °C and 18 °C. Relative humidity ranged between 75% and 87%.

Comparison SET A versus SET B

Analysis of the blood lactate concentrations in SET A and SET B revealed that the blood lactic acid time profile significantly differed between SET A and SET B. In SET A (Table 1), in which 4 minutes nonstop cantering episodes are implied, blood lactic acid concentrations were significantly higher than in SET B, in which the workload was similar but more gait variation was applied (see Table 2). In general SET A provided a bigger anaerobic trigger for the horses and lactate level differences were bigger between individual horses.

$[Lactate]_{start}$ at the beginning of the SETs was <0,8 mmol/L for all horses throughout the entire study. Therefore the data is consistent with the hypothesis that there is no significant lactic acid production prior to exercise and no further analysis of this parameter is needed.

Mean blood lactate for $[Lactate]_{canter1}$ was significantly higher in SET A (3,1 ± 1,6 mmol/L) than in SET B (2,1 ± 1,4 mmol/L) (P<0,0001). For $[Lactate]_{canter2}$ mean blood lactate concentration was also significantly higher in SET A (4,0 ± 2,5 mmol/L) compared to SET B (2,5 ± 1,5 mmol/L) (P<0,0001). Even at $[Lactate]_{end}$ after ten minutes of walk, blood lactate levels were still significantly higher in SET A (1,5 ± 1,5 mmol/L) compared to SET B (1,0 ± 0,5 mmol/L) (P<0,005). Figure 1 shows the mean $[Lactate]_{canter2}$ for each horse in SET A and SET B.

Figure 1: mean [Lactate]$_{canter2}$ in SET A and SET B
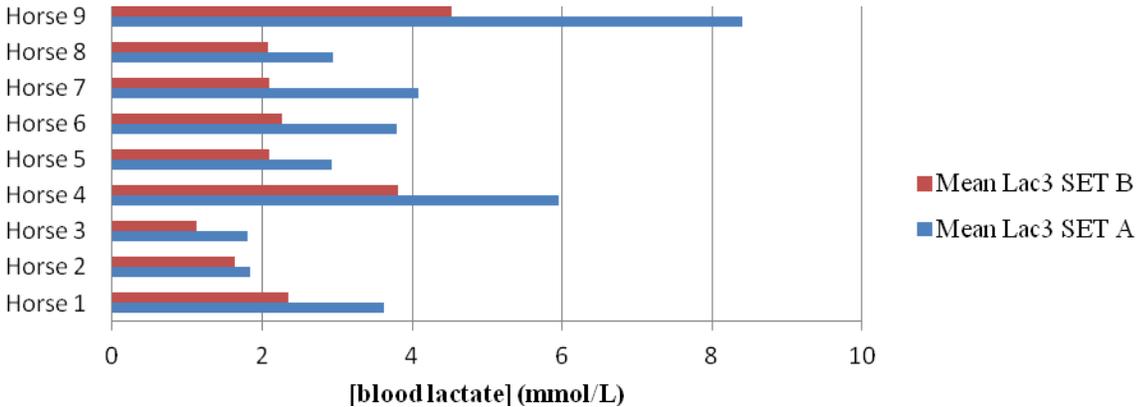
When comparing maximal heart rates between SET A and SET B the study showed that the smaller intervals of cantering in SET B lead to lower heart rate peeks. The mean HR$_{maxLC}$ was significantly higher in SET A (172 ±23 beats/min) than in SET B (165 ±23 beats/min) (P<0,01). Mean HR$_{maxRC}$ was also significantly higher in SET A (177 ± 24beats/min) than in SET B (165 ± 20 beats/min) (P<0,01). Mean heart rate in trot HR$_{trot}$ was the same in SET A and SET B (130 ± 14 beats/min).

Training response

Blood lactic acid time profile

Quantification of training response by follow-up of blood lactic acid time profiles showed a progressive decrease in blood lactate concentrations in response to both SETs throughout the study. Data from SET A as well as from SET B showed a significant decrease in lactic acid concentration from 8 weeks of training at[Lactate]$_{canter1}$ and [Lactate]$_{canter2.}$ In week 0 mean [Lactate]$_{canter1}$ was 3,9 ± 2,1 mmol/L and 3,5 ± 1,5 mmol/L in respectively SET A and SET B. In week 8 mean [Lactate]$_{canter1}$ was 2,4 ± 0,5 mmol/L in SET A and 1,7 ± 0,8 mmol/L in SET B, expressing a significant training response in both SETs (P<0,05). A similar response was expressed in [Lactate]$_{canter2}$ with mean lactate concentrations of 5,0 ± 3,2 mmol/L and 3,8 ± 1,9 mmol/L in week 0 compared to 3,0 ± 1,2 mmol/L and 1,9 ± 0,6 mmol/L in week 8. Resulting in a significant positive training response of 2,0 mmol/L decrease in SET A and 1,9 mmol/L in SET B (P<0,05). Mean lactic acid concentration at [Lactate]$_{end}$ also decreased in both SETs, however not significant. 2,7 ± 2,0 mmol/L and 1,3 ± 0,7 mmol/L in week 0 compared to 0,9 ± 0,2 mmol/L and 0,9 ± 0,2 mmol/L.

