Applied Animal Behaviour Science 288 (2025) 106661

Contents lists available at ScienceDirect

Applied Animal Behaviour Science

journal homepage: www.elsevier.com/locate/applanim

Effect of turnout rugs on the behaviour of horses under mild autumn conditions in the United Kingdom

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ARTICLE INFO

Keywords:
Horse rug
Horse blanket
Discomfort
Insect avoidance
Thermal comfort

ABSTRACT

The use of rugs (blankets) for horses is commonplace as a protective measure to keep horses warm and dry in inclement weather, or to protect them from direct sunshine or insects under warmer conditions. However, rugs can also result in thermal or general discomfort, and information on horse responses to rugs is needed to inform owner decisions. The aim of this experimental study was to assess the effect of turnout rugs on the behaviour of horses under relatively benign weather conditions, looking for indications of either positive (protective) or negative (discomfort) effects. Ten healthy horses, accustomed to wearing rugs, were recruited from two sites in southern England, and observed for 30-minute sessions (15–24 sessions/horse, 172 in total). Observations were counterbalanced to allow approximately equal numbers of observations with turnout rugs on and off, each horse experiencing both conditions. Ambient temperature varied from 1 to 15 °C, and windspeed from 6 to 15 mph and no signs of heat or cold stress were observed during the study. Generalised estimating equations (GEE) were used to estimate the parameters of the regression models and to account for correlations between repeated observations on the same individual horses. Significant interactions between Rug status and Location were found for *Standing, Grazing, Walking* and *Tail Swishing.* Rug wearing was associated with decreased *Walking, Tail swishing,* and *Grooming Self* at both study sites, decreased *Head Shaking* at one site and increased *Grazing* at one site. *Tail Swishing* increased by 1.33 counts for every 1 °C rise in temperature, and decreased by 0.84 counts for every 1mph increase in windspeed Midges (*Culicoides* spp) were informally observed at both sites and would have been more active at higher temperatures and lower windspeeds. Overall, the turnout rugs appeared to reduce this insect nuisance (as indicated by the reduced tail-swishing and head-shaking). However, the rugs were generally heavier than required for this purpose, and reduced *Grooming Self* and *Walking* could indicate restrictions imposed by rug design. In conclusion, when weather conditions are relatively mild (above 5 °C) horse welfare may be improved by the use of lightweight turnout rugs for fly protection.

1. Introduction

The use of rugs (alternatively described as blankets in some studies) for horses is commonplace as a protective measure. In colder climates, rugs are commonly used to keep horses warm (Mejdell et al., 2020). Generally, robust, waterproof “turnout” rugs are provided for horses kept (permanently or for short periods per day) outside, whilst insulated “stable” rugs are provided for horses housed indoors. Under very cold ambient temperatures, the effectiveness of this practice is demonstrated by an increase in lumbar surface temperature in rugged horses of up to 9 °C compared to non-rugged horses (Hammer and Gunkelman, 2020). In an online survey in the USA, just over half of owners stated that they rugged their horses for most of the winter period, primarily to protect their horses from rain, while the primary reason given for not rugging horses was that the horses had access to shelter (DeBoer et al., 2022). In Sweden 90.9 % of respondents stated that their warmblood horses were provided with rugs during turnout, while the corresponding number in Norway was 83.7 %. Rugs were mainly used during rainy, cold, or windy weather conditions and when ambient temperatures fell to 10 °C or less (Hartmann et al., 2017). In more temperate environments rugs are also commonly used, with 85 % of Australian owners rugging their horses, some employing as many as five or six rugs on the same horse simultaneously (Cox et al., 2023).

