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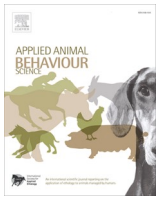

Horses' resting behaviour in shelters of varying size compared with single boxes

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ABSTRACT

Lying behaviour in horses is affected by factors such as bedding, housing and available lying area. For group-housed horses, social factors may influence access to available lying area and affect their ability to meet their need for sleep, including essential REM sleep. REM sleep can only be achieved when the whole body, including the head, is supported by the ground, so lateral recumbency is important to meet horses' sleep requirements. This study investigated the effects of available lying area in shelters on horses' lying and rising behaviour, on disturbance behaviour by horses, and on lying bouts by individual horses. Lying and rising behaviour was video-recorded for eight horses in single boxes (control treatment) and in an open-barn with three available lying area of 8, 18 and 28 m^2/horse, respectively in the shelters. The results revealed significantly less lateral recumbency in the shelter with 8 m^2 lying area/horse (22 min, $p = 0.04$) compared with the single boxes (52 min), and a tendency for more lateral recumbency with 18 m^2 lying area/horse (48 min, $p = 0.07$) compared with 8 m^2 lying area/horse. Rising without prior rolling was the most common rising behaviour in the single boxes. Frequency of rolling prior to rising varied from 14% to 55% for all housing systems, compared with previous observations of ~30% irrespective of available lying area. This may be due to inter-individual differences, indicating a need for detailed studies of rising behaviour. Lying behaviour was affected by the behaviour of other horses and also significantly affected by available lying area. With more available area in the shelter, horses lay down for almost twice as many bouts ($p = 0.01$) and for almost twice as long as compared to a smaller area ($p = 0.001$). Number of lying bouts ($p = 0.001$) and behaviour during rising from the lying position were also affected by available lying area. It is therefore likely that the space requirement to meet horses' need for rest will be larger in group-housed horses than for horses in individual boxes.

1. Introduction

Measuring the lying behaviour of horses (*Equus caballus*) could be a way to assess horse welfare (Auer et al., 2021). The Five Domains model developed by Mellor et al. (2020) considers nutrition, environment, health and behavioural interactions, all of which influence mental state. Sleep and rest are important for all domains of horse welfare. Open barn systems, housing horses in groups, may have benefits over tied stalls and boxes (Yngvesson et al., 2019), e.g. group housing allows horses to perform more goal-directed behaviours, improving welfare (Mellor et al., 2020). However, group housing may pose other welfare risks related to social competition for limited resources such as lying area. Feral horses have been observed lying for 1–2 h/day (Duncan, 1980; Kownacki et al., 1978), while stalled horses lie for 3–5 h/day (Dallaire, 1986; Dallaire and Ruckebusch,1974). Horses perform four stages of sleep: wakefulness, drowsiness, slow-wave sleep and paradoxical (REM) sleep (Dallaire, 1986). Most sleeping time is spent standing, but during REM sleep horses need to rest their head on the ground. REM sleep can be achieved in lateral or sternal recumbency if the muzzle is in contact with the ground (Williams et al., 2008). Mean REM sleep duration is reported to be 30–70 min/day (Fuchs et al., 2018; Greening et al., 2021).

Horses can manage without lying down for several days, but eventually they must lie down (Dallaire, 1986). The horse's need for sleep, and especially for REM sleep, is not fully established, but several studies

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indicate that sleep deficiency impairs horse welfare (Fuchs et al., 2018; Greening et al., 2021; Keleman et al., 2021). Horses with reduced REM sleep have been found to collapse (Fuchs et al., 2018), sometimes repeatedly (Lyle et al., 2010). Hence sleep is considered crucial for animal welfare (Horne, 1985).

A study by Fader and Sambraus (2004) found that group structure is important for lying, with low-ranking horses in open barns having a shorter lying time than high-ranking horses. In addition, rest is affected by housing, e.g. Raabymagle and Ladewig (2006) found that sternal recumbency time and number of lying bouts increased with space in single boxes, while Kjellberg and Rundgren (2010) showed that horses kept in tied stalls had more, but shorter, lying bouts than when kept in single boxes. Group-housed horses are reported to show more lateral recumbency with increasing lying area (Burla et al., 2017; Kjellberg et al., 2021a) and lying behaviour in open barn systems is reported to be affected by multiple factors (Hoffmann et al., 2012; Kjellberg et al., 2021a). Lying behaviour can also differ depending on type of pasture. Sassner et al. (2022) observed longer lateral recumbency among young horses on cultural pasture than in a nature reserve (103 and 42 min, respectively). Rolling by horses prior to rising has been observed to decrease with increasing space (Raabymagle and Ladewig, 2006), and in tied stalls compared with single boxes (Kjellberg and Rundgren, 2010), although Hansen et al. (2007) observed more rolling prior to rising on pasture than in stables.

