Original Research

Competition Horses Housed in Single Stalls (II): Effects of Free Exercise on the Behavior in the Stable, the Behavior during Training, and the Degree of Stress

Hanna Werhahn MSc, Engel F. Hessel Prof Dr, Herman F.A. Van den Weghe Prof Dr Ir

Division of Process Engineering, Department of Animal Sciences, Georg-August-University of Goettingen, Vechta, Germany

1. Introduction

Free-ranging horses spend up to 16 hours a day foraging, which generally happens with a slow and steady walk [1,2]. They also spend their whole lives in (family) bands with a constant social hierarchy [3,4]. Although housing horses in single stalls limits their natural behavior to a great extent (especially exercise and social behavior), this housing system is widespread in Germany, especially for competition horses. Free exercise on pastures or dry lots can improve the degree of animal welfare in the system [5], but allowing it is not taken for granted by many horse keepers [6]. Particularly, competition horses can be worth a lot of money; therefore, the most frequent reason for not allowing free exercise is the risk of injury [7,8]. Some riders also fear that free exercise might decrease performance in sport. Nevertheless, preventing horses’ natural requirement for exercise most likely poses a stressful situation for them.

The conventional way to get information on animal welfare is the analysis of animal behavior. In the absence of

ARTICLE INFO

Article history:
Received 22 March 2011
Received in revised form
06 May 2011
Accepted 14 June 2011
Available online 27 July 2011

Keywords:
Horse
Turnout
Single stall
Behavior
HRV

ABSTRACT

Although housing horses in single stalls limits their natural behavior to a great extent, this housing system is widespread in Germany, especially for competition horses. To improve the welfare of this system, free exercise on pastures or paddocks is deemed suitable, but it is also feared because of injuries and decreased willingness or motivation to perform. In the present study, three treatments were investigated with regard to their effect on the behavior of six competition horses in the stable, behavior during training, and on their degree of stress: daily training without free exercise (no turnout [NT]), solitary turnout for 2 hours after training, and 2-hour turnout in groups of two after training (group turnout). The horses’ behavior in the stable was continuously analyzed through video recordings (2 PM to 6 AM) on 3 days at the end of each treatment. The degree of stress was evaluated daily by heart rate variability at rest. The behavior during training was evaluated by a questionnaire answered by the riders, and the distance covered during training was measured by global positioning system. When NT was allowed, the horses showed less lying in the stable compared with the treatments with turnout. Heart rate variability measurements resulted in great individual differences, but generally, there was a higher degree of stress shown with the treatment NT according to the following parameters: standard deviation of inter-beat-intervals (SDNN), square root of the mean of the sum of the squares of differences between successive inter-beat-intervals (RMSSD), and ratio between low frequency and high frequency (LF/HF). The willingness to perform was evaluated as being slightly better in the treatments with turnout than in the treatment without turnout.
illness, behavior patterns (regarding locomotion, social interactions, ingestion, resting, etc.) are supposed to be performed as closely as possible to an animal’s behavior under natural conditions [9]. Deviations from the natural or normal behavior of individual horses, which are caused by the changes in the environment, are able to reveal valuable indications of animal welfare [10]. In the past 15 years, measuring heart rate variability (HRV) has become an accepted method for evaluating the degree of stress in organisms caused by disease or physical or mental strain [11]. Although developed in the field of human medicine, this technique has also been used to evaluate stress in animals in the recent years, including horses [12-14]. The analysis of HRV is based on the irregular time intervals between consecutive heart beats regulated by the autonomic nervous system. The primary pulse generator for heart beats, the sinoatrial node, is under control of the parasympathetic (vagal; high frequency impulse) and sympathetic (low frequency impulse) nervous systems. At rest, both branches of the autonomic nervous system are active, with a dominance of vagal regulation. Irregular time intervals between consecutive heart beats (great HRV) characterize the physiological and psychological flexibility of an organism and are, therefore, an indicator of its ability to respond to stress. Because of the great importance of stress in animal welfare, HRV is an adequate tool to evaluate the effect of defined situations on an animal’s well-being [11].

The aim of the present study was a systematic investigation of the effects of the prevention of free exercise and social interactions on the behavior in the stable, behavior during turnout and training, and on the degree of stress in competition horses under conditions of practice. Therefore, multiple parameters of behavior and stress measured in six horses housed in single stalls were analyzed in three treatments, varying in the configuration of free exercise. Changes between the treatments within the horses were the focus of the study instead of differences between the horses. Comparing different horses with each other is of little information because of the individual experiences in horse’s upbringing, housing, treatment, training, and so forth, before becoming a competition horse. Because they are widely used in Germany, the following management practices were selected: daily training without additional free exercise (no turnout [NT]), free exercise in groups of two horses after training (group turnout [GT]), and free exercise separately after training (solitary turnout [ST]).