Clipping the winter hair coat of horses is a procedure designed to increase heat dissipation during exercise, facilitate the drying of sweat after exercise, and for reasons of appearance. Sports horses are most

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https://doi.org/10.1016/j.applanim.2025.106661
Received 29 January 2025; Received in revised form 26 April 2025; Accepted 29 April 2025
Available online 2 May 2025

likely to be clipped, with clipping prevalence reported as 68 % of sports horses in Germany (Steinhoff-Wagner, 2019), 67 % in Sweden and 35 % in Norway (Hartmann et al., 2017). Because clipped horses have a greater heat loss capacity, nearly all (over 95 %) are rugged day and night outside of exercise periods (Cox et al., 2023; Steinhoff-Wagner, 2019; Hartmann et al., 2017). However, at an ambient temperature of 6°C, clipped horses provided with rugs showed only marginally improved thermal comfort (indicated by respiratory rate) compared with unclipped rugged or unrugged horses (Morgan, 1997).

To some extent owner practice around winter rugging aligns with research showing that non-rugged horses seek shelter and heat primarily when conditions are wet (Proops et al., 2019), or wet and windy (Jorgensen et al., 2016), more so than when the weather is cold and dry. Horses that were trained to indicate their preferences using an operant conditioning procedure chose to wear rugs when the weather was wet and windy, and when the temperature dropped below −10 °C (Mejdell et al., 2019). In addition, providing rugs appears to reduce, although not eliminate, shelter seeking in wet and windy conditions (Jorgensen et al., 2019).

However, protection from inclement weather is not the sole reason for rug use. Lightweight rugs are often provided under summer conditions to protect horses from irritation caused by insects or from the direct effects of solar radiation (Padalino et al., 2019). In Australia, 60 % of owners said they rugged their horses on summer days, citing insect nuisance as the primary driver (Cox et al., 2023) and nearly 50 % of Swedish owners rugged their horses for this same reason (Hartmann et al., 2017). Padalino et al. (2019) found that a lightweight rug greatly reduced signs of irritation due to flies, with lower observed levels of tail swishing and pawing.

Other reasons for using rugs are to slow the rate of cooling after exercise (Hartmann et al., 2017) and to maintain cleanliness (Hartmann et al., 2017; Cox et al., 2023). Finally, under hot (>25 °C) and humid conditions, rugs containing ice packs can be used to cool horses effectively and reduce physiological signs of stress (Ojima et al., 2022).

Despite the protective benefits of rugs, there are also potential negative impacts for horse welfare. Rugs, depending on their precise design, may induce pressure or cause skin chafing or sores particularly around the withers (ridge between shoulder-blades) (Clayton et al., 2010). Horses are unable to put on or take off rugs themselves and so have little control over this aspect of their lives. After exercise, rugs reduce the cooling capacity of horses via reduced sweating and blood vessel dilation, leading to a risk of over-heating (Hartman et al., 2014). At temperatures above 20 °C, horses that had been trained to indicate their preferences chose not to wear rugs (Mejdell et al., 2020) and, despite reducing insect nuisance, at an ambient temperature of 26 to 32 °C and humidity of 22–33 %, horses wearing lightweight rugs had a higher rectal temperature and sweated more than non-rugged horses (Padalino et al., 2019). Horse welfare organisations have pointed to potential discrepancies between owner perceptions and horses' needs and have raised other concerns e.g. that rugs might interfere with Vitamin D metabolism or cause skin infections.

Another concern raised by researchers (e.g. Hartmann et al., 2017) and horse welfare organisations is that rugs may impede normal horse behaviour. Given the varying needs of horses of different breeds and ages under variable weather conditions and insect pressure, it is not surprising that up to 70 % of horse owners expressed uncertainty about rug use (Cox et al., 2023).

The aim of the current study was to describe the effect of turn-out rugs on the behaviour of healthy horses during autumn, a period which is marked in the UK by relatively mild but falling temperatures and increasing rainfall. It is a time of year when most flying insects have ceased activity but some (e.g. midges, *Culicoides* spp) remain active and when many owners are uncertain about the costs and benefits of rugging horses. To our knowledge there has been no previous research in this area.