Bedding type and thickness are important, e.g. Burla et al. (2017) found that increasing amounts of soft bedding, such as straw and wood shavings, increased lying time among group-housed horses compared with soft rubber mats, while Greening et al. (2021) found that horses spent less time in lateral REM sleep when the bedding was thin. Studies comparing different bedding materials have shown that straw sometimes increases lateral recumbency (Pedersen et al., 2004; Kwiatkowska-Stenzel et al., 2016), but not always (Ninomiya et al., 2008; Werhahn, 2010; Koster et al., 2017). These conflicting results may be due to individual preferences in horses. Edible bedding (e.g. straw) in shelters can lead to group members interrupting lying bouts (Baumgartner et al., 2015), possibly due to increased foraging in the bedding (Werhahn et al., 2009).

In summary, lying behaviour in horses is influenced by bedding, health, age and available lying area, while group-housed horses can also disturb each other. Therefore the lying area in shelters could be an important factor for horses' possibilities to meet their need for sleep. The aims of this study were to investigate horses' lying behaviour in shelters with different available lying area, starting at lowest minimum area of 8 m^2 required by the Swedish Board of Agriculture, and to formulate appropriate recommendations for horse owners. Research questions were:

- How does available lying area in shelters affect horses' lying and rising behaviour compared with boxes?
- How does available lying area affect disturbance behaviour in horses and lying bouts by individual horses?

2. Material and methods

2.1. Horses

All horses were gelded Swedish Warmblood (SWB) school horses, aged 3–17 years, kept at Swedish National Equine Centre Strömsholm and used for riding by students in the Equine Science programme at the Swedish University of Agricultural Sciences. All horses were trained 3–4 days/week at an intensity dictated by their education level, with 2 days/week spent hacking, except for the 3-year-old. Horse height was 1.62–1.74 m over the withers. All horses were well-accustomed to each housing system and had spent at least two months with access to all four shelters in the open barn facility before starting the study. The horses were also accustomed to each other, since they had spent 6–8 weeks together on pasture and time together in the open barn during autumn prior to the study. No horse displayed any stereotypic behaviour.

2.2. Data collection

The study comprised four treatments, in four 10-day periods (Fig. 1). Each period was divided into seven days of acclimatisation, followed by three days of video recording. All horses were exposed to all treatments in a cross-over design. During treatment 1 (control), the horses were kept in single boxes (10.5 m^2/horse) at night, and in a paddock during daytime (when not being ridden). This stable was insulated but not heated, meaning that the outside weather had an impact on temperature at nights. Due to limited number of boxes, these horses were divided into two treatment groups, period 1a and 1b, starting with four horses in period 1a and followed by another group of four horses in period 1b. Only the four horses being filmed were housed in the single boxes, while the other four remained in the active open barn with the other horses during the period. The horses participating in period 1a and 1b spent daytime together in the paddock with the other horses participating in the same treatment period. The same four single boxes, bedded with shavings, were used during the two periods in treatment 1. In treatment 2, the horses only had access to one shelter with available lying area of 8 m^2/horse. In treatment 3, the horses had access to two shelters, with total available lying area of 18 m^2/horse. In treatment 4, the horses had access to a shelter with total available lying area of 28 m^2/horse. All shelters were bedded with straw. In total, 12 horses were included in video-recorded observations across all four treatment periods, but only 10 horses were housed in the active open barn during treatments 2–4. Eight horses were observed during treatments 1–3 and participated in all four treatments. The horses were identified using symbols and letters on their rugs. The study ran from mid-February 2016 to early May 2016. Average daytime and night temperature was, respectively: − 1 °C and − 2 °C during treatment 1; + 9 °C and 0 °C during treatment 2; + 6 °C and − 1 °C during treatment 3; and + 15 °C and + 3 °C during treatment 4. All horses in treatments 1–3 wore rugs. Due to the warm weather during treatment 4, several horses no longer wore rugs, which led to difficulties in identifying some horses at night, so individual recordings were not possible in treatment 4.

Activities in single boxes and shelters were monitored using up to four infrared (IR) night-and-day network cameras for outdoor use (HIKVision model: DS 2CD4D26FWD-IZS). Data for the same set-up and horses were used previously in Kjellberg et al. (2021b). No video recordings were made when the horses were outside in the paddock during treatment 1, while four cameras were used when they were housed in the single boxes. Two cameras were used during treatment 2. Four cameras were used during treatment 3 for video-recording (two in each shelter) and two cameras during treatment 4. Observations were carried out as continual focal sampling for treatments 1–3 and continuous group sampling for treatment 4, and recorded as listed in Table 1.

