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Factors influencing resting heart rate in endurance racehorses

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Summary: In endurance racing, horses are stopped several times during a race for a veterinary inspection at so-called vet gates and heart rate is the relevant factor for the decision to continue the race. The influence on resting heart rate ($HR_{Resting}$) of endurance racehorses of the following factors was examined: 1) variation by day; 2) morning and afternoon variation; 3) ambient temperature and relative humidity; 4) age and v_4 (v_4 = speed at which the blood lactate concentration is 4 mmol/L under the defined conditions); 5) the method used to determine $HR_{Resting}$: auscultation or heartrate meter (HRM). Methods: The $HR_{Resting}$ of 19 horses conditioned for endurance racing was determined. They were exercised either in a field or on a treadmill. It was found that $HR_{Resting}$: 1) differed between days ($P < 0.001$ in the treadmill group, $P = 0.047$ in the field group); 2) was higher in the afternoon than in the morning in the field group only ($P = 0.001$); 3) increased with higher ambient temperature ($P = 0.024$) while relative humidity did not affect it; 4) was not related to the age or v_4 of the horses; 5) measured by HRM was higher than by auscultation ($P = 0.001$). In conclusion the determination of $HR_{Resting}$ of a horse should be based on a mean value determined after measurements taken on several consecutive days under as far as possible standardised conditions.

Keywords: horse, endurance, age, daytime, fitness, relationship, temperature, variation

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Introduction

In endurance racing, horses are stopped several times during a race for a veterinary inspection at so-called vet gates. For a horse to continue competing, its heart rate (HR) must be at or below a fixed value within 20 min of arrival. In general, the upper limit for an 80-km race or longer is a HR of 64 beats/min (*FEI* 2017). The Veterinary Commission may change the fixed HR or the recovery time before or during the competition to adjust to particular conditions. The time between arrival at each vet gate and the start of the veterinary inspection is counted as part of the overall riding time. Thus, a fast recovery of HR is very important for success in endurance events. Any horse deemed unfit to continue (due to lameness or HR not recovering as expected, for example) is withdrawn from the event. The fixed HR rule has developed a life of its own because HR is only one criterion of the health status of a horse during an endurance race (*Sloet* 2004). Setting HR limits has led to the selection of horses with a low HR at rest and to efforts to reduce it during recovery after exercise using drugs, manual manipulation and other means (*Sloet* 2004, *Birt* et al. 2015). Recently it was found that there is a great likelihood that the recovery HR is related to the resting HR ($HR_{Resting}$) of horses (*Lindner* et al. 2020) supporting the long-established routine of selecting horses with low $HR_{Resting}$ to compete in endurance racing. This study was carried out to understand better how diverse factors may influence $HR_{Resting}$ in endurance horses and to improve their selection based on this variable. The variability in the $HR_{Resting}$ of horses between and within days, and the effects of age and the endurance variable v_4 (velocity run under defined conditions inducing 4 mmol/L blood lactate (LA) concentration) were examined, as well as the effects of ambient conditions and the measurement method. It was hypothesised that $HR_{Resting}$ would be the same within a day and between days, that ambient temperature, relative humidity and measurement method would affect the values and that the age and v_4 of horses would not.

Material and methods

Horses

Nineteen horses participated in this study. All procedures were approved by the Bioethics Committee of the University of La Plata, Argentina. All horses were already being prepared for, or competing in, endurance races (Table 1). The horses were located in two establishments within 20 km of each other: A) Twelve horses were being conditioned on an 1800-m field track; and B) Seven horses were being exercised on a treadmill only (Mustang 2200, Kagra AG, Fahrwangen, Switzerland).

The field horses were trotted and cantered 3–4 times between 10 and 30 km per week and walked in a horse walker on the other days, except Sundays, when they were not exercised. The treadmill horses were worked every second day on the treadmill to collect data for a research project (*Lindner* et al 2020) and walked on a horse walker on the days in between. These horses were not exercised on Sundays either.

All horses were stabled in boxes overnight and kept during the day individually in paddocks. They were fed between 6–8 kg of concentrate per day and between 8–10 kg of hay. Water was always available. All horses were dewormed regularly and vaccinated against influenza, tetanus and equine encephalomyelitis. They were examined clinically every morning.