The present article focuses on the degree of stress and behavior in the stable and during training. The effect of the treatments is evaluated with regard to animal welfare to provide indications on how the single-stall housing system may be improved.

2. Materials and Methods

2.1. Location of the Study

The research was carried out in a training and competition yard in Noerten-Hardenberg (County of Northeim, Lower Saxony, Germany) in the period between June 7, 2010, and July 18, 2010. The stable contained 16 single stalls (3.00 m × 3.50 m, 10.5 m²) in two rows, with an aisle (width: 4 m) in the middle (Fig. 1). The stalls were 0.20 m deeper than the aisle and were separated by 1.30-m hardwood walls with 1-m vertical lattice bars on top (distance between bars: 6 cm). The fronts had sliding doors (width: 1.50 m) consisting of the same material. The lattice bars of the doors had windows (width: 0.70 m) allowing the horses to put their heads into the aisle. These windows were open all the time during the investigation. The brick walls of the stable formed the back of the stalls. The stable ceiling height was 3 m. Along the southern side of the stable, 17 windows (0.70 m × 1.20 m, 0.84 m²) at a height of 1.50 m and with a distance of 1.20 m provided light and ventilation (windows were left slightly open). Two doors (3 m × 3 m, 9 m²) at the ends of the aisle were open during the day and closed at night between 10 PM and 6 AM. Each stall was equipped with a feeding trough for concentrates and an automatic drinking bowl. Six stalls situated next to each other were used for the investigation (Fig. 1). All the stalls in the stable had horses in them, and the horse next to horse 6 did not change during the investigation.

The pasture (60 m × 90 m, 5400 m²) was located about 300 m southwest of the stable. For the investigation, the area was divided into three paddocks, each sized 30 m × 60 m (1800 m²), using electrical fences. This size gave the horses enough space for free exercise in walking, trotting, and cantering (German guidelines advise at least 150 m² for two horses [15]).

2.2. Animals

Six German Warmblood Horses (height: between 1.65 and 1.75 m; weight: between 600 and 650 kg) were used.
for the investigation. All six horses were schooled in dressage and show jumping, and were deployed in competitions in one of these disciplines at prenovice to advanced class. Horse 1 (H1) was a 4-year-old Hanoverian mare, horse 2 (H2) was a 6-year-old Hanoverian gelding, horse 3 (H3) was a 7-year-old Holstein gelding, horse 4 (H4) was a 10-year-old Hanoverian gelding, horse 5 (H5) was a 4-year-old Hanoverian gelding, and horse 6 (H6) was a 6-year-old Hanoverian gelding. These horses were selected because they were of similar age, available for the whole study (not for sale within the time of the study), trained by one rider, and their owners agreed that they passed all three treatments.

All six horses were moved into their experimental stalls 2 weeks before the investigation was started. They were accommodated in six stalls next to each other, and the experimental group partners were kept in neighboring stalls. They were used to having free exercise three to four times a week on pasture or paddock (both on their own and with their experimental group partner for 1 to 2 hours). The riders were asked to retain their method of training during the investigation according to their normal routine. Because the method of training was not standardized, duration of the training varied (between 21 and 65 minutes).

2.3. Bedding Materials and Feed

The experimental stalls were strewn with wheat straw. New straw (approximately 10 kg/stall) was given every morning after feeding, and the stalls were mucked out only once every 4 weeks.

Oats and muesli (Torneo Muesli, onOvo GmbH, Hannoversch Münden, Germany) were fed three times a day (6 AM, 12 PM, 4 PM). At 12 PM, 50 g of mineral feed (Torneo Mineral, onOvo GmbH, Hannoversch Münden, Germany) was added to the concentrates. H1 received 1.3 kg of muesli three times a day, whereas all other horses received 1 kg of oats at 6 AM and 4 PM, and 0.5 kg of oats and 0.7 kg of muesli at 12 PM. Hay was given in the morning and in the afternoon before the concentrates. H3 received 4 kg of hay at any one time, whereas all other horses received 5 kg. The amount of feed, feeding quality, and type remained constant over the course of the experiments. Water was available in the stable at all times for each individual horse.

2.4. Measurement Techniques

2.4.1. Behavior in the Stable

Three video cameras (Panasonic CCTV WV-BP 310, Panasonic Corporation, Kadoma, Osaka, Japan) were fixed underneath the ceiling opposite to the experimental stalls (Fig. 1); thus, each camera recorded the behavior of two horses. To allow recording at night, infrared light sources were fixed underneath the ceiling within each stall. The videos were recorded in digital format using a Noldus MPEG Recorder 2.1 (Noldus Information Technology, Wageningen, The Netherlands). A computer to record data (Dell Precision T3400 Workstation, Dell Inc., Round Rock, TX) and a monitor screen to control recordings were located in a metal box within the stable (Fig. 1). The recordings were stored daily on external hard disks. Subsequently, the data were analyzed using the Observer XT 9.0 (Noldus Information Technology, Wageningen, The Netherlands).