2.3. Facilities

Treatment 1: A stable with 25 single boxes (3 × 3.5 m) was used in the control (treatment 1), where the horses were housed prior to the treatments in the active open barn. This stable was situated immediately next to the active open barn. In treatment 1, the horses were fed haylage according to their individual needs (1.3–1.8 kg DM per 100 kg bodyweight) four times a day, and concentrate twice. They spent 4–6 h daily in a paddock measuring 12,000 m^2. Each single box had an automatic watering bowl and had deep littering consisting of wood shavings. The bedding was mucked out every 8 weeks. The horses were able to socialise with neighbouring horses through nose contact via grids.

Treatments 2, 3 and 4: In all these treatments, the horses were housed in an open barn system for 24 horses at Swedish National Equestrian Centre Strömsholm. The open barn system consisted of one paddock of 3600 m^2 and had a total indoor lying area of 460 m^2 divided

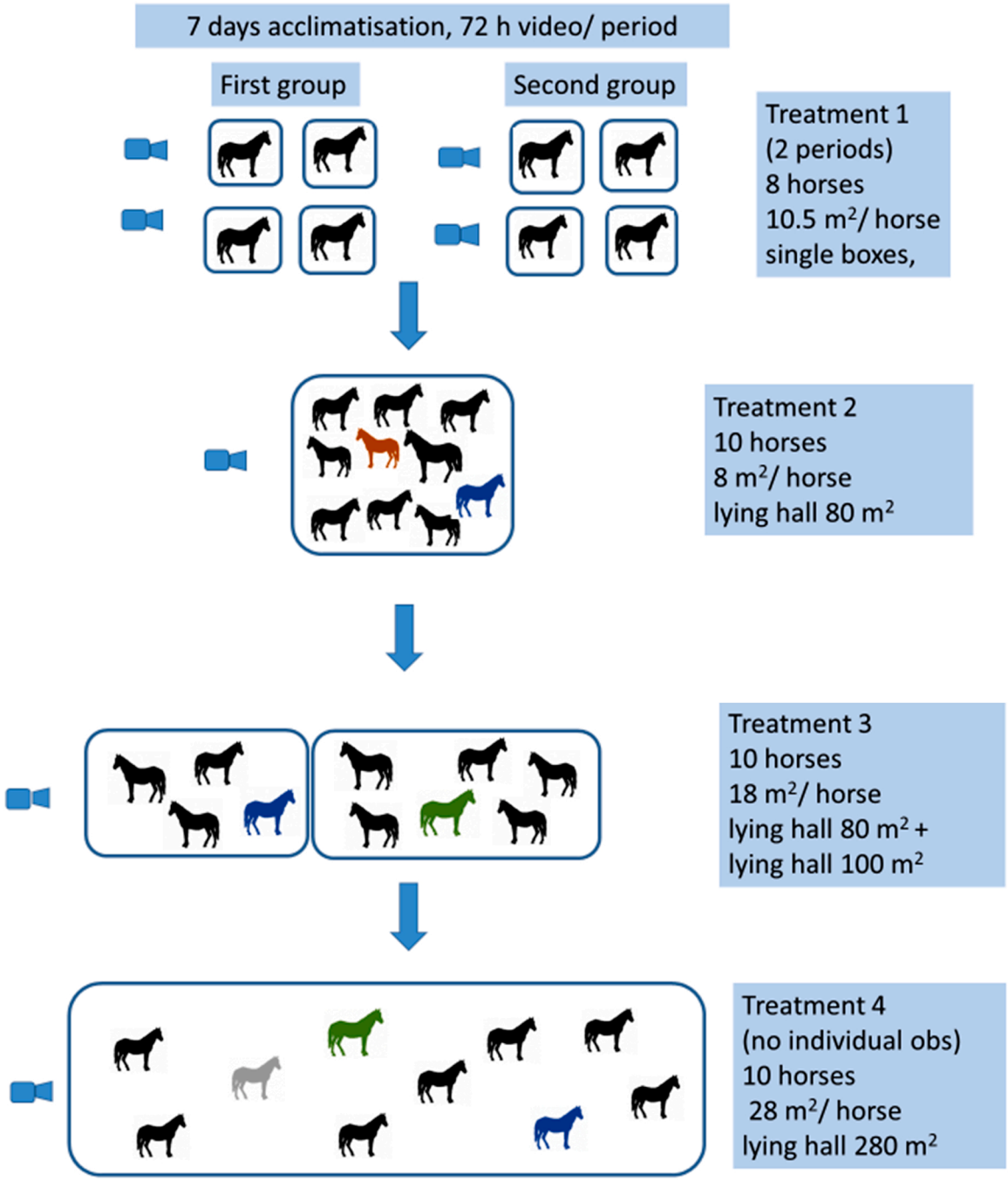

Fig. 1. Flow chart showing treatments 1–4. In treatment 1 (control), the horses spent the night in single boxes and daytime together in a paddock. The eight horses in treatment 1 were divided in two periods due to limited number of available cameras, with the four being filmed housed in the single boxes and others remaining in the active open barn. Horses in treatment 2 had access to one shelter. Horses in treatment 3 had access to two shelters (one of which was that used in treatment 2). Horses in treatment 4 had access to a large shelter. Horses in black participated in all four treatments, those in blue in treatments 2–4, those in green in treatments 3 and 4, the red horse in treatment 2, and the grey horse in treatment 4.

into four shelters, with the possibility of closing individual shelters (Fig. 2). The shelters used in the study were different. Those in treatment 2 and 3 had open fronts, designed as sheds, while the shelter in treatment 4 had enclosing three entries. The horses were housed and fed using the HIT Active Stable® (Weddingstadt, Germany) feeding system, which delivered haylage and concentrate at automatic computer-controlled feeding stations, as described by Kjellberg and Morgan (2021b). The bedding in the shelters was straw, on a concrete floor, so the horses were also able to feed there. The straw, with a depth of around 30 cm, was topped up once a week and removed once a year when the horses left for pasture. The system had automatic watering bowls. The horses' use of the shelters during treatments 2–4 and their behaviour in these were monitored using up to four IR night-and-day network cameras for outdoor use.

2.4. Statistical analysis

The results shown are mean values of all observations. Observations during treatments 1, 2 and 4 were based on 72 h of video recording, but there were only 48 h of video recording in treatment 3, as the horses

Table 1
Ethogram of behaviours exhibited and recorded during video observations. Ethogram based on Raabymagle and Ladewig (2006), further modified with added details.

Behaviour exhibited	Behaviour explained
Sternal recumbency	Lying down on sternum with hindquarters touching the ground and with head up or nose touching the ground and legs not stretched out