Heart rate time profile

The heart rate time profile showed a moderate decrease, however not as consistent as the lactate parameters. In SET A results for HR_{maxLC} and HR_{maxRC} showed a slightly lower mean in week 8 compared to week 0. HR_{maxLC} was 177 ± 30 beats/min in week 0 and 174 ± 19 beats/min in week 8. HR_{maxRC} was 182±28 beats/min in week 0 and 179 ± 22 beats/min in week 8. Differences were not significant.
Results were similar for HR_{LC} (169 ± 30 beats/min in week 0 and 165 ± 19 beats/min in week 8) and HR_{RC} (173 ± 29 beats/min in week 0 and 171 ± 21 beats/min in week 8), also not significant. Mean HR_{trot} was slightly lower in week 8 than in week 0 (132 ± 14 beats/min and 136 ± 22 beats/min) but again the difference was not significant. Overall there was no significant training response in heart rates.

In SET B HR_{maxLC} was even slightly higher in week 8 (165 ± 24 beats/min) than in week 0 (167 ± 19 beats/min). HR_{maxRC} did show a mild decrease from 166 ± 21 beats/min in week 0, to 164 ± 20 beats/min in week 8. Mean HR_{trot} decreased from 131 ± 14 beats/min to 130 ± 12 beats/min. As in SET A none of the heart rate parameters showed a significant training response.

Correlations heart rate and blood lactic acid

Heart rate monitoring is non-invasive and might prove useful in determining fitness differences between individual horses. Eventually the KFPS is looking for selection criteria in a breeding program to improve fitness in the Friesian breed. Since Lactate]$_{canter2}$ in SET A had the biggest standard deviation (2,5) it is most useful in differentiating between horses with a lower fitness level and those with a higher fitness level. In order to determine the value of several heart rate parameters, the correlation of these parameters to the [Lactate]$_{canter2}$ in SET A was calculated. In this way it is possible to determine the predictive value of heart rate parameters for the degree of lactic acid accumulation after 4 minutes of cantering in SET A.
Mean values ±SD and correlations between the heart rate parameters and [Lactate]$_{canter2}$ are shown in table 3.

Table 3: Correlations heart rate parameters and [Lactate]$_{canter2}$

Heart rate parameter	HR_{maxLC}	HR_{maxRC}	HR_{LC}	HR_{RC}	HR_{trot}
Mean ± SD (beats/min)	172 ± 22	177 ± 24	162 ± 23	169 ± 24	131 ± 16
Correlation to [Lactate]$_{canter2}$	0,68	0,64	0,73	0,69	0,82

The correlation is highest for the average heart rate in trot (HR_{trot}), suggesting this parameter has the highest predictive value for the degree of lactic acid accumulation after 4 minutes of cantering in SET A. Regression analysis gave an R^2 of 0,63. This suggests a moderate to strong exponential relation between HR_{trot} and [Lactate]$_{canter2}$. Figure 1 shows the corresponding graph.

