Activity Behavior of Horses Housed in Different Open Barn Systems

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ABSTRACT

Housing conditions do not frequently meet the natural needs of horses. German and Swiss studies have shown that merely 16% of horses are kept in group housing systems, but even these vary greatly with different effects on horses' behavior. The objective of the survey was to determine whether horses show increased activity in barns with various options for movements and functional elements. Free movement stables allow horses to live within a herd, to decide whether to be outside or inside the herd, and to enable them fresh air supply. Data from 25 horses kept in three different open barns (O1–O3) were compared with that from two active barns with functional elements (active barn 1 and active barn 2), for example, automatic feeder, with five horses each. Activity-Lying-Temperature-pedometers fastened to a rear leg of each horse were used to measure activity. Animal data were recorded throughout a test period of 10 days per barn. The results showed a median of 46 to 68 mean daily activity impulses per 10 minutes for horses in stables O1 to O3. In stables active barn 1 to active barn 2, this measure was exceeded considerably with medians of 77 and 151. The activity impulses in the stable systems were significantly different at an error level of $\alpha = 0.05$. These results support previous studies and show that activity of horses depends on their opportunities for moving. The sectioning of a stable, placement of functional elements, and feeding frequency have considerable effects on the activity level of the horse. It is useful to integrate different functional areas in a group housing system.

Keywords: Horse; Activity; Movement behavior; Group housing systems; Open barn

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INTRODUCTION

The number of horses in Germany has increased from about 350,000 to more than a million within the last 20 years. Particularly, the increasing diversity of equestrian sports has lead to an increasing demand for horses and a constant increase in the number of horse breeds.[1] The horses have become an interesting leisure partner, but the stable designs quite often do not meet the natural demands of these horses.[2] In the wild, horses are social herd animals adapted to a wide range of environmental conditions. However, it is possible to keep them on pasture under extensive husbandry throughout the year.[3,4]

Nowadays, horses are kept in individual and in group housing systems. Overall, 84% of the total horses in Europe are kept in individual housing systems (boxes), and only 16% are kept in group housing systems.[5] Other studies even refer to nearly 90% of horses being kept in individual housing systems.[5,6] Almost every activity in the behavior of horses is connected with locomotion. Analyses from observations in stud farms showed that horses stalled in boxes usually remained stationary for a maximum of 23 hours per day and spent a maximum of 1 hour moving around.[7] However, findings indicate the significance of movement for the health of horses, adolescent horses in particular. Wilke[8] examined 694 foals and their mothers under different housing conditions with regard to the occurrence of osteochondrosis. Foals with a deficit of movement within the first 4 months of life had significantly more common osteochondrosis in the fetlock as compared with a foal with adequate movement opportunities.

Lack of movement and feeding deficits are also known to contribute to the development of colics.[9]

Nevertheless, Hoffmann et al[10] reported that providing additional movement, like pasture or horse walker, resulted in a lower stress load of group-housed horses.

In the wilderness, horses graze to a maximum of 16 hours per day. During this time, they slowly move forward taking short steps. When running, horses reach to a maximum speed of 70 km/hr[11] because of which their heart rate is boosted, thereby promoting blood circulation and energy supply of the organs. Heart rates of the horses participating in sportive competitions measured 181 $\pm$ 13 beats per minutes. But merely 1 minute after the activity, the heart rate dropped to 86 $\pm$ 12 beats per minutes.[12]

Although extensive regulations exist for common farm animal species in Switzerland and within the European Union (EU), none of them are applicable to horses. As described previously, most horses are kept in traditional individual housing systems. In contrast, different group housing systems are used to improve the behavior and welfare of horses. Often they are associated with disadvantages for the owner of the horse because the animal is not conveniently available for sport activities and is exposed to higher risk of injuries.[13,14]

Nevertheless, group housing systems pose a lot of advantages regarding social behavior and movement activity of horses. Group housing systems also have the advantage of lower buildings costs.[15] The number of studies on equine behavior in open barn systems is limited, especially for the new housing systems like open barn with functional elements. Regarding the behavior of horses, previously published data mainly refer to observations in their natural environment. For example, wild horses cover an average distance of 6 km per day,[16] depending on seasonal pasture conditions, grass quality, climatic conditions, and the distance between watering places. A similar behavior can be found in group housing of horses in open barns. It was observed that horses in open barns with paddock walk 1.2 km per day, whereas horses in boxes cover a distance of merely 0.17 km per day. In open barns with different functional areas and higher feeding frequencies, walking distance per day could be increased to 4.8 km.[17] Therefore, group housing systems have positive effects on the activity of horses.[18] Increased space with leafy paddock or pasture also helps to increase the activity per day. However, an expanded sand-paddock (540 m^2 instead of 270 m^2 for six horses) has no influence on activity behavior.[10] The highest space restriction with the strongest negative effect on activity behavior can be found in individual stabling in boxes.[7]