2.4.2. Heart Rate Variability

Six Polar Equine RS800CX Science devices (Polar Electro Oy, Kempele, Finland) were used to measure the HRV of the horses at rest. The devices consisted of a measuring girth containing two electrodes, a sender fixed on the girth, and a receiver. The receiver was located in a pocket fixed on an ordinary blanket girth. Each horse was equipped with a measuring girth and a blanket girth carrying the receiver daily from about 9 PM until 8 AM. For better conduction of the electric potential of the heart action from the body surface, the horse’s coat underneath the electrodes was wetted using ultrasound gel. The girths were padded in the area of the withers to avoid physical irritation. After measurement, the data were read out and stored using the software program Polar ProTrainer Equine Edition (Polar Electro Oy, Kempele, Finland).

2.4.3. Distance Covered During Training

Four global positioning system (GPS) devices (Garmin Forerunner 205; Garmin, Olathe, KS) were used to record the distance covered and the duration of training. The devices were fixed around the riders’ wrists. The measurements were started when the horse and rider left the stable for training and were stopped when they returned to the stable. After training, the data were read out and stored using the software program Garmin Training Center (Garmin, Olathe, KS).

2.4.4. Behavior During Training

The riders registered the horses’ behavior during training with the aid of a questionnaire. The horses’ behavior during the working phase of training (answer possibilities: particularly quiet, rather quiet, normal, rather agitated, particularly agitated), its concentration (answer possibilities: particularly good, rather good, normal, rather bad, particularly bad), contumacy (bucking, rearing, working against the rider, etc; answer possibilities: particularly little, rather little, normal, rather intense, particularly intense), and the horse’s urge to move (answer possibilities: particularly low, rather low, normal, rather strong, particularly strong) had to be described. The riders were asked to compare each horse’s behavior during training in each of the respective treatments with the horse’s previous behavior during training. For organizational reasons, it was not possible to blind the riders to the treatments. Training was carried out by three experienced riders (one rider trained H1, H2, H3, and H5; one trained H4; one trained H6), who also presented the horses at competitions. To retain the experimental rhythm of the day, the riders sometimes had to swap horses (eg, if a rider had no time to ride in the morning, one of the other riders trained the horse). To avoid differences in evaluation within the horses caused by different riders, only evaluations of the “main” rider of each horse were considered in the final analysis.

2.4.5. Temperature and Relative Humidity

During the experiments, two Tinytag Plus 2 loggers (Gemini Data Loggers Ltd., Chichester, UK) recorded air temperature and relative humidity after every hour, outside and within the stable.
2.5. Experimental Design

The study was carried out under conditions of practice because results of absolutely standardized conditions in relation to this topic cannot be transferred to practice and therefore are of little information. The whole investigation took 6 weeks and was divided into three 2-week periods. The experimental horses were also arranged into three groups (group 1 = H1 and H2; group 2 = H3 and H4; group 3 = H5 and H6). During the investigation, all six horses passed through each of the three treatments; each treatment lasted for 2 weeks. In the first treatment, free exercise was allowed after training for 2 hours in groups of two horses (GT); in the second treatment, solitary turnout (ST: one horse per pasture) was allowed for 2 hours after training (ST); and in the third treatment, no free exercise was allowed in addition to training (NT). Group 1 started with ST, then was subjected to GT, and then to NT. Group 2 was given NT at first, then ST, and then GT. Group 3 started with GT, then was subjected to NT, and then to ST (Table 1).

Training was carried out according to the horses’ individual training schedule between 8 AM and 11 AM, with the aim to achieve better performance at competition. Training was not standardized because this would have been against the practice, putting the horses behind their individual training penum, and thereby causing a financial loss for the owners if they offered their horses for sale. After training, between 11 AM and 2 PM, free exercise on pasture was allowed according to the respective treatment. In the treatments with turnout, the mid-day feeding was given after turnout. Depending on the particular time of training, the horses spent 30 to 120 minutes within their stalls between training and turnout.

2.6. Data Collection

The data were collected daily from Monday to Friday. No data were collected on Saturdays and Sundays because most of the experimental horses participated in competitions on one of the days, within the region around the stable (thus, they did not stay overnight). On the days of competition, free exercise was given according to the treatment given to the horses at the time. The exact time of day for training and turnout sometimes differed from the experimental times on Mondays to Fridays. The day after competition was always excluded from the analysis.