Owing to the lack of prior work in this area we had no strong hypotheses. However, we predicted the following broad patterns of response: Rugs might be associated with (i) reduced cold (increased grazing, reduced standing/huddling) (ii) over-heating (reduced activity, increased drinking) (iii) discomfort (increased rolling, rubbing, attempts to self-groom), (iv) influence of rug weight (reduced activity), (v) reduced insect nuisance (reduced tail swishing, stamping, head shaking).

2. Materials and methods

2.1. Animals and locations

Ten horses were recruited for this experimental study which received ethical approval from the RVC (URN 2017 1738-3). Six horses were recruited from the teaching herd at the Royal Veterinary College (RVC) in Hertfordshire, England, and four additional horses from a herd used for private riding lessons near Weymouth, England. The RVC site of approximately 25,000 m^2 was fenced and all six horses were turned out together. The Weymouth site comprised two paddocks, each fenced and with hedges and trees around the perimeter. Horses Sc and Ri were turned out in one of the paddocks, approximately 32,500 m^2, while horses Er and Ro were turned out in a smaller paddock, approximately 6800 m^2. During the period of the study all horses were turned out during the day to graze, with no additional feed or forage provided, and they were stabled overnight. During daytime turnout when not participating in the study the horses wore rugs all the time to which they were well accustomed. The horses were aged between 4 and 14 years and were of mixed sizes and genders (see Table 1). Full background histories were not known although many of the subjects had been obtained from rescue centres. All horses, at time of observation, were clinically healthy, with no known medical issues reported by their owners or carers. The horses were all known to not suffer from sweet itch or insect bite hypersensitivity, and none of them showed signs of hair loss, chafing or wounding from wearing the rugs.

2.2. Study design and behavioural observations

During the period of the study no extreme weather conditions were forecast. Rug-wearing was therefore allocated according to a counter-balanced schedule, independently of ambient temperature, wind speed or cloud cover. However, rugs were not removed (and hence no observations were taken) on days when rain was forecast. Counter-balancing was used when allocating conditions as “Rug on” or “Rug off” to ensure that there was a near-equal number of observations of each condition, spread evenly across morning and afternoon sessions (Table 1). Horses were observed in their usual paddocks with their companions present, all horses used were used to being rugged and showed no signs of discomfort or objection to the rugging process. At least two people were present when rugs were fitted or removed at the start of each morning or afternoon session to ensure handler safety, this was in line with RVC guidelines. The RVC horses were observed between the 12th to 23rd of October 2020, and the Weymouth horses between the 27th October to 7th of November 2020. Horses were observed in both morning (09:00–12:00) and afternoon sessions (12.00–16.00) each day. The same number of observations were scheduled for morning and afternoon with greater flexibility in the longer afternoon period. Daily recordings were taken of ambient temperature, precipitation, and cloud cover. The average wind speed at each location at the time of observation was taken from a live commercial weather forecasting site (Accuweather).

Individual horses were not always available for every scheduled observation period due to their use for other purposes. The minimum number of observations for an individual horse was 15 × 30 min sessions over 9 days and the maximum was 24 × 30 min sessions over 12 days (Table 1). All rugs were standard waterproof turnout rugs, provided by the owners and therefore of varying brands. They all had a heavyweight outer construction and between 0 g and 200 g of filling for insulation.

Table 1
Horse characteristics and number of 30-minute observation periods of Rug On and Rug Off Conditions counterbalanced across morning (AM) and afternoon (PM) observation sessions. Horse location: RVC = Royal Veterinary College; W = Weymouth. Horse gender (G = gelding; M=mare). Horse size (H=horse > 144 cm at withers; P = pony ≤ 144 cm at withers).

