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Effects of a light-colored cotton rug use on horse thermoregulation and behavior indicators of stress

Barbara Padalino [a,b,*], Jaymie Loy [c], Lesley Hawson [c], Hayley Randle [c]

[a] College of Veterinary Medicine and Life Science, City University of Hong Kong, Kowloon, HKSAR, Hong Kong
[b] Department of Veterinary Medicine, University Aldo Moro, Bari, Italy
[c] School of Animal and Veterinary Sciences, Charles Sturt University, Wagga Wagga, New South Wales, Australia

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ABSTRACT

When environmental temperatures exceed 25°C, horses are potentially subjected to thermal stress. It has therefore been recommended that horses should be provided with shade during hot days. However, this is not possible for horses grazing on many Australian rural properties. Although the positive effect that solar radiation blocking can have on reducing heat absorption is understood by some, conflicting views, mostly anecdotal, exist on the use of a light cotton rug on horses for this purpose. The aim of this pilot study was to examine the effects of wearing a light-colored cotton rug on horse heart rate (HR), respiratory rate (RR), rectal temperature (RT), sweat production, and selected stress-related behaviors. Data were collected for 2 groups of university-owned horses (n = 8 and 10, respectively). The horses were tied in an outdoor arena in direct sunlight for 2 hours on 2 different days (D1 and D2). Baseline behavioral and physiological data (T0) were noted, recording frequency (n/10 min) of tail swishing, licking-chewing, pawing, repeated head movements, and self-care and recording HR, RR, RT, and sweat production using a sweat score (0 = none to 5 = excessive). Half of the horses were then fitted with a light cotton rug, and all horses were observed and monitored at regular 15-minute intervals for a further 2 hours (T1-T8). The effect of repetition (D1 and D2) and time (T0-T8) was not significant; therefore, the data were combined and analyzed using the Mann-Whitney *U*-test with rug (rugged/unrugged) as the independent variable. RT and sweat score were significantly lower in unrugged horses compared to rugged horses (37.4 ± 0.3 vs. 37.7 ± 0.3°C; 0.5 ± 0.8 vs. 1.9 ± 1.3, respectively; $P < 0.001$). However, unrugged horses showed a significantly higher frequency of tail swishing and pawing (23.1 ± 25.9 vs. 8.7 ± 11.0 n/10 min; $P < 0.001$; 9.4 ± 21.2 vs. 5.8 ± 17.4 n/10 min; $P = 0.018$). Although wearing a rug did not have an effect on the other parameters, it is worth noting that HR, RR, and the occurrence of stress-related behaviors were higher than normal values for equids, suggesting that horses were potentially prone to discomfort. Overall, it appears that the use of light-colored cotton rugs may help reduce the irritation caused to horses by flying insects as evidenced by less tail swishing but may also lead to an increase in internal temperature and subsequently sweat production, increasing the risk of thermal stress and loss of electrolytes. Wearing a rug is not an adequate substitute for the provision of shade when ambient temperatures exceed 25°C.

Introduction

Direct sunlight has a significant impact on mammalian core body temperature as radiation is absorbed by the body as heat (Hodgson, 2014; Holcomb et al., 2013). As mammalian homeotherms, horses regulate and maintain their core body temperature through thermoregulation (Mrowka & Reuter, 2016) involving physiological and behavioral processes (Holcomb et al., 2013). A number of mechanisms are used to dissipate heat and reduce core temperature including evaporation, conduction, radiation, and convection (Hodgson, 2014). Evaporation is the primary process with the body tissues conducting heat to the skin, via the bloodstream and skin capillaries, transferring it to the external environment (Kohn & Hinchcliff, 1995). The horse's large body mass to surface area ratio reduces the individual's ability to achieve rapid heat transfer efficiently. Morgan (1998) reported a baseline rate of total heat loss from horses of 142 W m^{2-}, which remains stable in

* Address for reprint requests and correspondence: Barbara Padalino, University of Bari, Casamassima St Km 3, 70010 Valenzano, Bari, Italy. Tel: +390805443935; Fax: +390805443925.
E-mail address: barbara.padalino@uniba.it (B. Padalino).

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ambient temperatures ranging from 5°C to 25°C. Horses living in countries such as Australia will be exposed to potentially extreme weather conditions (well in excess of 25°C often accompanied by high humidity) in the summer, often for consecutive days (Australian Government Bureau of Metereology, 2018).