2.6.1. Behavior in the Stable

Video recordings of the horses’ behavior in the stalls were analyzed on three consecutive days of each period of the investigation. Because the horses were supposed to be acclimatized to the treatment, the days at the end of the second week were chosen for behavior observation. The observations were carried out continuously by one person (who also carried out the experiment) between 2 PM and 6 AM the next morning (16 hours), while all the horses were in their stalls. Frequency, mean duration per appearance, and total duration within the observation time were documented for each recorded type of behavior.

The observed behaviors were grouped into the following five categories: “eating” (hay and concentrates), “standing alert” (watching the surroundings attentively or nervously), “occupation” (investigating/eating bedding material, drinking, investigating stall equipment like trough, grits, drinking bowl, etc), “dozing” (stand quietly, one hind leg relaxed), and “lying” (sternal and lateral recumbency). Additionally, the frequency of “locomotion” (more than three steps without interruption) was recorded.

2.6.2. Heart Rate Variability

To estimate HRV, the inter-beat-interval data of four (the least common denominator of lying periods per night) 5-minute intervals from different periods of recumbency between midnight and 5 AM were selected and analyzed for each horse and each night. The 5-minute intervals were chosen in the middle of the periods of recumbency (mean duration: 29.07 minutes) when the horse was lying quietly.

To ensure a correct interpretation of the measurements, it is advised to analyze more than one parameter [16]. The following HRV parameters were quantified in the present study: two time domain parameters, standard deviation of inter-beat-intervals (SDNN) in ms (indicates general variability) and square root of the mean of the sum of the squares of differences between successive inter-beat-intervals (RMSSD) in ms (indicates vagal activity), and one frequency domain parameter LF/HF (ratio between low frequency [LF, ms²] and high frequency [HF, ms²] content of the inter-beat-interval-signal; indicates sympathovagal balance of regulation). The normal values for LF/HF range between 1.5 and 2.0. Because the parameters SDNN and RMSSD vary widely, normal values have not been defined [16].

The software program Kubios HRV (Biosignal Analysis and Medical Imaging Group, Kuopio, Finland) was used to calculate the chosen parameters. Artifact correction was adjusted at 0.5 seconds (ie, intervals deviating >50% from the previous interval were deleted) and interpolation rate was set at 2 Hz. The frequency band ranges were set from 0.01 to 0.07 Hz for LF and from 0.07 to 0.6 Hz for HF according to the recommendations of Kuwahara et al. [17] for HRV analysis in horses. The mean values of the aforementioned parameters were calculated per horse and per night, and these were used for statistical analysis.

2.6.3. Behavior and Distance Covered During Training

To create more concrete statements about the horses’ willingness to perform out of the differentiated answers given in the questionnaire, the riders’ answers about the horses’ behavior during the working phase, concentration, and contumacy were summarized into the feature “willingness to perform.” In addition to the questionnaire, the distance covered during training and the total duration of training were documented by the GPS devices. This was

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Experimental design</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Period of Time</strong></td>
<td><strong>Group 1 (Horses 1 + 2)</strong></td>
</tr>
<tr>
<td>Period 1 (weeks 1 + 2)</td>
<td>ST</td>
</tr>
<tr>
<td>Period 2 (weeks 3 + 4)</td>
<td>GT</td>
</tr>
<tr>
<td>Period 3 (weeks 5 + 6)</td>
<td>NT</td>
</tr>
</tbody>
</table>

NT, no turnout; ST, solitary turnout; GT, group turnout.
conducted to get an indication on the amount of exercise provided by training.

2.6.4. Temperature and Relative Humidity

The air temperature and relative humidity values were averaged according to the focus of the analysis. For the video observations, the values measured within the stable were averaged over the observation time (2 PM to 6 AM). For the HRV data, the temperature and relative humidity measured within the stable were averaged over night (9 PM to 6 AM). For the GPS data and behavior during training, the values measured outside the stable were averaged over the period of training (8 AM to 11 AM).

2.7. Statistical Analysis

The statistical evaluation of the data was carried out with the software program SAS 9.1 (SAS Institute Inc., Cary, NC).

The video observations resulted in values for the parameters total duration, frequency, and mean duration per appearance for the behaviors “eating,” “occupation,” “standing alert,” “dozing,” and “lying.” Because “locomotion” only occurred briefly, only frequency was recorded. If the data sets were not available in Gaussian distributions, they were transformed by taking the logarithm. The analysis of variance was computed by general linear model (GLM) procedure considering the random effect of the horse, the fixed effect of the treatment, and the interaction between horse and treatment (for all behaviors except for “locomotion”). The fixed effect of the period had no significant influence on the variables and thus was not included in the model. For the behavior “locomotion,” the random effect of the horse and the fixed effects of the period and of the treatment within the period were considered. The interaction between horse and treatment had no significant influence on the variable and thus was not included in the model. For all the behaviors, temperature and relative humidity were taken into account as covariates. In total, the video observations created 54 data sets (3 days in three treatments for six horses).