Descriptor	Horse ID									
	Te	Me	Gl	Au	Ca	Fl	Er	Ro	Sc	Ri
Location	RVC	RVC	RVC	RVC	RVC	RVC	W	W	W	W
Sex and neuter status	G	M	M	M	M	G	G	G	M	M
Size	P	P	H	P	H	H	H	H	P	P
AM On	4	5	4	8	4	4	2	2	6	6
AM Off	5	4	4	1	5	4	3	3	6	6
PM On	2	2	1	3	2	5	5	5	6	6
PM Off	5	5	6	4	5	2	5	5	6	6

The overall weight of representative rugs, determined after the study, was between 3 and 4 kg. After rugs were added or removed at the start of each session, at least 30 minutes elapsed before observations were taken, to help with acclimatisation and allow horses to settle after the associated handling.

Following the acclimatisation, observations were performed of a single horse for 30 continuous minutes, with the observer standing at the in the field at the edge of the field where the horses were housed. The observer was approximately 10 m from the observed horse during the 30-minute period and the observer made minimal movement during the period. However, if horses moved then the observer moved to maintain sightline and distance. Subsequent horses in the same herd were observed following the conclusion of the previous observation period.

During observation sessions data were transcribed directly onto paper forms by one observer, using an established ethogram (Table 2) where inter-observer reliability had previously been assessed (Daw, 2024). Times of initiation and termination of each behaviour were noted using a stopwatch so that data on both frequency and duration could be extracted. Some behaviours on the original ethogram were not observed during this study including: lick, sleep, play, jump/buck, yawn, shiver, mount, bite, kick, fight, groom other, investigate object, drink and stereotypic behaviours. The behaviours that were observed during this study are described in Table 2. If a horse moved out of sight, or was obscured by other horses in the field, this was recorded and accounted for in the analysis, but this rarely happened.

For statistical analysis no distinction was made between state and event behaviours. For all behaviours, counts were allocated based on the number of seconds they were performed during an observation session.

Table 2
Ethogram used for horse behaviour observations at pasture.

Name	Description
Stand (alert)	Standing stationary with ears directed or upright
Stand (rest)	Standing stationary with head relaxed or lowered
Lying Down	Hindquarters and sternum in contact with the ground (sternal recumbency) or hind quarters, side and neck in contact with the ground (lateral recumbency)
Walk	Slow movement in a 4-beat gait
Trot	Faster 2-beat gait, diagonal pairs of legs together
Canter	Faster 3-beat gait, extended stride
Gallop	Fastest gait, 2-beat legs on same side together
Graze	Horse ingesting grass or foliage (head down or up)
Roll	Putting back to the ground and moving whole body from side to side
Tail swishing	Sweeping movements of the tail, side-to-side or up and down
Rubbing self	Pushing any part of body against solid objects in repeated movement (head-h, leg-l, rump-r, side-s)
Head Shake	Rapid isolated movement of the head, vertically, horizontally or rotationally.
Groom (self)	Using mouth to gently rub and bite own coat (body – b, rump – r, legs – l, tail- t)
Stamp	Bringing one foot down to the ground hard (front and back, left and right - fl, fr, bl, br)

For state behaviours each second of observed behaviour was considered one count, and for event behaviours each occurrence was one count. Behaviours had durations that varied from 1 s (an almost instantaneous event e.g. stamping) to 1800s (the full observation period). The observer could not be blind to the rug status.

2.3. Statistical analysis

Using SPSS, a negative binomial distribution with a log link function was used to model the behavioural count variables. Generalised estimating equations (GEE) were used to estimate the parameters of the regression models and to account for correlations between repeated observations on the same individual horses. Explanatory variables entered into the model were Rug status (On or Off), Location (RVC or Weymouth), Time of Day (am or pm) and a Rug x Location interaction term plus the environmental variables Temperature, Wind Speed and Cloud Cover as co-variates. No variable selection procedure was carried out. Type I error was set at 5 %. Rate ratios and their 95 % confidence intervals were presented. A rate ratio of > 1 indicates an increase in incidence relative to the baseline condition, and a rate ratio of < 1 indicates a decrease in incidence relative to the baseline condition.