Lateral recumbency	Lying down on side with head and neck touching the ground, legs stretched out
Standing up with no rolling behaviour	Standing up, front legs stretching first, sitting, and then stretching also the hindlegs, without performing rolling behaviour just before standing up
Standing up after a half roll	Standing up after performing a half roll, defined as the horse first lying in sternal or lateral recumbency and then rolling with the back touching the ground, without rolling over to the other side, just before standing up (45°–90° roll)
Standing up after a full roll	Standing up just after performing a full roll, defined as the horse first lying in sternal or lateral recumbency and then rolling from one side to another over the back (180° roll)
Disturbance	A horse lying down is approached or touched by another horse and remains lying down, but changes position (e.g. lateral to sternal recumbency). This behaviour could not be recorded when horses were in single boxes
Forced to stand up	The horse is forced to stand up by another horse using physical contact or close physical approach, e.g. threat. This behaviour could not be recorded when horses were in single boxes.

broke through the barrier to a closed-off shelter on the last night. Observations of 'forced to stand up' and 'disturbed' were only recorded in treatments 2, 3 and 4, since these behaviours did not occur in period 1. For treatment 4, there were no individual recordings and this treatment was therefore not included in the statistical analysis, so the mean values only represent mean of the group of horses. Only eight horses participated in treatments 1, 2 and 3, and therefore only eight horses were included in the statistics. Statistical analyses were conducted using RStudio (Boston, USA, version 1.2.5033). The data were processed using Poisson regression, with horse as variable factor and treatment as fixed factor, using the model: glmer1 < -glmer (sternal~beh + (1|Namn), data = hast, family = "poisson"). To ensure that the variance was not the same as the mean in the analysis, a negative-binomial distribution was created according to the model: glmer.nb1 < -glmer.nb (sternal~-beh + (1|Namn),data = hast).

3. Results

3.1. Lying behaviour

Significantly less total time lying down was displayed when horses were housed in a shelter with 8 m^2 available lying area compared with 18 m^2 available lying area ($Z = 3.557$, $p = 0.001$) or single boxes ($Z = -4.299$, $p = 0.0001$) (Table 2). With 8 m^2 available, the horses spent less time in sternal recumbency compared with single boxes ($Z = -4.349$, $p < 0.001$) or 18 m^2 available lying area ($Z = 3.461$, $p = 0.002$). Significantly less time was spent in lateral recumbency with 8 m^2 available lying area compared with single boxes ($Z = -2.423$, $p = 0.004$). There was a tendency for shorter lateral recumbency with 8 m^2 lying area compared with 18 m^2 ($Z = 2.231$, $p = 0.07$). Minutes spent in sternal and lateral recumbency did not differ between single boxes and 18 m^2 available lying area per horse. There were no differences in percentage distribution between sternal or lateral recumbency in treatments 1, 2, 3 and 4. Lateral recumbency varied from 34% to 39% of the total lying time.