Overall, comparative studies of feral and stabled horses showed that their natural behavior is influenced by the housing system.[19] Strong variations in behavior were mainly observed for movement and feeding behavior of horses. Field studies have shown that the time adult horses spend recumbent is between 3% and 11% of the day, which equals 45 minutes to 2.5 hours.[20,21] During these lying periods horses prefer a dry and soft ground, and they prefer straw more than sand.[22,23] Systematic observation of lying behavior in horses is necessary to ensure that horses are able to perform normal sleeping behavior in individual and group housing systems.[24]

The Hinrichs-Innovation und Technik (HIT)-Active Stable (HIT GmbH, Weddingstedt, Germany) is a new concept for group housing systems. HIT aimed at bringing forward species-appropriate horse husbandry. The HIT-Active Stable is characterized by a horse-individual feeding technology (Horseking, Wasserbauer GmbH, Austria), free opportunities for horse exercise and rest, as well as a special arrangement of the different functional areas.

Implementation of sensors to measure the behavior of animals is very common and an interesting branch of precision livestock farming. Animal monitoring is very helpful for efficient management and to ensure animal health, especially in big farms. It is necessary to monitor the differences in the behavioral repertoire of animals in the domestic environment. The variation in animal behavioral repertoire can be qualitative (eg, abnormal behavior) or quantitative (eg, time budget modifications). These two variations can help to perceive effects of husbandry practices on animals' behavior and welfare.[25,26]

The pedometer is an instrument used to measure and monitor animal behavior. Yet, pedometers are primarily used for dairy cow management where the data help in estrus detection, which is the most important parameter for optimum fertility management, particularly in combination with artificial insemination.[26] But with this system it is also possible to differentiate between the animals' recumbent and standing at rest positions. In contrast, pedometers register the activity and lying time of the animals as electric impulses. Activity changes are more precisely registered by sensors which are fastened to the leg (ie, pedometers) than those fastened to the neck (so-called rescounter) and position systems.[27,28]

This study was performed to investigate five different types of open barns for horses. The objectives of the present research study were to identify effects on horse's behavior in differently structured group housing systems (space and functional areas).

The interest of this investigation was to find reasons why horses should be kept in group housing systems and how the design of free movement stables could increase activity.

The objective of this preliminary study was to quantify whether horses show increased activity in open barns with different options for movement and distances between functional elements.

MATERIALS AND METHODS

Experimental Design

Data for the present study were collected between February and March 2008 in Germany from five different free movement stables. They were classified into open and active barns. Open barns are stables which have no direct functional elements except for paddock, hayrack, and shelter, which are generally close to each other. The horses were provided with hay once to twice a day ad libitum. The idea of the active barns was to use different elements to animate the horses to walk around and not to stand at hay rack all day long. The active barns had transponder-controlled automatic hay rack and concentrate feeders. Here, the animals were fed individually several times a day. Additionally, the functional elements (automatic feeding systems and drinker) were placed away from each