Experimental design

The $HR_{Resting}$ was determined in the morning between 07:30 and 09:30 and in the afternoon between 17:00 and 18:30 before feeding. At least 4 h elapsed after exercising before the afternoon measurements were taken. Field horses were fed at 05:30 in the morning, while treadmill horses were fed 30 min after the determination of $HR_{Resting}$. After placing the HR meters (HRMs) on the thorax of the horses they were left alone in their paddocks and all disturbances avoided. The HR was recorded for 15 min, and a 5-min section of the recording with steady signal was used to calculate the mean HR, representing $HR_{Resting}$. The HR was determined by auscultation for 1 min at the beginning of the 15-min period.

Morning and afternoon $HR_{Resting}$ were determined for the field horses on three consecutive days and for the treadmill horses on six consecutive days. The ambient temperature (°C) and relative humidity (%) were measured with commercial equipment and documented during the $HR_{Resting}$ measurements.

Heart rate measurement

Heart rate was determined by auscultation with a stethoscope placed on the left side of the horse's chest, just behind the elbow and with a commercial HRM (Polar S610, Polar Electro, Finland). These were attached to the thorax of the horses according to the manufacturer's instructions and recorded the HR at 5-s intervals. Gel was applied to improve the conductivity of the HR signal between the electrodes and the skin of the horses (F7 Gel, Gel Conductor Classic, Laboratorios FABOP, Buenos Aires, Argentina). The data recorded by HRM were transferred to a computer through an interface (Polar USB IR Interface, Polar Electro, Finland) for analysis by specialist software (Polar Equine SW, Version 4.02.036 H, Polar Electro, Finland).

v_4 (speed at which the blood lactate concentration is 4 mmol/L)

Six horses of the field group and the seven horses of the treadmill group were submitted to standardised submaximal exercise tests (SETs) to determine their v_4 at the beginning of the study. The horses of the field group performed the SETs on a sandy 1800 m circular field track and the treadmill horses on a treadmill (Mustang 2200, Kagra AG, Fahrwangen, Switzerland). Warm-up consisted of 5 min walking and 5 min trotting; the field horses were ridden.

The SET in the field consisted of a maximum of five rounds on the track at 5, 6, 7, 8 and 9 m/s, respectively. The SET on

Table 1 Horses examined | *Untersuchte Pferde*

Horse	Type of exercise	Breed	Gender	Age (years)	Withers height (cm)	Body weight (kg)	Competitive status
1	Field	PBA	Stallion	9	152	422	Competing
2	Field	PBA	Gelding	9	155	428	In preparation
3	Field	PBA	Gelding	8	148	425	In preparation
4	Field	PBA	Gelding	5	150	425	Competing
5	Field	PBA	Gelding	6	146	420	Competing
6	Field	AA	Mare	5	146	432	Competing
7	Field	PBA	Gelding	6	146	497	In preparation
8	Field	AA	Gelding	8	155	521	In preparation
9	Field	PBA	Gelding	7	150	445	Competing
10	Field	PBA	Gelding	8	154	472	In preparation
11	Field	3/4 BSH, 1/4 PBA	Mare	8	162	589	Competing
12	Field	PBA	Gelding	7	146	398	In preparation
13	Treadmill	PBA	Mare	2	139	336	In preparation
14	Treadmill	PBA	Mare	4	154	476	In preparation
15	Treadmill	PBA	Stallion	5	144	369	In preparation
16	Treadmill	PBA	Mare	2	147	406	In preparation
17	Treadmill	PBA	Gelding	8	152	457	In preparation
18	Treadmill	PBA	Mare	3	148	370	In preparation
19	Treadmill	PBA	Gelding	3	146	330	In preparation

PBA = Purebred Arabian AA = Anglo Arabian BSH = Brazilian Saddle Horse the treadmill was performed with the treadmill inclined at 6% after a warm-up on a 0% slope. The treadmill SET consisted of 5 min at each speed, starting at 4 m/s with subsequent steps increasing incrementally by 0.5 m/s.

The increase of the speed from round to round (field) and from step to step (treadmill) was such that a continuous increase in blood lactate concentration (LA) from the concentration before exercise but after warm-up to ≥ 4 mmol/L was obtained in not less than four intervals, so to obtain at least four values to describe the blood LA–running speed curve. The SETs were discontinued when the blood LA was ≥ 4 mmol/L (determined on site by Accusport™; Roche Diagnostics, Mannheim, Germany; *Lindner* 1996). The running speed in the field was determined with a stop-watch by dividing the distance run by the measured time. The treadmill had an integrated speedometer. Blood samples were drawn by puncture of the jugular vein prior to SET but after warm-up and as soon as possible after each round in the field, normally within 20 s. Horses continued exercising immediately after blood sampling. The treadmill was stopped for 60 s between steps to draw blood samples (within 15 s).