The provision of shade during periods of hot, sunny weather for animals is known to be important and has been linked to behavioral and physiological benefits for horses (Holcomb et al., 2015; Holcomb & Stull, 2016). The Australian Animal Welfare Standards and Guidelines (2018) include standards that must be adhered to and guidelines defined as “recommended practices to achieve desirable animal welfare outcomes” (www.animalwelfarestandards.net.au); the provision of shelter is recommended to safeguard horse welfare in summer. Similarly, the Australian Horse Welfare and Well-Being Toolkit (Australian Horse Industry Council, 2013, p.11) provides advice for horse organizations and event-based horse welfare officers, recommending the provision of shade and working on nonreflective surfaces under weather conditions classified as moderate and above.

A number of studies have considered equine management practices across Australia. McGowan et al. (2010) reported that 80% of horses are rugged at some point during the year, and 50% wear a rug all year round. Rugging has been suggested to protect horses from thermal stress in winter (Hammer & Gunkelman, 2017; Hartmann et al., 2017) through increasing horse surface temperature, the extent of which may depend on rug weight (Slaubaugh & Hammer, 2015). A choice-based study conducted by Mejdell et al. (2016) suggested that horses preferred to wear a rug when the weather was wet, windy, and cold.

In some countries, rug use is justified on the basis of avoiding the occurrence of skin conditions such as rain scald (dermatophilosis) due to the skin remaining wet for prolonged periods particularly on the back, but in other countries, the use of rug may actually potentiate dermatophilosis (Huntington et al., 2004). Working horses are commonly clipped/shorn (removing part or all of their coat) to limit excessive sweating and to facilitate rapid drying after work. The removal of a horse coat eliminates their piloerection mechanism, necessitating the use of rugs to enable the horses to maintain sufficient temperature when not working (Hammer & Gunkelman, 2017; Morgan, 1997). Rugs have also been designed specifically for performance and therapeutic reasons, for example, some incorporate ceramic components in their linings to promote heat production through infrared and reportedly reduce warm-up time before sporting activity (Sheel, 2002), while others incorporate magnets for therapeutic use (Edner et al., 2015; Rindler et al., 2014).

Rugging horses is a practice that requires high levels of owner input but does not necessarily benefit the horse (Hartmann et al. 2017; McGowan et al. 2010) although Azarpeykan et al. (2016) found that rug use all year around did not impair serum vitamin D and calcium levels. The physical impact of persistent rug wearing has yet to be fully investigated, but Clayton et al. (2010) found rugs may exert sufficient pressure on the withers to induce pressure sores. Those responsible for horses need to ensure that rug use takes into account the individual horse’s conformation to avoid the development of pain-related problems, appreciate the potential impact of persistent rug wearing on the horse’s longer term ability to thermoregulate, and consider the effect on the horse’s fundamental behavioral needs such as self-grooming and allogrooming (Hartmann et al., 2017; McDonnell, 2003).

The use of light cotton rugs in summer is commonly justified on the basis that they reflect sunlight and therefore decrease heat gain as demonstrated by light-colored roofs resulting in lower building heat gain (Suehrcke et al., 2008). Light cotton rugs are used to prevent or reduce the skin reactions especially for those horses suffering from insect bite hypersensitivity, to keep the horses’ coat clean and free of dust, and to prevent bleaching of the coat hair (Huntington et al., 2004).

There is no published research examining the effect of the use of light-colored rugs on physiological and behavioral parameters in horses. It was hypothesized that fitting horses with a light cotton rug in hot and sunny environmental conditions may affect behavioral and physiological measures. The aim of this pilot study was to compare the heart rate (HR), respiratory rate (RR), rectal temperature (RT), sweat score, and behavior of horses with and without a cotton rug when ambient temperatures exceed 25°C.

Methods and materials

Animals

Eighteen horses, a group of 6 geldings and a group of 12 mares, were selected at random from the horse herd belonging to Charles Sturt University, Wagga Wagga, NSW, Australia, in 2 different days. Horses ranged from 4 to 15 years old (7.5 ± 2.5), there were 8 standardbreds and 10 thoroughbreds, and all were black or bay in color. All the horses were in good health and appropriate body condition. All horses were subjected to identical husbandry practices including housing, grazing management, and environmental acclimatization. Before data collection, the horses had been housed in their usual outdoor yards for 1 hour and before that at pasture as per their normal husbandry conditions. The 2 groups of horses were tested between time 12.30 (T0) and 14.30 (T8) on the 10th of March (D1) and the 6th of April 2017 (D2) following the same procedure. The study was therefore repeated twice.