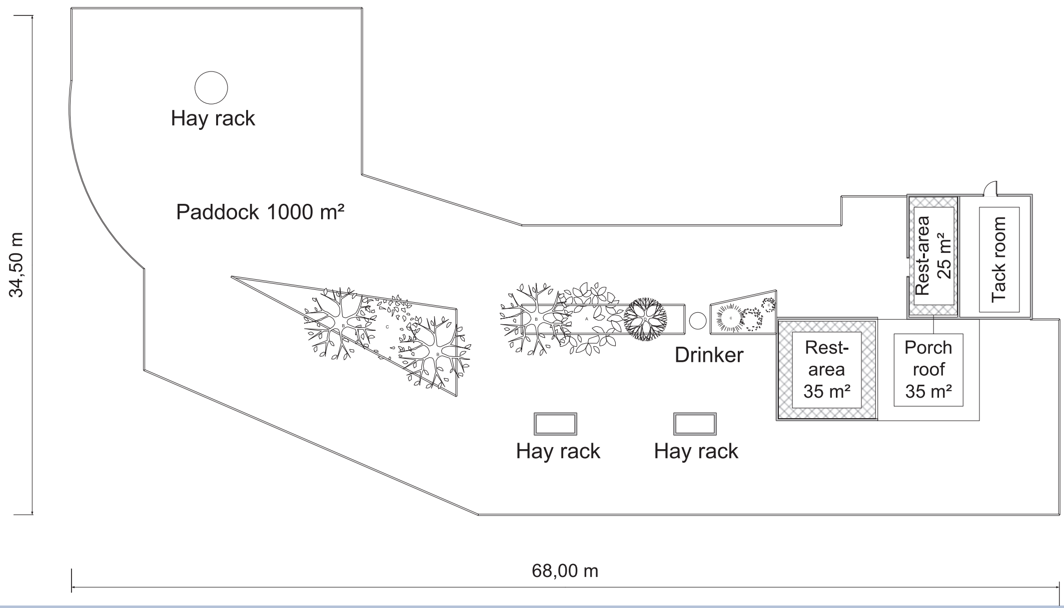

Figure 1. Plan view open barn 1.

other purposely and active barns had an increased space offer.

One group of horses was initially housed in a paddock system (PS) (Fig.1), and then the same horses were relocated into a newly built active barn where records were documented for 4 weeks (Fig. 2). Conditions were not standardized and all animals were kept under field conditions on different farms, with the group sizes ranging between five and 20 horses (Table 1). Five to six horses from each stable were used in this experiment.

The minimum requirement of floor space of $3 \times \text{withers}^2$ per horse in group housing systems was fulfilled in each of the examined systems.[29]

In every investigated group housing system, five to six animals were fitted with a pedometer and observed for 10 days. In total, the movement behavior of 26 horses was investigated.

Open Barn 1 (O1). This open barn consisted of a big designed paddock and two open stables with porch roof (Table 1). The paddock was divided by bushes. There were three hay racks for feeding. The feeding with concentrate was split in two portions per day. The watering place had a central position in the paddock close to hay racks and stable (Fig. 1).

Open Barn 2 (O2). Open barn 2 was a typical conventional group housing system with a plain sand paddock (Table 1). The group housing system had an effective length of 30 m and was constructed as half-circle. The horses could move freely during the entire day. Hay was offered three times a day and concentrates were fed once a day in the stable. The watering place was located in one corner of the paddock. The open barn was divided into a movement and a lying area.

Open Barn 3 (O3). Open barn 3 was also a typical conventional group housing system with plain sand paddock surrounding the stable (Table 1). The shelter floor was covered with sand. Hay was fed three times a day under the porch roof of the stable where the watering place was located as well. Additionally, the horses received concentrate once a day.

Paddock System. The construction of a new active barn A2 offered the opportunity to investigate an old PS (Fig. 2) before relocation of the horses to the new barn system with functional elements. Five horses were kept in the old PS at day time in a conventional sand paddock with hay rack and watering place. During the night, three of the five horses were stabled in straw bedded boxes, and two horses spent the night in a rubber-coated paddock with shelter (Table 1). Data from the PS had to be carefully treated because the conditions differed largely from any of the other stables investigated.

Active Barn 1 (A1). The group housing system was divided into movement and lying areas. The stable floor was built using concrete, which was then coated by rubber mats. Additionally, the rest area was equipped with HIT-Softbeds (special padded thicker rubber mat) and an integrated horse toilet. The horse toilet was a small area of 6 m^2 which was filled with wood shavings (Table 1). The horse toilet was not used for proper appointment, and sometimes the horses were found recumbent inside it.

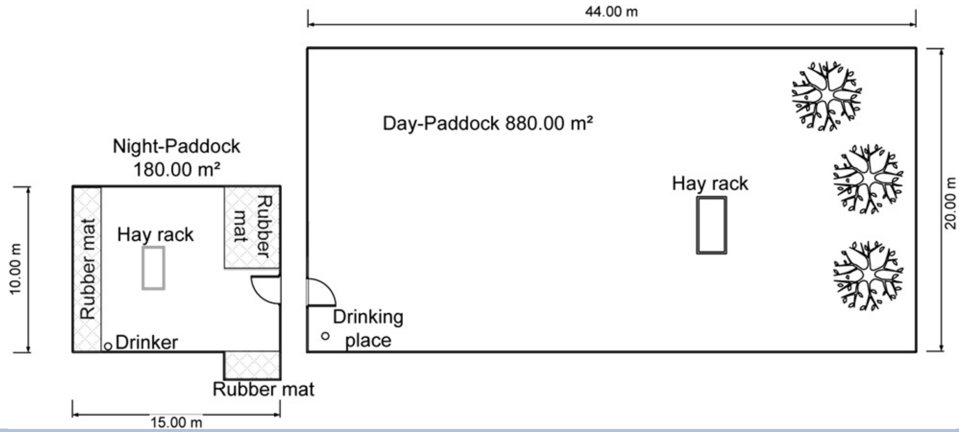

Figure 2. Plan view of paddock system (PS).

