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\textsubscript{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\textsubscript{Resting}: auscultation or heart rate meter (HRM). Methods: The HR\textsubscript{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\textsubscript{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\textsubscript{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

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 Any horse deemed unfit to continue (due to lameness or HR not recovering as expected, for example) is withdrawn from the event.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\textsubscript{Resting}) of horses (Lindner et al. 2020) supporting the long-established routine of selecting horses with low HR\textsubscript{Resting} to compete in endurance racing. This study was carried out to understand better how diverse factors may influence HR\textsubscript{Resting} in endurance horses and to improve their selection based on this variable. The variability in the HR\textsubscript{Resting} of horses between and within days, and the effects of age and the variance 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\textsubscript{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

| 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
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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 stopwatch 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 v₄ 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 measure-ment (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%
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The mean HRRest ing determined by HRM was higher than the morning or the afternoon and the age of the horses (both P > 0.05; n = 60). The HRRest ing increased with increasing temperatures. The relative humidity did not affect significantly the HRRest ing determined by HRM (P > 0.05; n = 60). Neither ambient temperature nor relative humidity had a significant effect on HRRest ing determined by auscultation (both P > 0.05; n = 60).

Relationship between HRRest ing and age

There was no significant relationship between mean HRRest ing in the morning or in the afternoon and the age of the horses (both P > 0.05; n = 19).

Relationship between HRRest ing and v4

The v4 of each group of horses was not significantly related to the morning or the afternoon mean HRRest ing (both P > 0.05).

Comparison of HRRest ing measured by auscultation and HRM

The mean HRRest ing determined by HRM was higher than the mean value determined by auscultation (P = 0.0001; difference between HRRest ing by HRM and by ausculta tion = 1.90 ± 2.68 beats/minute; 60 measurements). Analys ing 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 HRRest ing values of horses conditioned for endurance racing.

The mean HRRest ing 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 HRRest ing values of endurance racehorses (Rose et al. 1979, Paull et al. 1987). Paull et al. (1987) found the mean HRRest ing 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 HRRest ing 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 HRRest ing 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 HRRest ing of endurance racehorses (the HR will recover faster after exercise when the HRRest ing of a horse is lower; Lindner et al. 2020). This would mean that horses with a lower HRRest ing could leave the vet gates during an endurance competition earlier than those with a higher HRRest ing because they would reach the HRecovery value fixed beforehand by the racing authorities within a shorter time, giving them a competitive advantage during endurance races.

The mean HRRest ing 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 HRRest ing in this study.

In both groups there was a marked difference between HRRest ing 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 HRRest ing. Certainly, the differences between morning and afternoon HRRest ing 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 HRRest ing 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 HRRest ing 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.
The v4 of both horse groups was not significantly related to the morning or the afternoon mean HR_{resting} values. v4 is the parameter that has most often been shown to be associated with the competitive performance of horses (Lindner 2010a), including endurance racing (Demanceau 1989, Erickson et al. 1990, Lindner 2010b, Frappont 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 they take 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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Die Ruheherzfrequenz von Distanzrennpferden beeinflussende Faktoren

Bei Distanzritt-Wettbewerben handelt es sich gemäß dem Reglement für Distanzrennen und -fahnen um Ausdauerpferde für Pferde auf einer Geländestrecke von bestimmter Länge unter besonderer tierärztlicher Kontrolle (Verband Deutscher Distanzreiter und -fahrer VDD) festgelegt. 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 reitfähig sind, werden vom Wettbewerb ausgeschlossen. Die Regeln der Fédération Équestre Internationale (FEI) 2017 und des VDD fordern, dass Pferde, die je nach Klassifizierung 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 Distanzrennerprüfung anhand niedriger Ruhe-Herzfrequenzen (HF_{Ruhe}) selektiert werden werden in der Annahme, dass sich die maximale HF mit zunehmender Tagestemperatur (P = 0,024) während sie die Luftfeuchtigkeit nicht beeinflusste; 4) hatte keine Beziehung zum Alter und zur v4 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 v4 und der HF_{Ruhe} festgestellt werden.

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