Study protocol procedure

Horses were led together to an outdoor arena at 12.20, tied up in direct sunlight, and allowed to acclimatize to this environment for 10 minutes. Baseline recordings (12.30; T0) were taken for each behavioral and physiological parameter. Horses were observed for 10 minutes, and then, their physiological parameters were recorded within the following 5 minutes. After recording behavioral and physiological baseline values, half of the horses were randomly selected to be rugged with a light cotton rug (Euro Hunter, Australia) (Figure 1). The same parameters were measured every 15 minutes for a total of 120 minutes (T1-T8). Time was measured using a digital stop watch (Dick Smith, NSW, Australia). Ambient temperature (°C), humidity (%), and wind speed (m/s) were monitored for the duration of the study, recorded at 5-minute intervals, using a weather station (Kestral 4000), positioned on the fence where the horses were tied.

Behavioral parameters

Behaviors believed to be indicative of stress were assessed according to a predetermined ethogram (Table 1) by trained

Figure 1. Rugged horse wearing light cotton sheet. Photograph: Barbara Padalino.

Table 1
Behavioral ethogram modified from Young et al. (2012) used to record horse behavior under direct sunlight with and without a light-colored cotton rug

Behavior	Description
Pawing	Striking a vertical or horizontal surface or the air with forelimb.
Tail swishing	Tail is flicked to one side and/or the other of the quarters.
Repetitive head movements	A repeated, relatively invariant sequence of movements with no obvious function including movements of the head such as headshaking, nodding, bobbing, and circling.
Licking and chewing	Gripping, mastication and swallowing feed, exploratory licking, and mouthing of surfaces and self, using the teeth, lips, or tongue.
Self-care	Noningestive behaviors involving the muzzle and teeth including allogrooming and swatting flies on body.

The occurrence of each single behavior was recorded on a time window of 10 minutes.

observers positioned approximately 5 m from the horse. A continuous time sampling method was used for each horse with all behaviors exhibited recorded. Every occurrence of each behavior was recorded instantaneously for 10 minutes providing data for sampling time intervals T0-T8.

Physiological parameters

HR was measured for a 15-second interval using a stethoscope (KindCare, China) and multiplied by 4 to obtain HR measured in beats/minute. RR was measured as breaths/minute by observing the number of flank movements in a 1-minute interval. RT was taken with a lubricated digital thermometer (ProVet, Australia) inserted into the rectum. Sweat score (from 0 to 5) was assessed, as per methods described by Holcomb et al. (2013), adding the presence of sweat at 5 specific body regions of the horse: neck, chest, girth, flank, and hindquarters (Figure 2).

Statistical analysis

Descriptive statistics were conducted, and normality was checked using the Anderson-Darling test for all recorded variables. The effects of repetition (D1 and D2), rug (rugged/unrugged), and time (T0-T8) on the physiological and behavioral variables were explored using Mann-Whitney *U*-test. *P* level was set at 0.05. Statistical analysis was performed using GenStat version 14 (VSNi International, Hemel Hempstead, UK). Data are expressed as mean ± standard deviation.

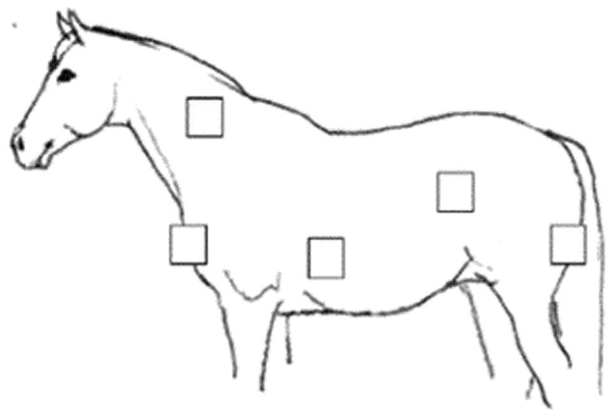

Figure 2. Diagram used to record visible, wet sweat in 5 body regions as indicated by boxes from Holcomb et al. (2013). Sweat score from 0 to 5.

Results

Weather/ambient conditions

Figure 3 illustrates the recorded environmental temperature and humidity during both days. The average temperature and humidity were 31.7°C and 22.5% and 26.0°C and 33.2% on day 1 and day 2, respectively. Both days were calm with a wind speed ranging from 0.5 to 2.5 m/s.