Table 1. Dimensions and stocking capacity of the open and active barns

	Open Barn				Active Barn	
	01	02	03	Paddock System	A1	A2
Number of horses	8	9	5	14	20	7
Total area (m^2)	1,000	750	600	800	4,500	2,000
Area per horse (m^2)	125	83	120	57	225	285
Shelter/stable	2	1	1	3	1	1
Shelter (m^2)	55	180	36	41	200	200
Resting area per horse (m^2)	6.9	20	7.2	4.1	10	28.6
Bedding material	Sand	Straw	Sand	Rubber mats	Padded rubber mats	Sand
Structured*	+	0	0	–	++	++

* = see explanation.
0 = divided in different area.
+ = functional elements.
++ = functional elements and automatic feeding.
– = not structured.

One corner, close to the stable, contained an automatic concentrate feeder which provided small portion of concentrates and mineral supplements for each horse throughout the day. An automatic hay dispenser with four feeding places was installed in the middle of the paddock, enabling the individual roughage supply around-the-clock. Two separate straw-feeders were placed at the end of the paddock. The watering place was located in front of the stable.

Active Barn 2 (A2). Active barn 2 was a newly constructed housing system which in the future might accommodate 30 horses. The group housing system had a big paddock divided into a movement and a lying area (Fig. 3). The shelter had a sandy ground and an automatic concentrate feeder attached to one side. The automatic hay dispenser with four feeding places was installed at the other end of the paddock.

Animals. Age of the tested animals ranged between 3 and 23 years. Each experimental group contained mixed herds with mares and geldings and heterogenic structure in terms of size and breed (warm-blooded breed types and ponies). In each barn, different types and ages of horses were used for the investigation (Table 2).

Measuring with Pedometer. Activity-Lying-Temperature (ALT) pedometers were used to record movement activity and lying time for a period of 24 hours a day (Engineering office Holz and Schleusener, Germany). The mode of operation of pedometers for the measuring parameter animal activity worked on the principle of pulse metering. The activity was measured using an analogue piezo-sensor, the lying time with digital position sensors, and a thermal sensor recorded the ambient temperature at the pedometer (Engineering office Holz and Schleusener, Germany). The µ-processor

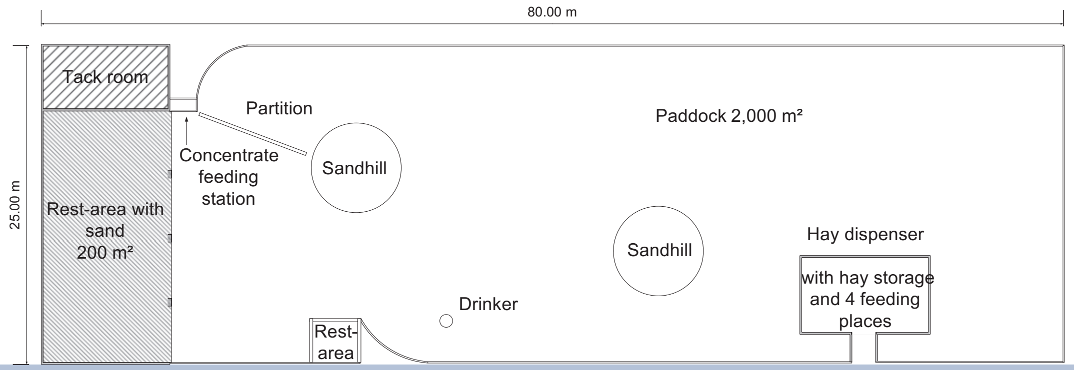

Figure 3. New active barn with functional elements.

Table 2. Overview of breed, gender, and age of horses included in the study

Horse	Stable	Breed	Gender	Age (years)
1	A1	Friesian horse	Gelding	3
2	A1	Arabian	Gelding	6
3	A1	Knabstrup	Gelding	6
4	A1	Arabian	Gelding	10
5	A1	Warmblood	Gelding	12
6	O1	Knabstrup-Warmblood-mix	Gelding	6
7	O1	Cruzado-Andalusian	Mare	6
8	O1	Haflinger	Mare	7
9	O1	Rhinelander Warmblood	Gelding	15
10	O1	Standardbred	Gelding	15
11	O1	Haflinger	Gelding	16
12	O2	Half-blooded Arabian	Mare	6
13	O2	Half-blooded Arabian	Mare	13
14	O2	Half-blooded Arabian	Mare	15
15	O2	Half-blooded Arabian	Mare	16
16	O2	Half-blooded Arabian	Mare	28
17	O3	Paso Fino	Gelding	7
18	O3	Pinto	Gelding	11
19	O3	Pinto-Trakehner	Gelding	12
20	O3	Arabian	Mare	12
21	O3	Standardbred	Gelding	15
22	PS, A2	German riding pony	Gelding	7
23	PS, A2	Haflinger	Mare	9
24	PS, A2	Standardbred	Mare	11
25	PS, A2	Thoroughbred-heavy horse-mix	Gelding	14
26	PS, A2	Hanoverian	Mare	16