Figure 2: Relation between HR_{trot} and $[Lactate]_{canter2}$

$$y = 0.075e^{0.0291x}$$
$$R^2 = 0.6321$$
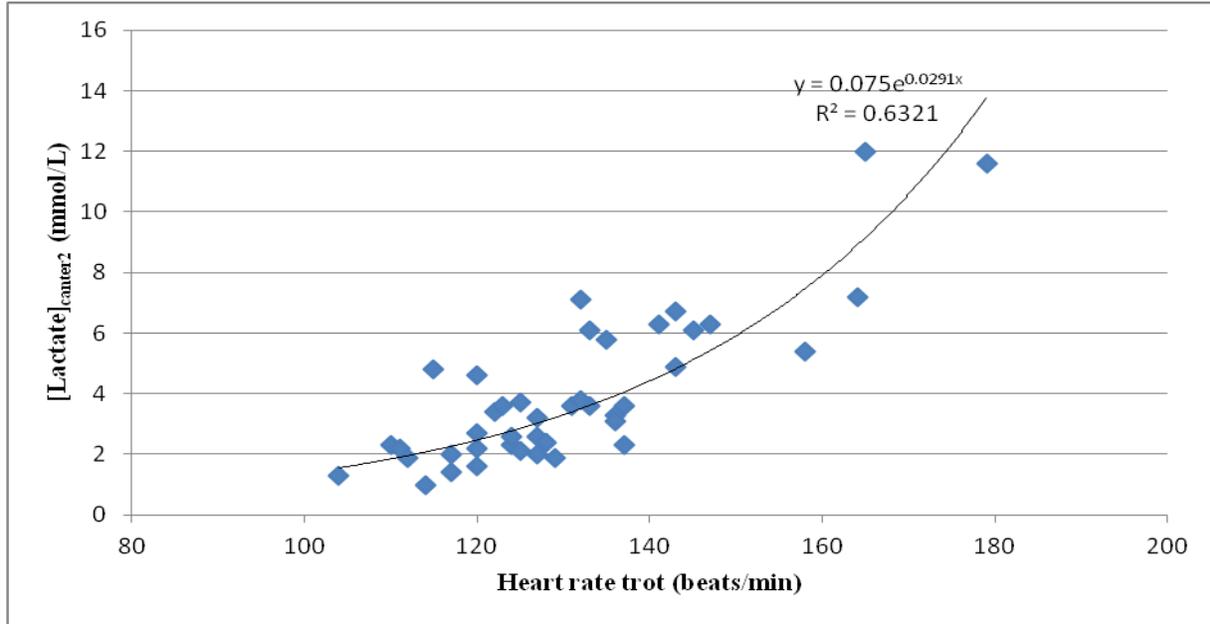
Correlation heart rate and training response in $[Lactate]_{canter2}$

The biggest training response was also noticeable in the parameter $[Lactate]_{canter2}$ from SET A. To assess the correlation of heart rate parameters to training response, heart rate parameters of week 0 were correlated to the difference in $[Lactate]_{canter2}$ between week 8 and week 0 in SET A. The difference in blood lactic acid concentration at $[Lactate]_{canter2}$ between week 8 and week 0, is set as the training response $[Lactate]_{canter2}$. Figure 3 displays this training response per horse.

Figure 3: Training response in $[Lactate]_{canter2}$ (mmol/L) from SET A
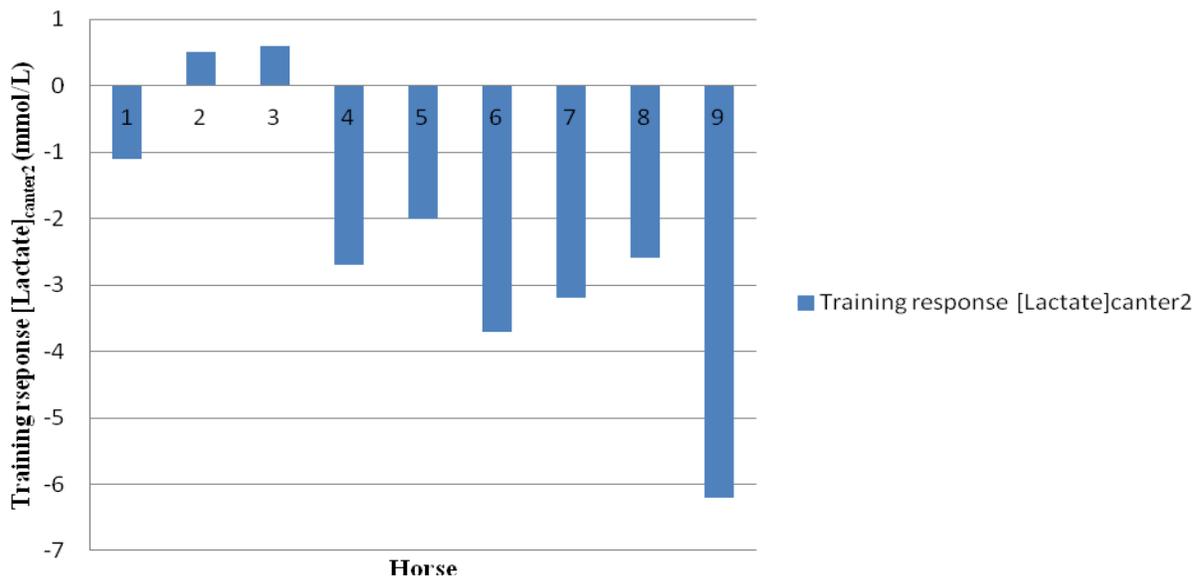
Table 5 displays the correlation of the heart rate parameters from SET A in week 0 to the training response.