Behavioral and physiological parameters

All behavioral and physiological measures were nonparametric (all AD, $P < 0.05$). None of them were influenced by repetition (D1 and D2) (all *U*-test, $P > 0.05$) or time (T0-T8) (all *U*-test, $P > 0.05$). The effect of rug (rugged/unrugged) was significant for RT, sweat score, tail swishing, and pawing, but not for HR, licking, repeated head movement, and self-care behaviors (Table 2). Rugged horses showed a significant increase in RT and sweat production compared to unrugged horses. Rugged horses showed a lower frequency of stress-related behaviors, particularly tail swishing and pawing, than the unrugged horses. The mean values of HR, RR, and the mean occurrence of stress-related behaviors were higher in both rugged and unrugged horses than normal values for equids (Huntington et al., 2004; Young et al., 2012).

Discussion

Many horse owners believe to improve the welfare of their animals in warm conditions by using cotton rugs to provide reflective cover to their animals, reducing the risk of heat stress, and protecting them from flies and other insects. This pilot study explored the use of a light cotton rug on physiological and behavioral parameters, to better understand their effects on horse welfare on a hot sunny day when ambient temperatures exceed 25°C. The use of the cotton rug had significant impact on the RT, sweat score, and some behavioral parameters. The data partially supported the hypothesis since rugged horses showed clinical signs of thermal stress (increased RT and sweat score) but they displayed less tail swishing and pawing, suggesting that they were less bothered by flies. Our data contribute to filling a gap in knowledge within equine management, adding objective scientific evidence-based findings on the use of light cotton rugs in horses on hot sunny days where temperatures exceed 25°C.

The thermoneutral zone of horses ranges from 5°C to 25°C (Morgan, 1998). Within this range, horses can comfortably maintain their body temperature with little metabolic energy expenditure (Morgan, 1998) or negative impact on welfare (Dalla Costa et al., 2014). During the study, the environmental temperature was in excess of 25°C, consequently it was likely that some thermoregulatory mechanisms were activated in the rugged horses. Although there was no significant difference between the rugged and unrugged conditions for HR and RR, the mean HR and RR for both groups were above the normal range of 28 to 36 beats/minute and 10 to 14 breaths/minute (Horace Hayes, 2002). The values found in this study are similar to results reported for other horses monitored in summer (Holcomb et al., 2013; Holcomb et al., 2015) indicating both rugged and unrugged horses may have been affected by the heat and needed to actively thermoregulate. An increase in HR and RR is indeed the first response of thermoregulation (Mrowka & Reuter, 2016).

Evaporative heat loss and sweat production significantly increase in horses that are experiencing thermal stress (Morgan, 1998). The sweat score was significantly higher in rugged horses indicating that they were less effective in using evaporative heat