Blood samples were collected in Li-heparinised evacuated tubes (Becton Dickinson, Heidelberg, Germany). The horse's speed at which the blood LA reached 4 mmol/L was calculated by exponential regression analysis (*Galloux* 1991).

Data analysis

All analyses were run on Statview 5.0 (SAS, Cary, NC, USA). The normality of the data was confirmed using the Kolmogorov-Smirnov test. All data are expressed as means ± standard deviation (SD). The $HR_{Resting}$ determined by HRM was used for the data analysis when not stated otherwise. Multiple analysis of variance for repeated measurements was applied to determine the effect of day and time of the day on $HR_{Resting}$. When a significant F-ratio was achieved with the level of significance fixed at $P < 0.05$, post-hoc comparisons were carried out via Fisher's least-significance test to locate specific significant differences between days and between morning and afternoon. Pearson coefficient of correlation was calculated to examine the relationship between the $HR_{Resting}$ measured on the first day of the study and the age and v_4 of the horses. The same statistical method was applied to investigate the relationship between the $HR_{Resting}$ determined by auscultation and by HRM as well as between $HR_{Resting}$ and the ambient temperature and the relative humidity. $P < 0.05$ was set as the limit to denote significance.

Results

Resting HR in the morning and afternoon on consecutive days

The individual mean $HR_{Resting}$ of the 19 horses involved in this study measured by HRM was between 26.8 ± 3.76 and 42.0 ± 4.10 beats/minute in the morning and between 29.8 ± 2.99 and 47.7 ± 2.08 beats/min in the afternoon.

The mean $HR_{Resting}$ of all horses exercised on the treadmill changed significantly during the six consecutive days of measurement ($P = 0.001$; Figure 1), but there was no significant difference between the mean $HR_{Resting}$ in the morning and afternoon ($P > 0.05$). The mean $HR_{Resting}$ in the morning of day 1 was higher than on day 3 ($P = 0.015$) and was lower on days 2 and 3 than on days 4, 5 and 6 ($P = 0.05$–0.001). The mean $HR_{Resting}$ in the afternoon was lower on day 1 than on days 4, 5 and 6 ($P = 0.020$–0.041).

The mean $HR_{Resting}$ of the horses exercised in the field differed between days and between morning and afternoon ($P = 0.047$ and $P = 0.001$ respectively; Figure 2). The mean $HR_{Resting}$ was higher in the afternoon than in the morning ($P = 0.001$) and higher in the morning on day 1 than on day 2 ($P = 0.027$).

Effect of ambient temperature and relative humidity on $HR_{Resting}$

The ambient temperature varied between days, between 25 and 30 °C in the morning and between 29 and 32 °C in the afternoon for the horses in the treadmill group (29.0 ± 1.46 °C and 31.3 ± 0.24 °C in the morning and afternoon, respectively; $P = 0.001$). The relative humidity was between 60%

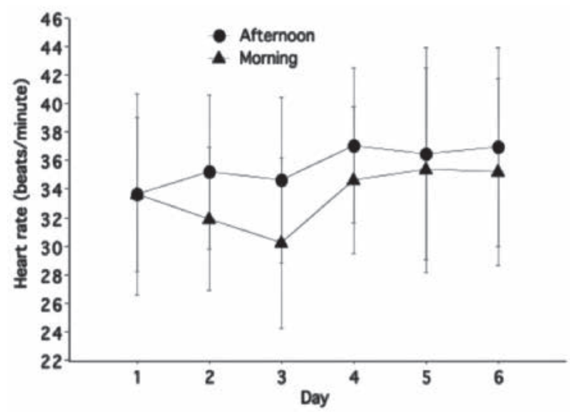

Fig. 1 Resting HR of horses in the morning and afternoon on six consecutive days (means ± SD; 7 horses, treadmill group) | *Herzfrequenz in Ruhe von Pferden morgens und nachmittags an sechs aufeinanderfolgenden Tagen (Mittelwert ± Standardabweichung; 7 Pferde, Laufbandgruppe)*