The HRV was measured 180 times (six horses on 30 days) in total and resulted in 131 analyzable data sets (19 measurements in ST, 13 in GT, and 17 in NT could not be analyzed because of technical problems). To create a Gaussian distribution, the logarithm of the SDNN data was taken. For the parameters RMSSD and LF/HF, the logarithm was taken twice to generate Gaussian distributions. The GLM procedure was used utilizing the same model values between .05 and .1 were seen as tendencies (t-test). If not explicitly indicated, the first 3 days of the treatments were not taken into account. This was done to reduce the effect of the previous treatment on the present treatment.

3. Results

During the investigation, the air temperature within the stable (averaged between 2 PM and 6 AM) varied between 18°C and 28°C, and the relative humidity varied between 53% and 67% (period 1: 18°C to 22°C and 53% to 63%; period 2: 24°C to 28°C and 57% to 63%; period 3: 22°C to 28°C and 54% to 67%). Outside the stable, the temperature (averaged between 8 PM and 11 PM) varied between 12°C and 29°C and the relative humidity varied between 51% and 88% (period 1: 15°C to 22°C and 51% to 88%; period 2: 12°C to 27°C and 58% to 80%; period 3: 17°C to 29°C and 54% to 85%).

3.1. Behavior in the Stable

The individual horse had a significant influence (P < .05) on the parameters total duration, frequency, and mean duration per appearance in all behaviors except for the frequency of “standing alert.”

The total duration of the horses’ behavior in the stable during the daily observation time (2 PM to 6 AM) is presented in Figure 2. The treatments resulted in significant differences in the time budgets. If turnout was allowed in groups (GT), the total duration of “occupation” was significantly shorter than in the treatment NT (P = .0037). In the treatment ST, the total duration of this behavior was between the other treatments without any significant difference. The behavior “lying” was performed significantly longer in the treatment GT compared with NT (P = .0165). The total duration of “lying” in ST was again between the other treatments without any significant difference. No significant differences could be found between the treatments in total duration of the behaviors “standing alert,” “dozing,” and “eating.” The interaction between horse and treatment had a significant influence on “lying” and “standing alert” (P ≤ .05). The total duration of the behaviors was not significantly influenced by either the temperature or relative humidity.
“Occupation” was observed significantly more frequently in NT than in GT \((P = .0211)\), and “lying” was observed significantly more frequently in GT than in NT \((P = .0239; \text{Table } 2)\). The frequency of the behavior “lying” was significantly influenced by temperature \((P = .0340)\): the higher the temperature, the less frequently “lying” was performed. In “locomotion,” the period had a significant influence on the frequency of appearance. It was performed most frequently during period 3 (58.42 times). In period 1, “locomotion” was performed significantly more frequently in NT (45.58 times) than in GT (25.57 times; \(P = .0195)\), whereas the treatments did not differ significantly during periods 2 and 4. All the other behaviors did not show any significant differences in frequency. Figure 3 presents the development of the frequency of “locomotion.” Between 2 PM and 8 PM, the frequency in GT varied to a considerably greater degree and was mostly lower than in ST and NT. From 8 PM onward, “locomotion” decreased and hardly differed between the treatments. Between 5 AM and 6 AM, “locomotion” increased again in all the three treatments.

The behaviors’ mean duration per appearance did not differ significantly between the treatments (Table 2). “Lying” was significantly influenced by the relative humidity: the higher the relative humidity, the longer was the mean duration of “lying” \((P = .0273)\).

### Table 2

<table>
<thead>
<tr>
<th>Behaviour</th>
<th>Treatment</th>
<th>n</th>
<th>Frequency</th>
<th>Mean Duration (Minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>LSM</td>
<td>SE</td>
</tr>
<tr>
<td>Occupation</td>
<td>ST</td>
<td>18</td>
<td>22.45&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>1.23</td>
</tr>
<tr>
<td></td>
<td>GT</td>
<td>18</td>
<td>20.69&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.20</td>
</tr>
<tr>
<td></td>
<td>NT</td>
<td>18</td>
<td>24.59&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.23</td>
</tr>
<tr>
<td>Lying</td>
<td>ST</td>
<td>18</td>
<td>4.69&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td>GT</td>
<td>18</td>
<td>5.48&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td>NT</td>
<td>18</td>
<td>4.94&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>0.23</td>
</tr>
</tbody>
</table>

NT, no turnout; ST, solitary turnout; GT, group turnout; n, number of values; LSM, least squares means; SE, standard error.

<sup>a,b</sup>Least squares means within a behavior with different letters are significantly different \((P < .05)\).