continuously recorded the step activity and lying position of the animal and added these together over the measuring interval configured at the start of the test (1–60 minutes).

The pedometers were attached to the rear leg of the horse to avoid gathering activity impulses from scraping and pawing front hooves. After evaluation of the data, the time each horse spent with moving and lying could be analyzed.

All data within each measuring period of 10 minutes were aggregated, resulting in a possible value range of 0 to 1,200 contacts for movement activity and 0 to 40 contacts for lying within this interval. Maximum of two impulses per second were registered for movement activity. The ambient temperature at the horses' leg was measured every 10 minutes but was not further regarded in this study. The data were transferred from the pedometer to personal computer by radio transmission and stored in Microsoft Access database for further processing.

Statistical Analysis. The records during exercises (eg, horseback riding) were removed before evaluation because it was impossible to standardize exercise in the given experimental setup. Later, the remaining data were averaged per horse and day to keep the effect of locomotion influenced by previous exercise as low as possible. This resulted in values for mean 10-minute-activity-impulses per horse and day, provided that at least 80 values were available per day. A minimum of 80 values per day were chosen to ensure that mean value per day included data from day- and nighttime. Data recorded on days where pedometers were installed in the evening or removed in the morning and therefore only included data of night hours were not used. Values from the same horse on different days were considered as repeated measurements.

Statistical evaluation of the data recorded by the pedometers was performed using the statistical software package SAS version 9.2 (SAS Institute Inc., Cary, NC, USA). Although the data were found inconsistent to normal distribution, nonparametric tests did not suit to account for all effects that were considered necessary for this study: effect of stable system (open barn, active stable), effect of stable (O1, O2, O3, PS, active barn 1 [A1], and active barn 2 [A2]), age of horse as co-variable, and horse effect. Considering the robustness of the *F*-test regarding violating the normality assumption,[30] the following mixed linear model was fitted with the following procedure to test hypothesis of particular interest:

$$\underline{y}_{ijkl} = \mu + \alpha_i + \beta_{ij} + \gamma x_{ijkl} + \underline{c}_k + \underline{e}_{ijkl}$$

where,

y_{ijkl} = mean activity impulses observed per 10 minutes in *ith* stable type, *jth* stable, *kth* horse and *lth* measurement

μ = general mean of population

α = fixed effect of *ith* stable system

β_{ij} = fixed effect of *jth* stable within stable system i

γ_{ijkl} = parameter estimate for covariable age in years (x)

c_k = random effect of *kth* horse, and

e_{ijkl} = residual.

Heterogeneity of variance was assumed for horses in the different stables. The *P* values were adjusted for multiple comparisons between stables by estimating the true $(1-\alpha)$ quantile with a simulation. The significance level α was set to 0.05.

Following this model, the null hypothesis H_{0a} that there was no difference between stable systems, and H_{0b} that there was no difference between stables within stable system, could be tested against their alternatives that there were in fact differences between stable systems or stables. It also could be tested whether there was an influence of age (given in years) on daily mean activity impulses per 10 minutes (H_{0c}).

RESULTS

Activity Behavior

Activity was measured in intervals of 10 minutes. At this interval, gaits can only be separated exactly when it comes to walk on the one side, and trot, canter, or gallop on the other side. A continuous walk for 10 minutes will usually result in step values from about 300 to 600, depending on walking speed. Higher step values imply the faster gaits, but because the distribution within the measuring interval is unknown, a value of 1,200, for instance, could be the result of a continuous trot or 5 minutes of gallop and another 5 minutes of standing. An overview about the distribution of daily mean 10-minute activity values for all barns under investigation can be observed in Table 3.

Open Barns Compared with Active Barns

The comparison of the open barns with the active barns displayed significant differences between the stable systems (Table 4). The least square mean difference between both systems amounted to about 56 steps per 10 minutes and was statistically significant (Table 5). The comparison between two barns each shows that the reason for this difference can be attributed to the activity level in barn A2 mostly. This barn differs significantly from all other barns and also showed the overall highest activity level. Although barn A1 comes in second place in this regard, there is no significant difference between barn A1 and barn O1, O3, or PS.