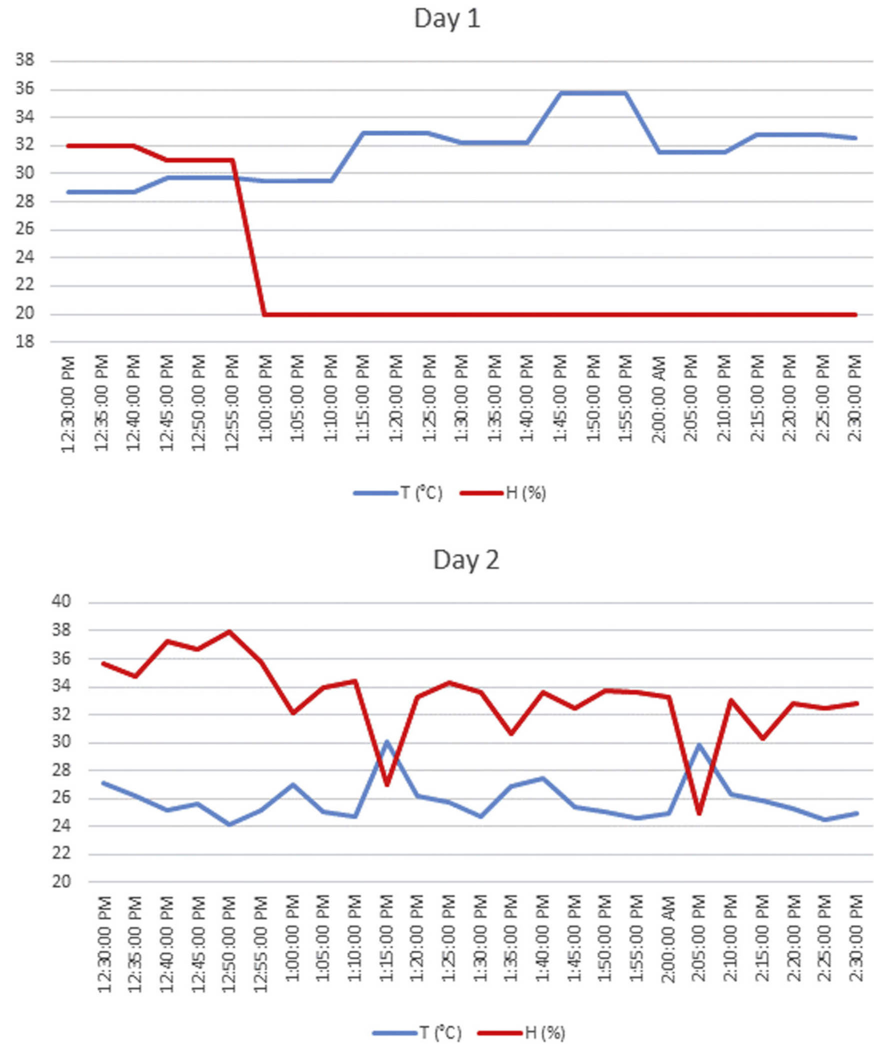

Figure 3. Temperature (°C) and humidity (%) recorded during the study every 5 minutes from 12.30 PM to 2.30 PM on the first repetition (10th of March; day 1) and on second repetition (6th of April 2017; day 2).

loss as a cooling mechanism. The wearing of a rug could have limited this natural process by providing a physical barrier to wind factor evaporation. Previously, Foreman et al. (2006) found that even a rug specifically designed to increase evaporative cooling in horses used after exercise did not help with cooling. The greater RTs and sweat production seen in rugged horses than in unrugged horses suggest that the light cotton rug may have inhibited the horses' ability to thermoregulate through the natural wind-mediated evaporation process. However, because the values of RT were still within the normal range for horses (Piccione et al, 2002), it is possible that both groups of horses were able to adequately thermoregulate regardless, although it could be argued that the rugged horses were under more heat stress. Similar increases in sweat production and RT have been reported by Holcomb et al. (2013, 2015) for horses standing in direct sunlight, which were unable to access shade. Therefore, rugging should not be considered an effective alternative to the provision of shade on hot days (i.e., those that exceed 25°C) to prevent heat stress.

In many areas of Australia, summers are characterized by hot, dry conditions, and the sun's ultraviolet radiation is higher in

Table 2
Physiological and behavioral parameters measured in rugged and unrugged horses

Parameter measured	Unrugged (n = 81)	Rugged (n = 81)	Mann-Whitney *U*	*P* value	Hypothesis accepted
Physiological measure					
Heart rate (beats/minute, bpm)	39.8 ± 7.6	39.3 ± 8.1	3086.0	0.507	Ho
Respiration rate (breath/minute, bpm)	23.9 ± 8.5	24.4 ± 9.4	3257.5	0.939	Ho
Rectal temperature (°C)	37.4 ± 0.3	37.7 ± 0.3	1865.0	<0.001	Ha
Sweat score	0.5 ± 0.8	1.9 ± 1.3	1409.0	<0.001	Ha
Behavioral measure					
Licking (n/10 min)	5.6 ± 5.5	6.3 ± 9.7	3058.0	0.453	Ho
Pawing (n/10 min)	9.4 ± 21.2	5.8 ± 17.4	2607.0	0.018	Ha
Repeated head movement (n/10 min)	7.9 ± 8.4	6.4 ± 9.6	2763.0	0.079	Ho
Self-care (n/10 min)	0.6 ± 8.4	1.2 ± 1.8	2785.0	0.061	Ho
Tail swish (n/10 min)	23.1 ± 25.9	8.7 ± 11.0	1939.5	<0.001	Ha

Data are expressed as mean ± standard error.