### 3.2. Heart Rate Variability

The HRV analysis revealed differences in the degree of stress between the treatments (Fig. 4). The treatments with turnout did not differ significantly in any of the three parameters (SDNN, RMSSD, and LF/HF), and the values describing the greatest degree of stress were always found when NT was allowed. The SDNN revealed a significantly lower value (indicating lower HRV and therefore a greater degree of stress) in NT compared with turnout in groups (GT; \(P = .0466\)). The vagal regulatory activity (RMSSD) in the treatment NT tended to be lower (indicating a lower HRV) than in both treatments with turnout (ST; \(P = .0707\); GT; \(P = .0632\)). The values of LF/HF ranged from 2.21 (GT) to 2.56 (NT) and did not show any significant differences. SDNN was significantly higher when the temperature was higher \((P = .0254)\), whereas the LF/HF was significantly higher when the relative humidity was higher \((P = .0202)\).

The individual horse had a significant influence on all parameters. H6 showed the lowest value for SDNN when ST was allowed (GT: \(P = .0062\); NT: \(P = .0528\) ) and had showed considerably higher values in general for LF/HF (averaged by treatments: 4.91 to 5.05) compared with the other horses (0.34 to 3.45). The lowest values for LF/HF were found in H1 and H5 (0.34 to 1.48).

Figure 5 shows the development of the parameters during the course of the treatments. The lowest values for SDNN and RMSSD were found during week 2 in the treatment without turnout (NT; days 7 to 10 for SDNN and days 6 to 9 for RMSSD). The values for LF/HF varied to a great extent in all three treatments.

Some other correlations were also found. The higher the temperature \((r = 0.27; P = .0089)\) and relative humidity \((r = 0.33; P = .0017)\), the higher was the LF/HF value; the higher the value of SDNN, the higher was the value of RMSSD \((r = 0.78; P < .0001)\); and the higher the value of RMSSD, the lower the LF/HF \((r = -0.58; P < .0001)\).

### 3.3. Behavior and Distance Covered During Training

Table 3 shows the horses’ willingness to perform, urge to move, the distance covered, and the duration of training in the treatments. The treatments were not significantly different in any of these parameters. The individual horse...
had a significant influence on the distance covered, the average speed, and the duration of training \((P < .01)\). When the temperature was lower, the average speed was higher \((P = .0124)\), whereas the distance covered and the duration of training were longer \((P = .0015\) and \(P = .0486\), respectively). When the relative humidity was lower, the distance covered was longer and the average speed was higher \((P = .0273\) and \(P = .0091\), respectively). The duration of training was longest in GT, a little shorter in NT, and the shortest in ST. The distance covered was longest in GT and almost the same in ST and NT. The horses’ willingness to perform was evaluated as being worst in the treatment NT.

The scores in ST and GT hardly differed from each other. The urge to move was highest in the treatment GT; ST and NT hardly differed. The correlation analyses revealed a relationship between duration of training and distance covered \((r = 0.74; P < .0001)\) and another between distance covered and average speed \((r = 0.66; P < .0001)\). The willingness to perform was evaluated as being better when the duration of training was longer \((r = 0.30; P = .0058)\). The urge to move tended to be higher when temperature was lower \((r = -0.19; P = .0840)\).

Regarding the individual horses, sporadic relationships were found. The urge to move was higher when temperature was lower in H3 \((r = -0.57; P = .0205)\) and H5 \((r = -0.47; P = .0492)\). When the relative humidity was higher, the urge to move was higher in H4 \((r = 0.50; P = .0566)\), H5 \((r = 0.64; P = .0043)\), and H6 \((r = 0.51; P = .0722)\). H4 also had a lower average speed when the relative humidity was higher \((r = 0.72; P = .0023)\). H1
showed better willingness to perform when the urge to move was lower ($r = 0.58; P = .0489$).

4. Discussion

4.1. Behavior in the Stable

The total duration of the observed behaviors (Fig. 2) shows that the horses spent most of their time in the stall “standing alert,” “standing occupied,” or “dozing.” In the present study, these behaviors were performed 66% to 71% of the observation time. Similar results have been documented in earlier studies [1,18,19]. The absolute time spent “lying” (2.1 to 2.5 hours) matches the findings of Littlejohn and Munro [20] and is a little less than the results of Kiley-Worthington [2] and Werhahn et al. [21]. This might have been caused by the selected observation time as the horses sometimes showed periods of “lying” after 6 AM. The total duration of “lying” and “occupation” was influenced by the treatment. These behaviors seem to be complementary. The more “lying” was performed, the less “occupation” was observed and vice versa. The shortest time “lying” and the longest time “occupation” were observed in the treatment NT. In group housing, Caanitz et al. [22] also observed less lying in nonexercised horses compared with exercised horses and interpreted this finding as compensating for the energy expended during exercise. In the present study, the lack of exercise on pasture in the treatment NT might have caused the decrease in the time spent “lying.” The time spent “occupied” might have been increased because the horses were not able to graze and occupy themselves in general on pasture, and thus were more occupied in the stall. They also might have ingested more straw because they were not able to graze. Heleski et al. [23] observed more time spent lying in the weanlings housed in single stalls than in group-housing systems. It was supposed that this observation was caused by a lack of activity and/or boredom in single housing on the one hand, and by more privacy to rest (especially in low-ranking animals) on the other.