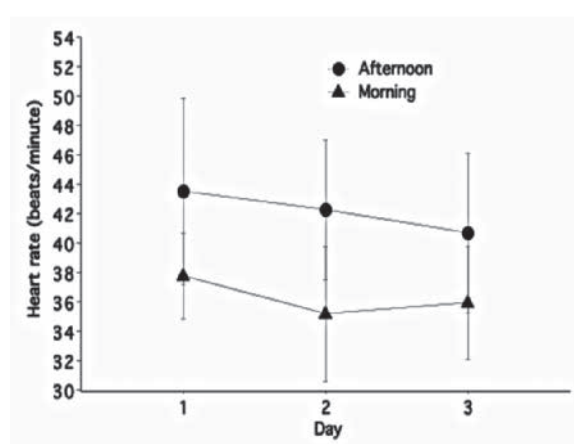

Fig. 2 Resting HR of horses in the morning and afternoon on three consecutive days (means ± SD; 12 horses, field group) | *Herzfrequenz in Ruhe von Pferden morgens und nachmittags an drei aufeinanderfolgenden Tagen (Mittelwert ± Standardabweichung; 12 Pferde, Feldgruppe)*

and 69% in the morning and between 39% and 57% in the afternoon (58.7 ± 1.49% and 44.4 ± 4.79% in the morning and afternoon, respectively; P = 0.001).

The ambient temperatures for the field group were between 20 and 27 °C in the morning and between 25 and 32 °C in the afternoon (24.6 ± 1.59 °C and 32.0 ± 0.00 °C, respectively; P = 0.001) while the relative humidity ranged between 66% and 84% in the morning and 44% and 80% in the afternoon (78.7 ± 1.52% and 48.0 ± 8.78%, respectively; P = 0.001).

The ambient temperature had a significant effect on the $HR_{Resting}$ values determined by HRM ($P = 0.024$; $r^2 = 0.09$; $n = 60$). The $HR_{Resting}$ increased with increasing temperatures. The relative humidity did not affect significantly the $HR_{Resting}$ determined by HRM ($P > 0.05$; $n = 60$). Neither ambient temperature nor relative humidity had a significant effect on $HR_{Resting}$ determined by auscultation (both $P > 0.05$; $n = 60$).

Relationship between $HR_{Resting}$ and age

There was no significant relationship between mean $HR_{Resting}$ in the morning or in the afternoon and the age of the horses (both $P > 0.05$; $n = 19$).

Relationship between $HR_{Resting}$ and v_4

The v_4 of each group of horses was not significantly related to the morning or the afternoon mean $HR_{Resting}$ (both $P > 0.05$).

Comparison of $HR_{Resting}$ measured by auscultation and HRM

The mean $HR_{Resting}$ determined by HRM was higher than the mean value determined by auscultation ($P = 0.0001$; difference between $HR_{Resting}$ by HRM and by auscultation = 1.90 ± 2.68 beats/minute; 60 measurements). Analysing these data separately between horse group and time of day did not yield a different result ($P < 0.05$ at least between HR measurements by auscultation and HRM).

The relationship between the values determined by both methods was significant ($P = 0.001$; $n = 60$; $r2 = 0.78$: Figure 3).

Discussion

This study examined the effect of several factors that could influence the $HR_{Resting}$ values of horses conditioned for endurance racing.

The mean $HR_{Resting}$ values determined were within those described in reference books on Equine Exercise Physiology for horses in general (*Jones* 1989, *Evans* 1994, *Babusci* and *Lopez* 2007). There are very few studies describing the mean $HR_{Resting}$ values of endurance racehorses (*Rose* et al. 1979, *Paull* et al. 1987). *Paull* et al. (1987) found the mean $HR_{Resting}$ of 53 competing endurance horses to be 41.4 beats/minute. *Rose* et al. (1979) observed that the first nine placed horses in a 100-km endurance race had a mean $HR_{Resting}$ of 32.0 beats/min while the mean value of the following nine horses was 35.2 beats/minute. This finding substantiates the comment of *Ridgway* (1989) that $HR_{Resting}$ plays an important role, among several others, in the selection of horses for endurance racing. Recently it was found that there is a large likelihood for the recovery HR to be related negatively to the $HR_{Resting}$ of endurance racehorses (the HR will recover faster after exercise when the $HR_{Resting}$ of a horse is lower; *Lindner* et al. 2020). This would mean that horses with a lower $HR_{Resting}$ could leave the vet gates during an endurance competition earlier than those with a higher $HR_{Resting}$ because they would reach the $HR_{Recovery}$ value fixed beforehand by the racing authorities within a shorter time, giving them a competitive advantage during endurance races.