Where there were significant interactions between Rug status and Location, the nature of that interaction was considered and described further. Significant main effects of either Rug status or Location were only considered further when no interaction was found. A separate regression was conducted for each behaviour in the ethogram, treating the behaviours as outcome variables. Prior to analysis some behaviours with very low counts were grouped into larger categories. *Standing* combined frequent observations of stand rest with very occasional observations of stand alert, *tail swishing* combined swishing sideways and up, *grooming self* combined grooming of all limbs and body, *stamping* combined sudden movement of any leg. A new category, *Active,* was created to combine trot, canter, gallop, and roll – all energy-intensive behaviours that were relatively uncommon.

3. Results

The prevailing weather conditions during the 172 autumn observation sessions are summarised in Table 3. In total, there were 79 observations of horses with rugs on, and 93 with rugs off.

Behaviours from the ethogram were observed at varying frequencies. The descriptive statistics for each behaviour are shown in Table 4, with data presented using both medians and means. The behaviours *Trotting,*

Table 3
Summary of environmental variables over all 172 observation sessions conducted in the October and November observation periods.

Variable	Minimum	Maximum	Mean (SD)
Temperature (C)	1	15	9.9 (3.13)
Wind Speed (mph)	6	15	9.3 (2.25)
Cloud Cover (% of cover)	10	100	71.0 (31.0)

Table 4
Descriptive statistics for each behaviour recorded during the 172 observation sessions. Each second that a behaviour occurred was treated as a count in the GEE, with a maximum count frequency of 1800 (seconds in a 30-min period). IQR = inter-quartile range. SD = standard deviation. Mean (SD) is calculated for observation periods when behaviours were observed. Percentage of time behaviour exhibited calculated by probability that behaviour occurs x mean duration when it is exhibited/length of observation period (1800s).

Behaviour	Number of sessions behaviour exhibited	Range (Max–Min)	Median duration when behaviour exhibited (IQR)	Mean (SD) duration when behaviour exhibited	Percentage of time behaviour exhibited
Standing	134	1800–0	315 (1045.25)	589.3 (633.7)	25.5
Tail Swishing	120	472–0	14.5 (39)	37.5 (62.6)	1.5
Head Shaking	58	7–0	1 (1)	1.7 (1.2)	0.0
Grazing	154	1800–0	1625.5 (761)	1340.4 (540.0)	66.7
Grooming Self	59	28–0	1 (1)	2.2 (3.7)	0.0
Walking	137	747–0	51 (69.5)	72.8 (84.1)	3.2
Trotting	19	181–0	13 (13)	23.2 (40.1)	0.1
Cantering	8	20–0	11.5 (8.5)	12.9 (4.7)	0.0
Galloping	3	23–0	11 (13)	14.7 (5.9)	0.0
Rubbing (head or body)	13	100–0	8 (35.5)	23.6 (31.3)	0.1
Stamping (any leg)	16	3–0	1 (0)	1.3 (0.6)	0.0
Lying Down	10	1471–0	341.5 (787.25)	490.6 (499.9)	1.6
Rolling	16	46–0	19 (18.25)	20.6 (11.4)	0.1

Cantering, Galloping, Rubbing, Stamping, Lying, and *Rolling* were performed infrequently, with zero instances recorded up to the 75th percentile and were, together, present in under 20 of the observation periods out of 172. Low means were observed for *Head Shaking, Grooming Self, Cantering, Galloping, Stamping* and *Rolling,* all behaviours with reasonable frequencies but short bout durations. Behaviours that were infrequent but lasted longer when they did occur, such as *Lying down,* showed a higher mean. *Standing* and *Grazing* which were performed for variable durations in many observation periods showed high means with large standard deviations.