Table 5: Correlations heart rate parameters and training response

| Heart rate parameter	HR$_{maxLC}$	HR$_{maxRC}$	HR$_{LC}$	HR$_{RC}$	HR$_{trot}$
Mean HR in week 0 (beats/min)	172 ± 28	176 ± 27	165 ± 28	167 ± 28	132 ± 21
Correlation coëfficiënt to [Lactate]$_{canter2}$	-0,90	-0,91	-0,89	-0,90	-0.84
R²	0.81	0.82	0.78	0.81	0.71

All heart rate parameters show a very strong negative correlation to training response in [Lactate]$_{canter2}$. Regression analysis reveals R^2 ranging from 0,71 to 0,82 suggesting a strong linear correlation between these heart rate parameters and training response (P-values<0,005). Figure 4 shows the relation between the several heart rate parameters and training response for the horses in this study.

Figure 4: Relation between HR parameters week 0 and training response in [Lactate]$_{canter2}$
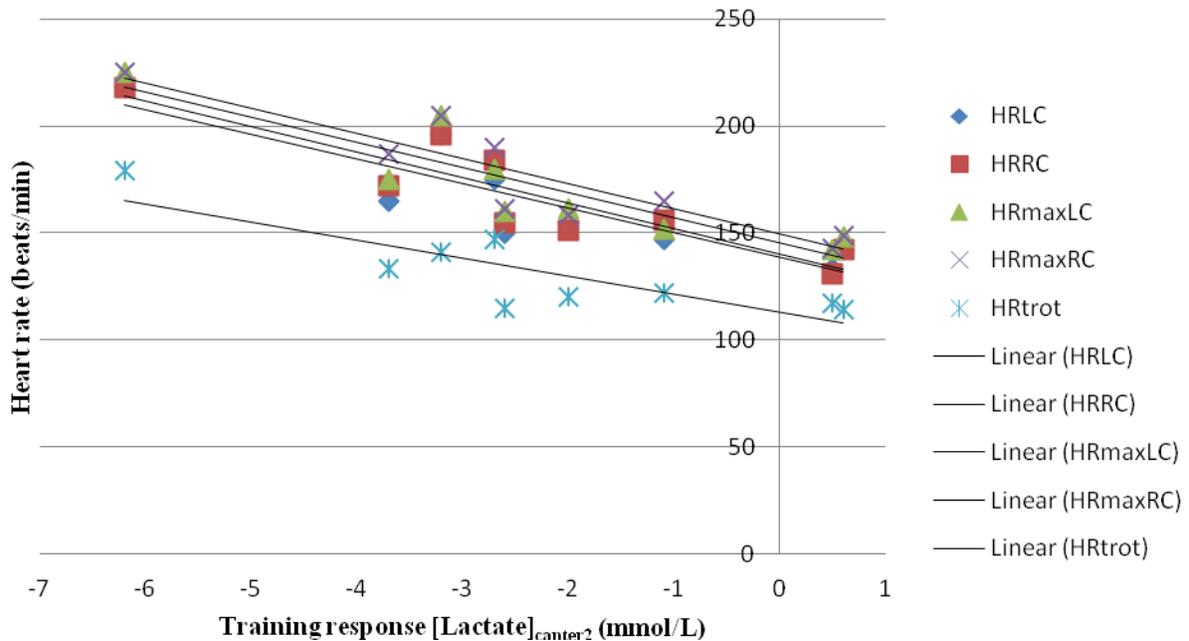
These results show that horses with higher heart rates also display bigger response to training, in the form of a decrease in lactic acid accumulation after canter. Figure 5 shows a similar relation between [Lactate]$_{canter2}$ in week 0 and the training response in [Lactate]$_{canter2}$ in 8 weeks. The corresponding correlation coefficient and R^2 are 0,98 and 0,96 respectively (P<<0,001).