The mean $HR_{Resting}$ values differed slightly but significantly between days in both horse groups. The ambient temperature and relative humidity also varied between days and at least the former had a significant effect on $HR_{Resting}$ in this study.

In both groups there was a marked difference between $HR_{Resting}$ values in the morning and in the afternoon; this was greater in the field group. The difference between the morning and afternoon ambient temperature and the relative humidity was also greater for the field group, which indicates the possible effect of both weather variables on $HR_{Resting}$. Certainly, the differences between morning and afternoon $HR_{Resting}$ values were influenced by an endogenous circadian rhythm as described by *Evans* et al. (1976) and confirmed by *Piccione* et al. (2005, 2009).

The age of the horses did not show a relationship to the $HR_{Resting}$ values, neither in the morning nor in the afternoon. The narrow range of age values may be the reason for this result because such a relationship has been reported previously (*Physick-Sheard* 1985, *Clayton* 1991). However, *Younes* et al. (2016) also did not observe such a relationship in purebred Arabian horses of 4–6 years old and neither did *Betros* et al. (2013), who compared a group of on average-12-year-old mares with a group of on average-22-year-olds. In contrast, *Visser* et al. (2012) describe a decrease in $HR_{Resting}$ in Warmblood Dutch riding horses, but these were growing horses, aged between 9 and 22 months. The discrepancies between findings may be accounted for by breed and age differences of the horses used in the studies.

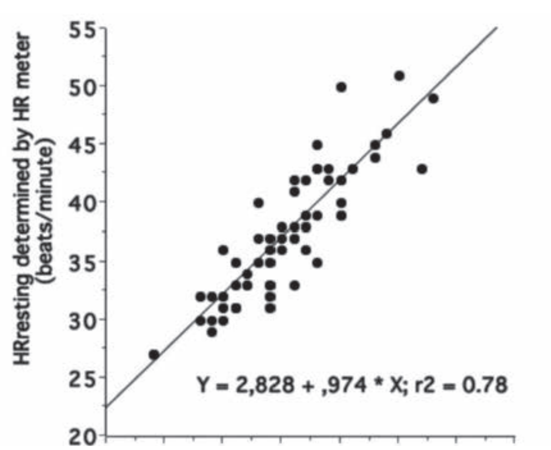

Fig. 3 Relationship between $HR_{Resting}$ determined by auscultation and HRM (P = 0.001; 60 data pairs) | *Beziehung zwischen der mittels Auskultation und Herzfrequenzmessgerät bestimmten Herzfrequenz in Ruhe von Pferden (P = 0.001; 60 Wertepaare)*

The v_4 of both horse groups was not significantly related to the morning or the afternoon mean $HR_{Resting}$ values. v_4 is the parameter that has most often been shown to be associated with the competitive performance of horses (*Lindner* 2010a), including endurance racing (*Demonceau* 1989, *Erickson* et al. 1990, *Lindner* 2010b, *Fraipont* et al. 2012). Therefore, it is likely that horses with a lower $HR_{Resting}$ are not fitter than those with a higher $HR_{Resting}$, but benefit from the system of fixed $HR_{Recovery}$ values in place in endurance racing (*FEI* 2017). These are arbitrary and penalise horses with a higher $HR_{Resting}$ during endurance competitions because it takes them longer to leave the veterinary inspection gates during a race. A relationship between $HR_{Resting}$ and endurance or overall fitness has not yet been found (*Bassan* and *Ott* 1968, *Wittke* et al. 1968, *Ehrlein* et al. 1970, *Skarda* et al. 1976). This system may not only be preventing fair competitive conditions for all horses, but may be compromising their health and welfare because the HR of horses with lower $HR_{Resting}$ may be able to recover sufficiently to continue competing despite their health already being compromised.