Open Barns

Figure 4 shows that the horses in open barns O1 to O3 and PS had an overall lower mean daily 10-minute step count compared with the active barns.

However, there were no significant differences within the open barn stables O1 through O3 and PS when testing between pairs of stables at the experiment wise significance level $\alpha = 0.05$ (Table 5, open barns).

Active Barns

Although both active barns offer similar space for movement per horse and include the same functional elements, the mean daily 10-minute step count shows differences. The lowest observations in barn A2 were still higher than the highest observations in barn A1. The comparison of both active barns displayed in Table 5 consequently shows a significant difference.

Table 3. Comparison of activity patterns and behavior of horses housed in different barns

		Distribution of Daily Mean Activity Impulses Per 10 Minutes						
Barn	Number	Maximum	Q75	Median	Q25	Minimum	Mean	Standard Deviation
A1	45	114.21	92.33	77.46	66.22	53.35	78.53	15.46
A2	44	219.06	170.78	151.89	140.81	119.75	155.32	23.92
O1	66	91.38	77.83	68.39	51.39	19.83	63.28	20.26
O2	55	81.77	56.81	46.30	39.84	33.84	49.23	12.28
O3	55	194.63	66.10	53.59	42.06	34.35	58.44	26.04
PS	55	112.14	71.50	53.97	45.23	29.09	59.82	20.61

A1, A2: active barns; O1, O2, O3: open barns; PS: paddock system.

Table 4. Results of *F*-tests of fixed effects and co-variables

Effect	Numerator DF	Denominator DF	*F* Value	Pr > *F*
Stable system	1	20.90	136.09	<.0001[a]
Barn (stable system)	4	9.28	33.35	<.0001[a]
Covariable age	1	8.13	4.20	0.0739

[a] Shows significant differences at significance level $\alpha = 0.05$.

Moving from PS to Newly Constructed Active Barn (A2)

Figure 5 shows the change of activity after moving the horses from PS (pre-test) to A2. The mean activity level based on mean daily 10-minute values was more than doubled again; the maximum observation in PS was lower than the minimum observation in A2. The least square mean difference of about 96 steps per 10 minutes was statistically significant (Table 5, comparison between A2 and PS).

DISCUSSION

The results show that the activity level of horses was increased in active barns when compared with open barn systems. However, significant differences were only found between barn A2 compared with all remaining barns and between barn A1 and O2 (Table 5). Thus, higher activity behavior can be generated in an active barn as can be seen in barn A2, but barn A1 shows that this does not necessarily have to be the case.

Activity Behavior

Our hypothesis of active barns being capable of increasing activity of horses was confirmed because the stable system had a significant effect on mean daily 10-minute activity. However, it is not clear to which change between stable systems this increase can be attributed. Our results correspond well with other studies which found that an increase of movement activity can be achieved by sub-dividing the available area into different sections and altering feeding frequencies.[17] It is not possible for our investigations to differentiate between those effects. Further investigations should focus on changing only one parameter at a time in the experimental setup.

Although overall space allowance is also important for the activity behavior of the horses, it is not the only factor that affects the horses' motivation for running and playing.[18] Our results show that although both active barns offer comparable space per horse and include the same functional elements, the distribution of activity nevertheless shows large differences. The distributions of mean daily 10-minute activity of the active barns A1 and A2 do not overlap. Reasons for this could be the higher space availability per horse in A2 and possibly better arrangement of functional elements.[28] The results correspond well with Rehm,[31] who likewise observed increasing movement behavior per hour with increasing space. In contrast, Hoffmann et al[10] and Frentzen[17] were unable to discover an influence of paddock size on movement activity, and Piotrowski[32] reported that doubling and tripling the size of an enclosure (single size: 30 m^2/horse) had only marginal effect on movement behavior. However, in the given experimental setup the direct influence of available space per horse on activity level could not be tested explicitly.