Because studies revealed that the prevention of exercise leads to unspent energy and therefore to more restlessness [24,25], it was expected that the horses would perform more “locomotion” in the treatment without turnout. This was only observed within period 1. Generally, most “locomotion” was shown in period 3 of the investigation. Although the temperature in periods 2 and 3 was higher than in period 1, a clear interpretation of this observation is not possible from the available data. The development of locomotion during the course of the observation time decreased considerably in all three treatments from 8 PM onward (Fig. 3). Around that time, regular business in the stable and the entire yard was finished. Additionally, the horses had finished their hay and therefore resting behavior might have gained in importance. Around 5:30 AM, morning business started in the yard which might have led to the increase of locomotion as the horses were waiting for their feed.

In an earlier study [21], a more restless behavior was observed in horses when NT was allowed. This was revealed by more frequent changes between the behaviors and more frequent aggression against the neighboring horses. In the present investigation, this reaction was also expected but was not found in the analysis of the behavior in the stable, although a marginal effect was found in the day-to-day handling of the horses.

4.2. Heart Rate Variability

Provided that certain conditions are maintained (eg, measurements of the same duration, at the same time of day, in a similar state of activity; well-documented correction of artifacts), the analysis of HRV in horses is evaluated as being a sensitive measure of both physical and emotional stress responses [11,26]. As these conditions were considered in the present study, the results are seen as reliable. However, the measurements only give information about changes in the degree of stress within the experiment. Because basal values in horses contain large inter-individual variations, the results do not allow a safe evaluation of the absolute level of stress in the individuals [12,27,28].

The HRV analysis in the present study revealed a stressing effect of the prevention of free exercise. All three parameters (SDNN, RMSSD, LF/HF) indicated a lower HRV (ie, decreased vagal regulatory activity), and therefore a greater degree of stress in the treatment NT compared with the other treatments on average (Fig. 4). This result is similar to the findings of Hoffmann [29], who showed that the degree of stress in horses decreases when additional exercise (turnout on pasture or in a horse walker) is offered. Considering that free-ranging horses spend up to 16 hours a day foraging, which happens predominantly at a walking pace [12], this result demonstrates the importance of free exercise for horses.

The available data only permit speculation about the deviations found in the individual horses. According to the literature, external influences such as age, gender,

---

### Table 3

Means (M) and standard deviations (SD) of the behaviors “willingness to perform” and “urge to move” during training as well as the distance covered and duration of training subdivided according to treatment

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>ST M</th>
<th>SD</th>
<th>GT M</th>
<th>SD</th>
<th>NT M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Willingness to perform (score)</td>
<td>86</td>
<td>2.82</td>
<td>0.79</td>
<td>2.80</td>
<td>0.85</td>
<td>3.01</td>
<td>0.76</td>
</tr>
<tr>
<td>Urge to move (score)</td>
<td>86</td>
<td>2.68</td>
<td>0.86</td>
<td>2.90</td>
<td>0.80</td>
<td>2.64</td>
<td>0.73</td>
</tr>
<tr>
<td>Distance (km)</td>
<td>82</td>
<td>4.28</td>
<td>2.13</td>
<td>4.69</td>
<td>2.05</td>
<td>4.30</td>
<td>1.88</td>
</tr>
<tr>
<td>Duration (minutes)</td>
<td>82</td>
<td>33.21</td>
<td>12.84</td>
<td>39.59</td>
<td>15.47</td>
<td>35.48</td>
<td>9.40</td>
</tr>
</tbody>
</table>

n, number of values; ST, solitary turnout; GT, group turnout; NT, no turnout.

Score (willingness to perform/urge to move): 1 = very good/very low, 2 = rather good/rather low, 3 = normal, 4 = rather bad/rather high, 5 = very bad/very high.
genotype, temperament, nutritional status, climate, disease (cardiac) have an effect on the regulation of cardiac activity [11,16]. At a younger age, HRV is generally greater. This might have been a reason for the low LF/HF in H1 and H5 as they were the youngest horses in the group.

Extreme weather conditions (high temperature and relative humidity) caused a higher degree of stress on average. This result matches the findings of Berger et al. [30] and Mayes and Duncan [31], who found that high temperature and insects led to more restlessness, and therefore to more stress. However, in the present study, these relationships varied to such a great extent in the individual horses that no clear interpretation was possible. Great inter-individual differences were also found in earlier studies in horses, which are similar to the large ranges of the analyzed values found in the present results [11,12,27-29].