The highest number of horses lying down simultaneously was seven in all shelters during the whole study. This was observed once when the horses had access to 8 m^2/horse, four times when they had access to 18 m^2 (only in the larger shelter, Shelter 2, 100 m^2) and 11 times when they had access to 28 m^2. In treatment 3, where the horses had access to two shelters, when they were lying down they spent on average more time lying down in the larger (Shelter 2, 100 m^2) than the smaller (Shelter 1, 80 m^2) shelter, measured both as sternal recumbency (17% and 83%, respectively) and lateral recumbency (8 % and 92 %, respectively) in each 24-h period.

Three horses were not observed in lateral recumbency at all when housed in the shelter with 8 m^2/horse and one of these was not observed in lateral recumbency in the single box either (Table 3). One young horse was observed to lie down twice on the hard surface outside the shelter when only given access to 8 m^2 lying area/horse. During the control treatment, none of the horses was observed to lie down in the paddock.

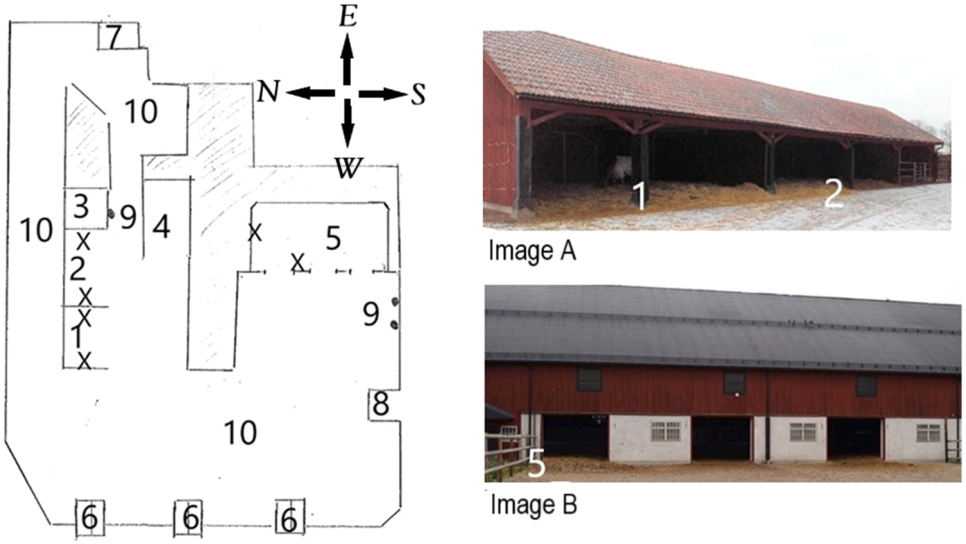

Fig. 2. Detailed design of the open barn and the shelters used in the study. 1) Shelter 1 (Image A: open front, 80 m_2) used in treatments 2 and 3). 2) Shelter 2 (Image A: open front, 100 m^2) used in treatment 3). 3) Acclimatisation box. 4) Shelter not used in the study. 5) Shelter 3 (Image B: four sides with three openings, 280 m^2) used in treatment 4). 6) Automatic forage stations. 7) Automatic concentrate station. 8) Hay bar (not used during the study). 9) Watering bowls. 10) Paddock. X) Cameras.

Table 2
Mean total lying time and time spent in sternal and lateral recumbency (max-min) in minutes, calculated for eight horses with different available lying area. There were significant differences in sternal recumbency and total lying time for available lying area of 8 m^2/horse compared with 18 m^2 lying area/horse ($Z = 3.461$, $p = 0.002$ and $Z = 3.557$, $p = 0.001$, resp.) and single box (control) ($Z = -4.349$, $p < 0.001$ and $Z = -4.299$, $p = 0.0001$, resp.) but no differences between available lying area of 18 m^2 and single box. Lying time in lateral recumbency showed significant differences between available lying area of 8 m^2/horse and single box ($Z = -2.423$, $p = 0.004$), and a tendency for differences between available lying area of 8 m^2/horse and 18 m^2/horse ($Z = {}^2.231$, $p = 0.07$). No individual observations were made when the horses had access to a lying area of 28 m^2/horse, and therefore no min-max range is presented for that treatment.