Frentzen[17] reported that functional area helps to increase activity. Further, it was found that the feeding frequency in combination with distance between functional elements has a significant influence on the movement activity. These results correspond well with the present study. A higher feeding frequency by use of automatic feeding systems could be a reason for the significant increase in activity in active barns compared with the open barns. The higher frequency of feeding per day comes as a natural behavior,

Table 5. Test results of pair-wise comparisons of least square means for daily mean activity impulses per 10 minutes between stable systems and barns

Comparison	Difference	Estimate	Standard Error	DF	*t* Value	Adjusted *P*
Open barns	O1–O2	8.5140	10.3727	6.81	0.82	.9516
	O1–O3	4.4455	9.8880	6.73	0.45	.9964
	O1–PS	3.4599	11.6293	8.88	0.30	.9995
	O2–O3	−4.0684	6.3365	7.35	−0.64	.9822
	O2–PS	−5.0541	8.8101	6.73	−0.57	.9892
	O3–PS	−0.9857	8.3364	6.04	−0.12	1.0000
Active barns	A1–A2	−80.9212	6.5626	8.16	−12.33	<.0001[a]
Active barns and open barns	A1–O1	15.5904	10.3493	8.76	1.51	.6609
	A1–O2	29.9407	7.7012	7.31	3.89	.0400[a]
	A1–O3	20.7279	7.8837	7.54	2.63	.1924
	A1–PS	19.7499	10.2607	7.49	1.92	.4455
	A2–O1	91.7142	9.2921	7.36	9.87	.0001[a]
	A2–O2	106.0600	6.2085	8.05	17.08	<.0001[a]
	A2–O3	96.8517	6.4334	7.93	15.05	<.0001[a]
Active barn 2 and pre-test in paddock system	A2–PS	95.7704	8.3007	6.09	11.54	.0002[a]
Stable system	Active–open	55.9548	4.7966	20.9	11.67	<.0001[a]

O1, O2, O3: open barns; PS: paddock system; A1, A2: active barns.
P values adjusted for multiple comparisons by simulation.
[a] Shows significant differences at significance level $\alpha = 0.05$.

especially the feeding habits of grazing for a considerable amount of the day which suit their digestive system best.[33]

Direct comparison of results is difficult because most other studies on movement behavior of horses used different measurement systems. For example, Klingler[34] used steps per time unit, and Frentzen[17] and Zeitler-Feicht[16] used kilometers per day. These methods turned out to be problematic because the measuring systems were unable to distinguish pawing and twitching from walking. Considering the experiences from previous studies and because in the present study interaction with other horses is measured as impulses which might falsely be interpreted as locomotion, translation of activity impulses into steps or distance was not attempted. Klingler[34] used a "Rocking Motion Recorder" which recorded an average of 247 activity impulses, respectively steps, per hour on horses in the pasture. The step-count is smaller than the median or mean observed in the daily 10-minute values for all barns when transformed to 41 impulses per 10 minutes. Open barn O2 with the lowest structure design of stable and the lowest daily mean of about 49 activity impulses per 10 minutes still shows a slightly higher activity level compared with the step-count of Klingler.[34] Differences between O2 and A1 were significant, where O2 showed the lowest activity level. Furthermore, all other barns consisted of structured elements and could help motivate the horses to walk around in different ways. Klingler's[34] results were exceeded by the minimum mean daily 10-minute values in A1 and A2 during the experimental period. It might be possible that the stable's design was not entirely responsible for this exceptional behavior because horses were moved from the PS (pre-test conditions) into the new active barn with a short adaptation phase of 10 days. This period might have been too short for acclimatization and curiosity to subside so that they showed more activity than would be the case after several months in the same environment. The overall activity level increased about threefold after horses were moved from PS to A2 when using mean or median daily 10-minute values (Table 3), which confirmed results from other studies. An increasing movement behavior was observed when horses were transferred from one to another keeping system[31] or pasture,[35] unless the new housing system restricted movement, which naturally led to decreasing movement behavior.

Age of horses seemed to have no significant effect on activity behavior (estimated effect: 1.225 steps/age in years) in the present study (Table 4), which might be explained by Rose-Meierhöfer and colleagues[36] assumption that horses mainly animate themselves to move around. No horses of age <3 years were available for this study which might explain why there was no influence of age. Generally, horses show higher activity at young age compared with older horses.[37]

Nevertheless, Hoffmann et al[10] reported that keeping horses in groups has a positive effect on their movement behavior. In the present study, the largest group of 20