Australia than in many other countries (Gies et al., 2004), and therefore, assisting horses to thermoregulate effectively is a critical aspect of animal care and welfare. Although there is evidence that horses acclimatize to hot weather conditions (Geor et al., 2000), there is still a significant risk of heat stress for horses that are unable to dissipate heat effectively, which therefore can compromise the animals' welfare (Holcomb et al., 2013; Holcomb et al., 2015). In a recent Australian survey on horse management practices, all participants (n = 505) reported providing some form of shelter. However, although most participants provided either natural or man-made shelter within the horse's paddock, 8% reported using rugs rather than providing shelter (Thompson et al., 2017). Bearing in mind that most Australian horses are kept in the paddock on a full-time basis (Thompson et al., 2017), it can be argued that the provision of shelter should become mandatory and not just recommended, to safeguard horse welfare.

According to the scale of behavioral indicators of stress developed by Young et al. (2012), both rugged and unrugged horses showed a moderate to high level of stress. Pawing, tail swishing, and repeated head movements (all behaviors that have been considered related to stress) were displayed by both groups, confirming that both groups were uncomfortable in direct sunlight (Holcomb et al., 2013). Tail swishing and pawing were the only behaviors that differed significantly between the 2 groups, with unrugged horses displaying these behaviors more frequently. According to Young et al (2012), tail swishing indicates low-level stress, while pawing indicates medium-level stress. It can therefore be suggested that unrugged horses were more annoyed by flies as they did not have a physical barrier to prevent flies landing on their sensitive body (Watson, 2017). In this instance, tail swishing may be a result of insect avoidance behavior (McDonnell, 2003). Although in summer there are many flies, in certain climatic zones of Australia, some horses may develop fly-related skin disease, which is known as insect hypersensitivity or variously as summer itch, Queensland itch (Rose and Hodgson, 2000), or sweet itch. The findings of this study support the use of rugs to protect horses from insects and associated sensitivities and reactions to insect bites. However, a different type of rug that does not lead to an increase in body temperature should be recommended.

Our findings need to be considered as preliminary owing to a number of limitations. It must be considered that there may be some human error factors in the recorded data, given that HR was monitored by listening and counting and that RR was monitored visually using auscultation, which can be a difficult practical technique to master. The use of thermo-imaging and electrocardiogram technology could improve this in future studies. The number of horses, their use in an experiment, and repetitions were reduced to a minimum to meet ethical requirements; consequently more repetitions, a crossover design (allowing the same horses tested to be twice with and without rug with a washout period in between), a longer period of recording, and more horses of different breeds and ages should be investigated in future studies. Breeds, sex, and age of horses have all been indeed found to influence the reaction of an individual horse to changes in atmospheric conditions (Janczarek et al., 2015). It is interesting to note that no white horses and only particular type of rug were included in this study. Given that we are examining heat reflection, it raises the question of whether the cotton rug would have the same effect on a light-colored animal and whether different types of rug would give the same findings. Our data are therefore only applicable to dark horses and for the use of the tested light-colored cotton rug. Finally, it was impossible to ascertain whether the expression of stress-related behavior was due to heat and insect stress or also due to other possible stressors, such as separation from a herd mate or being tied for a substantial amount of time adjacent to a nonpreferred conspecific. Notwithstanding these limitations, this pilot study provides evidence-based information on an increasingly debated horse management practice. Cotton rugs are used extensively in Australia (McGowan et al., 2010; Padalino et al., 2016; Thompson et al., 2017). Based on our findings, it appears that on hot sunny days, a light-colored cotton rug leads to an increase in internal temperature and sweat production, but it may help in protection from flying insects. Overall, to safeguard horse welfare, the use of rugs should always be considered in relation to the environmental temperature, the presence of skin disease, the type of management, and monitoring the behavioral and physiological parameters of the rugged horse.

Conclusion

Light cotton rug use had significant effect on RT, sweat score, and some behavioral parameters. Significant increases in RT and sweat score suggest that cotton rug use may result in clinical signs of thermal stress in horses. To be free from thermal discomfort, horses should not wear these rugs and instead should have access to shade on hot sunny days. Significant differences between rugged and unrugged horses (decreased pawing and decreased tail swishing) suggest that cotton rug use may be beneficial in terms of reducing the impact of flies and other insects on horse comfort and therefore welfare. Further studies, addressing the mentioned limitations, are needed to confirm our preliminary results.

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Authors' contributions: Barbara Padalino designed the experiment, collected the data, analyzed the data, and wrote and edited the article. Jaymie Loy collected the data and edited the article. Lesley Hawson and Hayley Randle wrote and edited the article.

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Ethical considerations

This study was approved by the Animal Care & Ethics Committee of Charles of Sturt University (approved protocol A16102).

Conflict of interest

All of the authors declare that there is no conflict of interest.

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