Figure 5: Relation between [Lactate]$_{canter2}$ week 0 and training response in [Lactate]$_{canter2}$
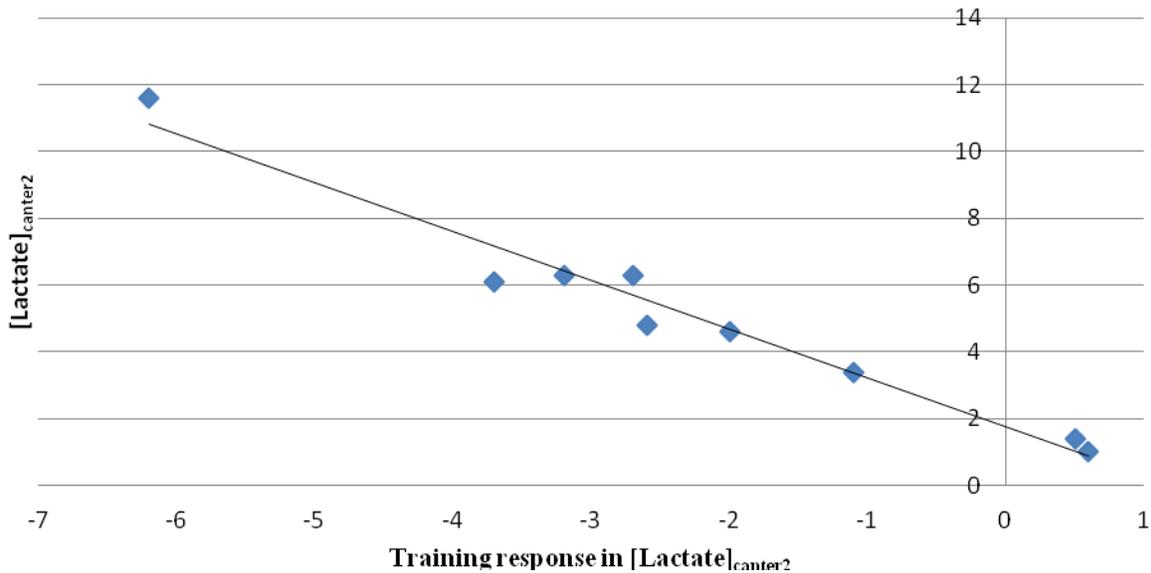
Similarly to the relation with the heart rate parameters, horses with high blood lactic acid concentration at the start of the study displayed the biggest training response.

Discussion

The horses in this study had higher blood lactate concentrations and higher peak heart rates in SET A compared to SET B. Out of 43 measurements, 15 were above the anaerobic threshold of 4 mmol/L after cantering, compared to 4 out of 43 in SET B. Therefore the study shows that SET composition is of significant influence on both the degree of lactate accumulation and peak heart rates in canter. Shorter cantering intervals limit lactate accumulation and heart rate peaks. These findings also show that blood lactate accumulation is, for the biggest part, caused by cantering and not by isometric muscle activity in the body core from walking "in connection". This is consistent with the findings in human studies that showed that isometric exercise did not necessarily lead to increased blood lactate concentrations.[14, 15] Our findings show that SET A has a better discriminative value than SET B to assess training fitness.

These insights are of great value when training young horses in practice. The large number of horses reaching the anaerobic threshold of 4 mmol/L in a SET based on a daily training in the ABFP tests, suggests that it is important to watch for overreaching. This is consistent with the conclusions of Munsters et al. Comparing the data to the findings of Sloet et al. during a similar lunging test in young Dutch warmblood horses, suggests that Friesians reach anaerobic threshold earlier. However findings of Sloet et al. are based on a lunging test and not a ridden test. An interesting subject for further research would be to focus on blood lactate production of young inexperienced warmblood horses during a ridden SET.[5]

Reaching anaerobic threshold on a daily basis is undesirable for making progress in training and is likely to increase the risk of injury. Apart from that it might also be of negative influence to the mental status of a horse. Young horses that reach their anaerobic threshold every training will be sore most of the time and might develop a reluctance to work.[4] Training young Friesian horses with short cantering intervals can help to prevent overreaching and make training more efficient. Choosing the right intervals can therefore prevent injuries and enable a horse to make good progression. In practice this comes down to cantering intervals of no longer than one minute for inexperienced young Friesian horses. Our results suggest that SET A is appropriate to assess training status and SET B provides a good guidance for training protocol, preventing overreaching.

Both blood lactate levels and heart rates during both SETs decreased over eight weeks of training in young Friesian horses in this study. Nevertheless only the decrease in blood lactate concentration was significant. All heart rate parameters showed a moderate decrease in mean value at the end of training compared to week 0, however this was not significant. This is inconsistent with Munsters et al. and Sloet et al. who did find a significant training response in heart rates.[3, 5] Although not significant, the moderate decrease in mean heart rates over a period of training in this study is consistent with the findings of Munsters et al.