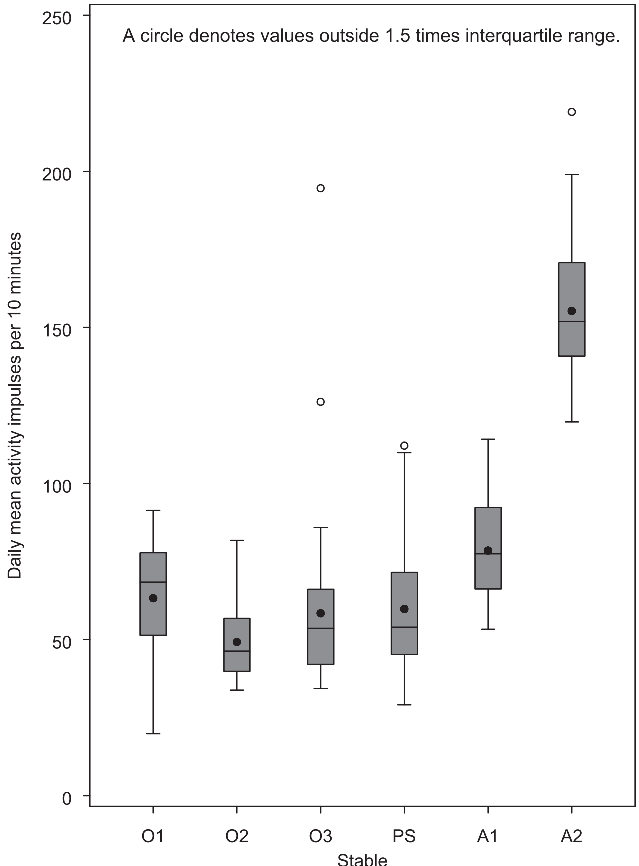

Figure 4. Mean daily 10-minute activity values of horses in open barns (O1, O2, O3), PS and active barns (A1, A2).

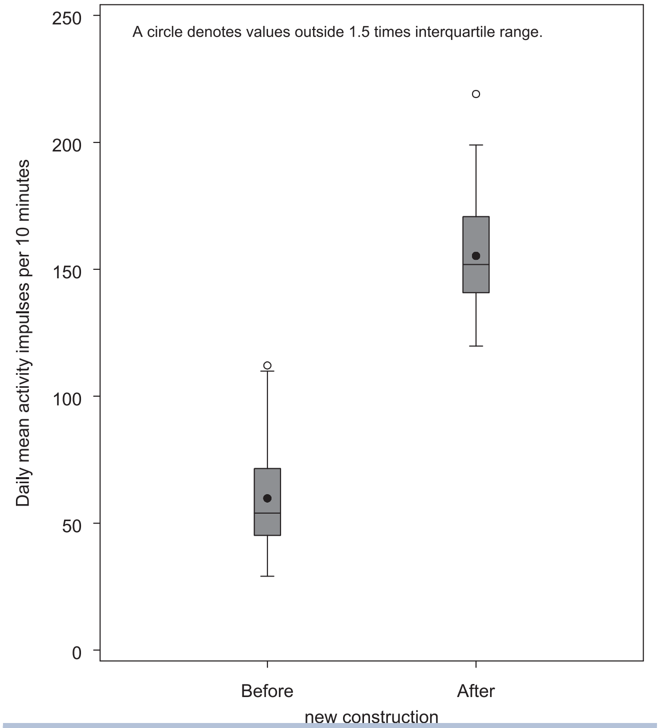

Figure 5. Mean daily 10-minute activity values of horses in PS and after new construction as active barn.

horses was kept in stable A1, showing the second highest activity. Rose-Meierhöfer et al[36] reported that large groups increase movement activity because of higher interaction between animals. This effect was particularly obvious in young horses equipped with ALT-pedometers. Yearlings kept in small groups having a maximum of 11 individuals showed 55 activity impulses per 10 minutes, whereas in larger groups of 23 yearlings 99 impulses per 10 minutes were recorded.

Another effect that might have been connected to the activity behavior of the horse is the time horses spent recumbent. This time was influenced by the bedding material and affected the welfare and health of the horses.[38,39]

Overall, one might wonder whether the measured activity behavior is representative for average activity throughout the year. Berger et al[40] observed a rhythm by seasonal changes in wild as well as domesticated horses which decreased their activity during winter time to save energy. To get a more general impression of horses' activity behavior including seasonal influences, it would therefore be necessary to repeat the observations during a whole year or at least during alternate months with same horses in the same stables.

In general, the measurements recorded by ALT-pedometers are still limited. It would be necessary to define more appropriate assessment factors and develop better methods for evaluation to get a more holistic impression of the horses' behavior across different housing systems.

CONCLUSIONS

The results of this study indicated that the activity of horses is affected by space and functional areas. Using feeding automation for hay and concentrates in addition to a structured stable design, which in this study was defined as active barn, leads to a significantly higher activity behavior of horses compared with the conventional open barns. There are different elements that can be implemented to increase the activity behavior. Along with "high technique" like automatic feeders, bushes and other elements should also be implemented to motivate animals to walk around. Although providing more space increases activity, it will not have a long-term effect like feeding system. Future research is necessary to generalize the results as the given sample size and selection of horses does not allow to draw conclusions for larger populations.

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