Available lying area/ horse	Sternal recumbency	Lateral recumbency	Total lying time
single box, 10.5 m^2	94(25–183)	52(0–123)	145(29–269)
shelter, 8 m^2	47(0–136)	22(0–86)	69(0–222)
shelter, 18 m2	82(35–137)	48(0–142)	130(35–270)
shelter, 28 m^2	82	51	132

3.2. Lying bouts and standing up behaviour

The horses had significantly fewer lying bouts/horse in the shelter with 8 m^2 available lying area compared with the single boxes ($Z = -2.910$, $p = 0.01$) or the shelter with 18 m^2 available lying area ($Z = 3.564$, $p = 0.001$) (Table 4). There were no differences in number of lying bouts between the shelter with 18 m^2 available lying area and the single boxes. Number of lying bouts during a 24-h period was 1–6 in the single boxes, 0–5 with 8 m^2 lying area and 2–10 with 18 m^2 lying area. Comparing total lying time per bout, the horses lay down in significantly longer bouts in the single boxes and with 18 m^2 available lying area compared with 8 m^2 lying area ($Z = 2.478$, $p = 0.04$ and $Z = -2.345$, $p = 0.05$, respectively). Standing up without performing any form of prior rolling behaviour was the most common behaviour in the single boxes and in the shelters with available area per horse of 8 m^2 and 28 m^2 (Table 4). The horses performed more full rolling behaviour when the available lying area in the shelter increased from 8 m^2 to 18 m^2/horse. Full rolling behaviour was only observed once in the single boxes. Standing up after a half roll was observed in all four treatments, but more often in the single boxes and in the shelter with access to 18 m^2 available lying area per horse (treatment 3) compared with 8 m^2 and 28 m^2 per horse (treatments 2 and 4). There were no differences between single boxes and the shelter with 18 m^2 available lying area when comparing rolling behaviour prior to standing up. About a quarter of all lying bouts were ended by the horse being forced up by another horse in all shelters and the frequency of this, on average every 10 min, did not seem to differ with available lying area. All horses were forced to stand up by another horse at least once in the shelters with 8 or 18 m^2 available lying area. No horse rolled before being forced to stand up. The horses were disturbed on average every 9 min in the shelters. Analysis of disturbances revealed no differences between 8 and 18 m^2 available lying area/horse in relation to lying time. Analysis of individual observations revealed that all horses except one were disturbed once or twice during one of the 24-h periods. Forcing another horse to stand up was performed by all horses, but disturbances were only recorded for five horses. These behaviours were also noted when the horses had access to 28 m^2 available lying area but since the horses could not be identified, no individual comparisons were possible.

4. Discussion

4.1. Effect of available lying area in the shelter on horses' lying behaviour

This study recorded horses' lying behaviour in shelters with varying available lying area and compared this with the lying behaviour of horses kept in single boxes. Resting time, and especially duration of REM sleep, is important for horse welfare, with a reported need for 30–70 min REM time per 24-h period (Fuchs et al., 2018; Greening et al., 2021).

Lateral recumbency, a prerequisite for REM sleep, was used in the present study as an approximation of time spent in REM sleep. The horses were found to have mean lateral recumbency of 22 min/24-h period when given access to 8 m^2 lying area. Of course, their REM sleep

Table 4
Number and duration of lying bouts by horses (mean±standard error) and behaviour when standing up for shelters with different available lying area (presented as percentage of standing up events). There were significant differences in number of lying bouts between 8 m^2 available lying area and single boxes ($Z = -2.910$, $p = 0.01$) and 18 m^2 available lying area ($Z = 3.564$, $p = 0.001$) and in lying duration between 8 m^2 available lying area and single boxes ($Z = 2.478$, $p = 0.04$ and 18 m^2 available lying area ($Z = -2.345$, $p = 0.05$). No individual observations were made when the horses had access to 28 m^2 lying area, and therefore no standard error is presented for this treatment.

Available lying area/ horse	Mean no. Of lying bouts	Mean lying duration, min/bout	No rolling	Half roll	Full roll	Forced to stand up
single box, 10.5 m^2	3.5 ± 0.3	40.8 ± 2.7	71 %	29 %	0 %	–
shelter, 8 m^2	2.1 ± 0.3	30.6 ± 3.4	33 %	12 %	29 %	26 %
shelter, 18 m^2	4.0 ± 0.5	40.0 ± 2.7	22 %	22 %	33 %	24 %
shelter, 28 m^2	3.6	37.1	64 %	9 %	5 %	21 %

Table 3
Time (minutes) spent in different lying positions (mean±standard deviation) by the eight horses participating in treatments 1 (control), 2 and 3. Horses 1–4 were aged 8–17 years, horses 5–8 were aged 3–4 years.