The significant training response in lactate levels but not in heart rates proposes that a horse's aerobic capacity can already improve significantly without significant heart rate decrease in the same period. Some other studies also suggest that aerobic capacity in horses can improve without significant heart rate decrease as an effect of training.[17,18] In human studies however lactic acid and heart rate decrease are often described as occurring simultaneously.[19] This makes lactate concentration an even more interesting parameter when assessing fitness in young Friesian horses. The combination of heart rate and lactate seem more valuable as the parameters individually, as proposed in other literature.[14] Even though the population of horses in this study was rather small and training levels were similar, heterogeneity in fitness between horses was quite large. As depicted in figures 2 and 3, horses that had the highest heart rates and blood lactic acid concentrations in week 0, also showed the biggest response to training. So horses with a lower level of fitness at the start of this study did however show the biggest improvement in 8 weeks of training, encompassing the standard training and on top of that weekly performance of the SET tests. In general the horses with the lowest fitness levels were the horses that had had the least training prior to the start of this study. Munsters et al. found a large heterogeneity in training response in the horses in the ABFP tests of the KFPS. The population in this study was representative for the population in the ABFP test. Based upon the small population, we can't discern whether the heterogeneity in training response in our study should be addressed to a genetic background, rather than to differences in preparation prior to the ABFP test. Striking in our study is the fact that horses with the worst training parameters at the beginning of the training, also showed the largest training response. This is suggestive for the theory that heterogeneity of training response in the ABFP are caused by difference in fitness level at the

start. This is quite important, since one could wrongfully categorize a Friesian horse as predisposed to poor performance and thus not fit for a sports career based upon these "negative" starting parameters. Our study shows that it is important to be careful with such an approach. The research of Munsters et al. only incorporated one blood lactic acid measurement. Therefore training response on that parameter could not be assessed and is solely based on heart rate, which is a more unstable parameter than blood lactic acid concentration. If blood lactic acid concentrations were indeed measured at the start as well as at the end of that study, it might have shown that horses with the worst training parameters at the start had the biggest training response, just like in this study.

Furthermore this study showed that average heart rate in trot has a stronger correlation to [Lactate]$_{canter2}$ than peak heart rates during canter and average heart rates during canter. An exponential relation fits well with the data. It matches with the fact that lactate concentrations can approximate zero but never reach it. This correlation is an interesting finding for future research on heart rate and lactate concentrations. Study results on correlations between heart rate and lactate vary a lot. Munsters et al. found a significant correlation between heart rate in canter and blood lactate concentration after canter.[3] Munoz et al. found significant correlations in Andalusian horses but not in Anglo-Arabian and Arabian horses.[16] There is no literature that focuses on the correlation between average heart rate in trot and lactate concentration after cantering. It might be interesting to look into the predictive value of average heart rate in trot for degree of lactate accumulation. If further research is consistent with the findings in this study, average heart rate in trot can be a useful parameter for evaluating fitness in young Friesian horses. It would mean that it is an important parameter to follow up while training Friesian horses.

Conditions were pretty stable throughout the study. The moderate weather conditions were unlikely to interfere with the results.[10, 11] Limitations of this study include the small population of horses (n=9). This might also explain why the moderate decrease in mean heart rates during canter, although similar to the findings of Munsters et al. are not significant in this study. Even though the population in this study was small, it was definitely representative for answering our research questions.

Conclusion

SET A seems more suitable than SET B for assessing fitness in Friesian horses, whereas SET B provides a good template for training Friesian horses in the aerobic window.
Friesian horses reach their anaerobic threshold quicker than warmblood horses.
Based on a decrease in blood lactate concentrations after cantering, the fitness of the young Friesian horses in this study improved significantly as of 8 weeks of training. Mean HR time profile was not a good parameter to assess training response after 8 weeks.

Average heart rate in trot has a strong correlation to blood lactate concentrations after cantering in Friesian horses. This makes it an interesting parameter for further research on fitness assessment. It could be a useful parameter to monitor during daily training of Friesian horses, rather than to focus on HR during cantering which tends to push Friesian horses quickly into their anaerobic threshold.

Horses that started the study with the lowest level of fitness showed the biggest training response, most clearly expressed through lower blood lactic acid concentrations after cantering, emphasizing the importance to be careful with categorizing a Friesian horse as predisposed to poor performance and unfit for a sportive career based upon training parameters assessed at the beginning of training.

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