The SDNN and RMSSD values in NT were lower in the second than in the first week in the present study, which might indicate that the degree of stress increases with the longer period of prevention of free exercise (Fig. 5). These values tended to increase toward the end of the treatment in GT. No clear trend is visible for the parameter LF/HF during the course of the treatments. Particularly high or low values in all parameters on particular days were predominantly caused by outliers in individual horses, which cannot be explained by the available data.

Visser et al. [13,32] found a relationship between temperament and HRV. In fact, horses characterized as highly responsive to changes in the environment had a lower HRV. Although Visser et al. [13,32] measured HRV during the experimental situation and not at rest (as in the present study), their findings have been proved by the present study, at least in tendency. For example, H2 was described as being little sensitive to changes in the environment and steady in behavior and performance. The highest HRV was measured in this horse compared with the other horses. The lowest HRV was measured in H4. This horse was considered to have a rather phlegmatic character, but sometimes it reacted very intensely to specific changes in its environment.

4.3. Behavior During Training

Because the horses showed very individual reactions, the treatment did not influence the horses' behavior during training in any clear direction. As there are many factors influencing the behavior during training and the evaluation by the riders is not quite objective, two explanations are supposable for this observation. On the one hand, it is possible that the treatment really did not influence the behavior. On the other hand, it is possible that changes in the behavior might not have been revealed clear enough by the recorded parameters. The average willingness to perform was slightly lower in NT than in the treatments with turnout. This result proves that free exercise has positive physical and mental effects in the horse [33]. A horse's good ability to move is the prerequisite for athletic use [33,34]. Rivera et al. [35] also observed that young horses kept on pasture acclimatize easier to training and the use of equipment than horses housed in a stable. This observation was traced back to the fact that horses on pasture train their ability to adapt to new situations better than horses in a low-stimulus environment like a stable. The housed horses in the investigation of Rivera et al. [35] also showed more activity, such as jumping and bucking (these behavior patterns are called "contumacy" in the present study), which was predicted by Hogan et al. [25] as being the result of unspent energy because of stabling. The horses' contumacy in this study led to a worse evaluation of willingness to perform because it was part of this parameter. The results, therefore, confirm the findings of Rivera et al. [35] and Hogan et al. [25] that a lack of free exercise has rather a negative effect on training.

Besides the risk of injury, free exercise is feared to decrease motivation for locomotion, and thus for training. In contrast, the present study revealed the highest urge to move in the treatment GT, which might have been caused by a better mental balance as a consequence of free exercise and social contact [33]. The duration and distance covered during training is dependent to a great extent on the rider and his/her conception of training. The willingness to perform was evaluated as being better when the duration of training was longer. This result disagrees with the results of Werhahn et al. [19] and Rivera et al. [35], who found that the training session was prolonged when the horses behaved restlessly and/or agitatedly. The riders in the present study had quite a tight time schedule for training all the horses they were responsible for, and at times this led to a reduction in the length of the individual training sessions. Possibly, the evaluations of the willingness to perform were better when the duration of training was longer, because when the riders spent more time with one horse they were able to deal with the individual in greater detail, which might have led to better performance.

The sporadic correlations found in the individual horses (Section 3.3) provide indications about the temperament of the horses in some cases. For example, H1 was found to be easily excitable and had a great urge to move during training and turnout. This horse's willingness to perform was evaluated as being better when the urge to move was lower. H4 had a completely different reaction. This horse had a more phlegmatic character with a low urge to move, which was rather increased—leading to a better evaluation—when the relative humidity was higher. This might have been because of the fact that the relative humidity tended to be higher when the temperature was lower. The causes and effects of these relationships are obviously very individual, and could not be clarified conclusively within this study.

5. Conclusions

In conclusion, this study shows that allowing or not allowing free exercise and its configuration (solitary or in groups of two) affects horses' behavior in the stable and during training, and also their degree of stress. The prevention of free exercise resulted in less lying and more occupation, which was interpreted as being a decreased demand for rest and as balancing the lack of occupation on pasture. When NT was allowed, all three HRV parameters at rest were lower, indicating a higher degree of stress in this treatment. High temperature and relative humidity also caused higher values for LF/HF, thereby indicating the
presence of stress. GT resulted in the lowest degree of stress, but the difference was only significant in SDNN compared with NT. The evaluation of training was best when turnout was allowed in groups, but the evaluation did not differ significantly between the treatments.

Housing horses in single stalls restricts natural behavior to a great extent. The present study demonstrates that management practices affect horses’ behavior and degree of stress during the entire day. Stress is supposed to be minimized to improve animal welfare in a housing system. Allowing free exercise and social interactions are invaluable tools to achieve this aim in horses, and thus should be facilitated by every horse keeper.

Acknowledgments

The authors thank Niels von Hirschheydt and his team, and the owners of horses for enabling the experimental work to be done.

References