		Horse							
Treatment	Behaviour	1	2	3	4	5	6	7	8
1: Single box 10.5 m^2	*Sternal recumbency*	71 ± 27	71 ± 54	35 ± 8	47 ± 19	117 ± 31	147 ± 54	130 ± 15	81 ± 11
	Lateral recumbency	0	41 ± 38	17 ± 17	20 ± 24	91 ± 17	76 ± 12	79 ± 16	77 ± 48
	Total lying time	71 ± 27	113 ± 89	52 ± 25	68 ± 39	208 ± 43	223 ± 66	209 ± 7	157 ± 37
2: Shelter 1 8 m^2/horse	*Sternal recumbency*	20 ± 8	39 ± 16	41 ± 31	28 ± 8	53 ± 9	68 ± 10	100 ± 33	2 ± 1
	Lateral recumbency	0	9 ± 16	17 ± 10	48 ± 15	45 ± 32	10 ± 5	63 ± 20	11 ± 12
	Total lying time	20 ± 8	48 ± 31	58 ± 26	77 ± 14	98 ± 35	78 ± 15	163 ± 52	13 ± 13
3: Shelter 1 + 2, 18 m^2/ horse	*Sternal recumbency Shelter 1*	0	0	39 ± 5	0	3 ± 4	75 ± 38	0	9 ± 13
	Sternal recumbency Shelter 2	97 ± 15	73 ± 5	0	56 ± 27	69 ± 33	45 ± 63	109 ± 26	55 ± 35
	Total sternal recumbency	97 ± 15	73 ± 5	39 ± 5	56 ± 27	71 ± 30	120 ± 25	109 ± 26	64 ± 22
	Lateral recumbency Shelter 1	0	0	9 ± 12	0	6 ± 8	22 ± 31	0	1 ± 1
	Lateral recumbency Shelter 2	22 ± 0	23 ± 6	0	43 ± 4	71 ± 64	27 ± 38	132 ± 14	33 ± 47
	Total lateral recumbency	22 ± 0	23 ± 6	9 ± 12	43 ± 4	76 ± 57	49 ± 16	132 ± 14	34 ± 46
	Total lying time	119 ± 15	95 ± 2	47 ± 17	99 ± 31	147 ± 86	169 ± 32	241 ± 40	97 ± 68

may have been slightly longer than 22 min, since horses can also achieve REM sleep in sternal recumbency if the head is supported by the ground (Williams et al., 2008), a position that could not be specifically analysed in this study. On adding the time spent in sternal recumbency, the total lying time increased to 69 min/24-h period, indicating a greater likelihood of satisfying the horses' need for rest and sleep. However, duration of lateral recumbency was halved in the shelter with 8 m^2 available lying area per horse compared with shelters with larger available area and individual boxes, raising concerns about the welfare of group-housed horses with limited lying area. The observed reduction in lying behaviour in small spaces is consistent with findings in other studies (Raabymagle and Ladewig, 2006; Burla et al., 2017; Kjellberg et al., 2021a).

Mean lying time of the horse group was not alarmingly low in the treatment with 8 m^2 lying area/horse, but five horses spent on average a mere 17 min or less in lateral recumbency. One of these horses was not observed lying in lateral recumbency at all, either in the single box (10.5 m^2) or when given access to 8 m^2 lying area/horse, meaning that this individual may have been at risk of sleep deprivation. In treatments 1, 2 and 4, mean duration of lateral recumbency was well above 30 min and the horses' need for sleep was likely better fulfilled. When the horses had access to two shelters in treatment 3 (total 18 m^2 lying area/horse), four of the horses only lay down in the larger of these shelters (100 m^2 versus 80 m^2), which indicates that even a small increase in lying area could be important for horses. To fulfil the need for sleep and rest, 18 m^2 lying area/horse seemed to be sufficient, as 28 m^2 lying area/horse did not significantly increase lateral recumbency. Dividing the lying area in treatment 3 between two shelters clearly affected the behaviour of the horses, e.g. four horses always chose the larger shelter for lying down and three others only spent up to 10 min lying down in the smaller shelter. The difference between one large shelter and several smaller shelters needs to be studied further to determine the welfare impact on horses.