In this study, the mean $HR_{Resting}$ values determined by HRM were higher than the mean values determined by auscultation. The relationship between the values measured by each method was high, but the result showed that the method used to determine $HR_{Resting}$ must be considered and that they should not be interchanged. It was not expected that the $HR_{Resting}$ values determined by auscultation would be lower than those measured by HRM because it was assumed that a person standing by the horse during auscultation would yield a higher HR within 1 min than would an HRM placed on a horse left alone in a box for 15 min. A possibility is that the data collected by HRM showed higher values than actually were the case. This assumption is triggered by the finding of *Parker* et al. (2010) who compared the measurements from an HRM (a model newer than that used in this study) with those from an electrocardiogram recorder and found significant differences between the methods, with smaller differences the less the horses moved. However, a more recent study with apparently the same HRM as that used by *Parker* et al. (2010) did not corroborate their findings (*Ille* et al. 2014).

In conclusion, the determination of $HR_{Resting}$ of a horse should be based on a mean value determined after measurements on several consecutive days under as far as possible standardised conditions.

Conflict of interests

None

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Erweiterte Zusammenfassung

Die Ruheherzfrequenz von Distanzrennpferden beeinflussende Faktoren

Bei Distanzritt-Wettbewerben handelt es sich gemäß dem Reglement für Distanzreiten und -fahren um Ausdauerprüfungen für Pferde auf einer Geländestrecke von bestimmter Länge unter besonderer tierärztlicher Kontrolle (Verband Deutscher Distanzreiter und -fahrer *VDD* 2019). Diese Kontrolle findet vor, während und nach den Ritten statt und beinhaltet die Beurteilung von Herzfrequenz (HF), Kreislauf, metabolischem Zustand sowie Gangwerk. Pferde, die nicht reittauglich sind, werden vom Wettbewerb ausgeschlossen. Die Regeln der Fédération Équestre Internationale (*FEI* 2017) und des *VDD* fordern, dass Pferde, die je nach Klassifikation des Rittes nicht innerhalb einer bestimmten Zeit (20 bis 30 Minuten) nach Ankunft in festgelegten Untersuchungs- und Versorgungszonen (Vet Gates) eine bestimmte HF (maximal 64 Schläge pro Minute) aufweisen, vom Rennen disqualifiziert werden, um eine Gesundheitsgefährdung der Tiere zu vermeiden. Die Veterinär-Kommission kann diese maximale HF bei extremen Bedingungen vor oder während des Wettkampfes verringern oder die Erholungszeit verkürzen, wenn spezielle Bedingungen dies erfordern (*FEI* 2017). Obwohl die HF nur eines von zahlreichen Kriterien zur Bestimmung des Gesundheitszustandes eines Pferdes während eines Distanzrittes darstellt, hat diese Regelung – unterstützt durch die einfache und objektive Messbarkeit – dazu geführt, dass die im Vet Gate gemessene HF häufig als wichtigster Faktor zur Beurteilung der Reittauglichkeit gilt. Das hat zur Folge, dass Distanzrennpferde mittlerweile auf Grund niedriger Ruhe-Herzfrequenzen (HF_{Ruhe}) selektiert werden in der Annahme, dass sich bei ihnen die HF nach Belastung schneller erholt. Diese Annahme ist nach den Ergebnissen der Untersuchung von *Lindner* et al. (2020) wahrscheinlich. Zudem ist die HF_{Ruhe} beim Pferd genetisch definiert (*Loving* et al. 1993). Jedoch konnte bisher für das Pferd nicht der Nachweis erbracht werden, dass die HF_{Ruhe} mit der Ausdauer bzw. Fitness zusammenhängt (*Bassan* and *Ott* 1968, *Wittke* et al. 1968, *Ehrlein* et al. 1970, *Skarda* et al. 1976, *Lindner* et al. 2020). Für die Auswahl der Pferde mit niedrigerer HF_{Ruhe} spielt die Genauigkeit der Bestimmung eine wesentliche Rolle. Somit ist es wichtig, die Größenordnung