4.2. Effect of lying area on disturbance behaviour and lying bouts

The horses performed fewer and shorter lying bouts in the shelter with 8 m^2 lying area/horse than in the other treatments. No statistical analysis was possible using data for the largest available lying area (28 m^2/horse), but the number of lying bouts (3.6/24-h) appeared to be at the same level as with a lying area of 18 m^2 (4.0 lying bouts/24-h). Bouts ended voluntarily or following interference. When rising from the lying position in single boxes, the horses generally did so without any prior rolling behaviour and they never showed a full roll, which is consistent with findings in other studies (Pedersen et al., 2004; Raabymagle and Ladewig, 2006). However, in a study by Chung et al. (2018), horses kept in larger single boxes (10.2–16.2 m^2) than in this study (10.5 m^2) exhibited rolling behaviour before rising from lateral recumbency, indicating that our result was due to the smaller boxes. Likewise, when the horses had access to the largest lying area (28 m^2/horse), standing up without prior rolling behaviour was the most common way of getting up. With the smallest available area in the shelter (8 m^2/horse), all horses except one showed a full roll prior to getting up on at least one occasion. Full rolling prior to rising has been observed in horses on pasture (Hansen et al., 2007), indicating that a full roll may be a comfort behaviour when there is enough space. In this study, frequency of rolling prior to rising behaviour varied from 14% to 55%, compared with around 30% in other studies (Pedersen et al., 2004; Raabymagle and Ladewig, 2006; Hansen et al., 2007). How rising behaviour varies between housing systems and whether it is a potential indicator of welfare status need to be studied in more detail.

Horses housed in groups inevitably affect each other, with one impact being that they may disrupt each other's rest. Disturbances in this study were defined as physical contact and were recorded only in the shelters, as the horses were housed alone in the single boxes. On comparing the different treatments in the shelters, the level of disturbance did not vary when corrected for lying time, but longer lying time involved numerically more disturbances. One horse was forced to get up three times during the three observation days in the hall with 18 m^2 lying area/horse, but that horse had total lying time of over 100 min so its welfare was likely not compromised. To our knowledge, disturbances during sleep in group-housed horses have not been studied previously. This study indicated that inter-horse variation in need for sleep and rest may be large, so disturbed sleep should be studied further.

4.3. Strengths and weaknesses

Using wood shavings in the single boxes and straw in the shelters could have affected the results, since lateral recumbency may be longer on straw (Pedersen et al., 2004; Kwiatkowska-Stenzel et al., 2016). However, straw has also been observed to decrease total lying time in shelters, due to disturbances between horses due to foraging in the straw bedding (Werhahn et al., 2009), leading to shorter lying bouts (Baumgartner et al., 2015). In an earlier study using the same horses, we found that foraging behaviour increased with larger lying area (Kjellberg et al., 2021a). Another consideration is that we only recorded lying behaviour in the horses, whereas Fuchs et al. (2018) used a polysomnograph and Keleman et al. (2021) used a gyroscope to measure sleep.

As previous housing conditions may influence sleep profile, to avoid carry-over effects we allowed an acclimatisation period of seven days before starting observations of a new treatment. The design of the shelters, and individuals within the social group affecting each other, likely also influenced the results. All shelters had openings on one side but the design varied, and to our knowledge there are no systematic studies of impacts of shelter design. There were some changes in group composition during the four treatments, which could have affected the social dynamics in the group and therefore the observed lying time and behaviour of the horses (Fader and Sambraus, 2004). Three horses included only in treatments 2 and 3 and three included in treatments 3 and 4 were all familiar with the other horses in the group and had been together on pasture and in the open barn prior to the study.

Disturbances were defined here as physical contact or close approach by a horse to a lying horse. However, horses can be disturbed during sleep and rest by sound and light, which can occur also when horses are kept in single boxes. Therefore, the horses kept in single boxes (control) could have had interrupted lying bouts. Disturbances were sometimes difficult to detect and could have been missed, e.g. threats and physical approaches farther away than 1 m away were difficult to see in the videos, but could have affected the behaviour of horses lying down.

4.4. Practical implications

This study revealed the importance of available lying area when housing horses in groups. If horses' need for sleep is not met, this can cause short- and long-term welfare issues, including episodic collapses (Fuchs et al., 2018). Building a shelter can be a major financial commitment for horse owners, so it is important to identify the optimal lying area. Based on findings in this study, the optimal lying area is between 8 and 18 m^2/horse, at least for shelters with one open side. The size of the horses may matter, as well as their personalities and social dynamics. A horse with height 175 cm (at the withers) would occupy an area of around 8 m^2 when lying and, depending on the social structure of the group, the individual distance between horses may be several metres. There may also be other advantages with larger shelters, such as better hygiene, possibilities for foraging and room for social and comfort behaviours. Our results need to be confirmed in systems without automatic feeding stations.

5. Conclusions

Available lying area and the behaviour of other horses affected lying behaviour in several ways. Greater available area in the shelter meant

that horses lay down for almost twice as many bouts and for almost twice as long as with a smaller lying area. Number of lying bouts and behaviour while rising from the lying position were also affected by available lying area. Thus it is likely that the space requirement to meet the need for rest in group-housed horses is larger, not smaller, than for horses in individual boxes.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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