des Einflusses verschiedener Faktoren auf die HF_{Ruhe} zu kennen. In dieser Arbeit wurden zu diesem Zweck die folgenden Faktoren geprüft, weil sie einen Einfluss auf die HF_{Ruhe} haben könnten: 1) Unterschiede zwischen unterschiedlichen Tagen; 2) Schwankungen zwischen morgens und abends; 3) Einfluss von Tagestemperatur und Luftfeuchtigkeit; 4) das Alter und die v_4 der Pferde (v_4 ist die Geschwindigkeit, bei der unter den gegebenen Bedingungen die Laktatkonzentration im Blut 4 mmol/L beträgt); 5) die Messmethode: Auskultation gegenüber HF-Messgerät. Von neunzehn Pferden im Alter von 2 bis 9 Jahren, die für Distanzrennen trainiert wurden oder schon an Wettkämpfen teilnahmen, wurde die HF_{Ruhe} bestimmt. 12 dieser Pferde wurden im Feld, 7 auf einem Laufband trainiert. Die HF_{Ruhe} wurde bei den Pferden der Laufbandgruppe morgens und abends an sechs aufeinander folgenden Tagen mit dem HF-Messgerät gemessen, bei den Pferden der Feldgruppe morgens und abends an drei aufeinander folgenden Tagen. Bei diesen Messungen wurden die Umgebungstemperatur und die Luftfeuchtigkeit protokolliert. Die Umgebungstemperatur schwankte bei der Laufbandgruppe morgens zwischen 25 °C und 30 °C und abends zwischen 29 °C und 32 °C, während sie bei der Feldgruppe morgens zwischen 20 °C und 27 °C und abends zwischen 25 °C und 32 °C lagen. Die Luftfeuchtigkeit betrug bei der Laufbandgruppe morgens zwischen 60 % und 69 % und abends zwischen 39 % und 57 %, bei der Feldgruppe morgens zwischen 66 % und 84 % und abends zwischen 44 % und 80 %. Bei sechzig Messungen mittels HF-Messgerät wurde zudem eine Minute lang die HF_{Ruhe} auch mit einem Phonendoskop bestimmt. Alle Pferde der Laufbandgruppe (sieben) und sechs der Feldgruppe wurden einem Belastungstest unterzogen, um deren v_4 zu bestimmen. Die v_4 ist der Parameter für den am häufigsten ein Zusammenhang zur Wettkampfleistung von Distanzrennpferden festgestellt worden ist (*Demonceau* 1989, *Erickson* et al. 1990, *Lindner* 2010b, *Fraipont* et al. 2012). Der standardisierte Belastungstest im Feld bestand aus fünf Runden à 1800 m mit zunehmender Geschwindigkeit je Runde unter dem Reiter (5, 6, 7, 8 und 9 m/s). Die Geschwindigkeiten der fünf Stufen auf dem Laufband entsprachen den Geschwindigkeiten im Feld, allerdings bei 6 % Steigung und ohne Reiter. Jede der fünf Stufen hatte eine Dauer von fünf Minuten. Vor einem Test wurden die Pferde etwa 15 Minuten lang im Schritt und im Trab aufgewärmt. Zwischen den Runden bzw. den Stufen wurden die Pferde bzw. das Laufband angehalten, um Blut aus der Vena jugularis per Punktion mit einer Einmalkanüle in ein mit Lithiumheparin beschichtetes Vakuumröhrchen zu füllen (meist innerhalb von 20 Sekunden nach Ende der Belastung). Aus der Beziehung zwischen der Blutlaktatkonzentration und der Laufgeschwindigkeit wurde mittels einer exponentiellen Regressionsgleichung die v_4 berechnet. Die HF_{Ruhe} 1) schwankte von Tag zu Tag signifikant ($P < 0{,}001$ für die Laufbandgruppe, $P = 0{,}047$ für die Feldgruppe; 2) war für die Laufbandgruppe morgens niedriger als abends ($P = 0{,}001$); 3) stieg mit zunehmender Tagestemperatur ($P = 0{,}024$) während sie die Luftfeuchtigkeit nicht beeinflusste; 4) hatte keine Beziehung zum Alter und zur v_4 der Pferde; 5) war gemessen mittels HF-Messgerät höher als mittels Auskultation ($P < 0{,}001$). Schlussfolgernd sollte die HF_{Ruhe} aus dem Mittelwert von Messwerten, die unter möglichst standardisierten Bedingungen an mehreren aufeinander folgenden Tagen gemessen wurden, gebildet werden. Zur Standardisierung gehören unbedingt der Zeitpunkt der Messung sowie die Messmethode. Erneut konnte keine Beziehung zwischen dem Parameter der Ausdauer v_4 und der HF_{Ruhe} festgestellt werden.

Schlüsselwörter: Pferd, Leistungsphysiologie, Alter, Tageszeit, Fitness, Beziehung, Temperatur, Schwankung