The GEE analysis was unable to produce parameter estimates for the behaviours *Trotting*, *Cantering*, *Galloping*, *Rubbing*, *Stamping*, *Lying down*, and *Rolling* due to their low frequencies of occurrence (Table 4). The significance values for the independent variables included in the GEE models for each of the remaining behaviours and behavioural categories are presented in Table 5. Significant interactions between Rug status and Location were found for *Standing, Grazing, Walking* and *Tail Swishing,* with additional main effects of Rug status alone for *Grooming Self* and *Head Shaking.* The nature of the significant interactions between Rug status and Location are illustrated using unadjusted descriptive data in Fig. 1. It can be seen that *Standing* increased when rugs were on at RVC, but decreased when rugs were on at Weymouth (Fig. 1a). *Walking* decreased when rugs were on at both locations, but more so at the RVC (Fig. 1b). Grazing increased when rugs were on in Weymouth, but not at the RVC but (Fig. 1c). Finally, *Tail swishing* decreased when rugs were on at both locations, but the rate ratio was greater at the RVC where there were particularly low levels of tail swishing when rugs were on, and less variation between horses (Fig. 1d).

The only behaviour influenced by time of day was *Grooming Self*, which was performed more in the mornings than afternoons (Tables 5 and 6). *Tail swishing* increased with higher temperatures and decreased with faster wind speeds (Tables 5 and 7). *Grooming Self* was also affected by wind speed (Table 5). However, parameter estimates and hence rate ratios could not be calculated for this relationship. Cloud cover affected *Active* behaviours, *Walking* and *Grooming Self* (Tables 5 and 7).

Where these significant effects of independent variables on behaviour were detected, the relative ratio in incidence rate of each behaviour was summarised by the rate ratios obtained using the GEE (Table 6). Where significant effects of the environmental co-variates were detected, the relative ratio in incidence rate of each behaviour was summarised by the rate ratios obtained using the models (Table 7). These rate ratios reflect the change in behavioural counts observed with an increase of 1 measured unit. However, it should be noted that no tail swishing was observed below 5 °C.

4. Discussion

Wearing turnout rugs during the variable UK autumn weather conditions was associated with decreased *Walking, Tail swishing, Head shaking* and *Self-grooming* at both study sites and increased *Grazing* at one site. The overall time budgets of the horses in our study (Standing (25.5 %), Grazing (66.7 %) and Walking (3.2 %) (Table 4) were similar to those obtained using validated accelerometer readings for UK paddock-kept horses during daytime hours of Standing (33.0 %), Grazing (60.8 %) and Ambulation (4.6 %) (Maisonpierre et al., 2019).

Given the ambient temperatures and time of year the study was conducted, we did not observe any of the common summer flies that can irritate horses such as horse flies (*Tabanus spp*), stable flies (*Stomoxys calcitrans*), bot flies (*Gasterophilus intestinalis*), house flies (*Musca domestica*) and face flies (*Musca autumnalis*) (Tarry, 1994), although formal evaluation of insect presence was not conducted here. These species, particularly the tabanids, can cause significant harassment and

Table 5
Statistical significance of Rug status x Location, Rug status, Location and Time of Day and environmental covariates on horse behaviour. Significant p-values (<0.05) are indicated in bold.

Behaviour	Rug status x Location p-value	Rug status p-value	Location p-value	Time of Day p-value	Temp p-value	Wind speed p-value	Cloud Cover p-value
Standing	**< 0.0001**	**0.035**	0.476	0.666	0.428	0.758	0.396
Tail Swishing	**0.042**	**< 0.0001**	**< 0.0001**	0.356	**< 0.0001**	**0.000**	0.051
Head Shaking	0.713	**< 0.0001**	0.674	0.137	0.972	0.358	0.439
Grazing	**< 0.0001**	0.123	0.849	0.480	0.854	0.464	0.634
Grooming Self	0.293	**0.016**	0.450	**0.031**	0.513	**0.007**	**0.029**
Walking	**0.003**	**< 0.0001**	0.376	0.706	0.394	0.382	**0.035**
Active (Trot, Canter, Gallop, Roll)	0.820	0.919	0.762	0.099	0.745	0.229	**0.000**

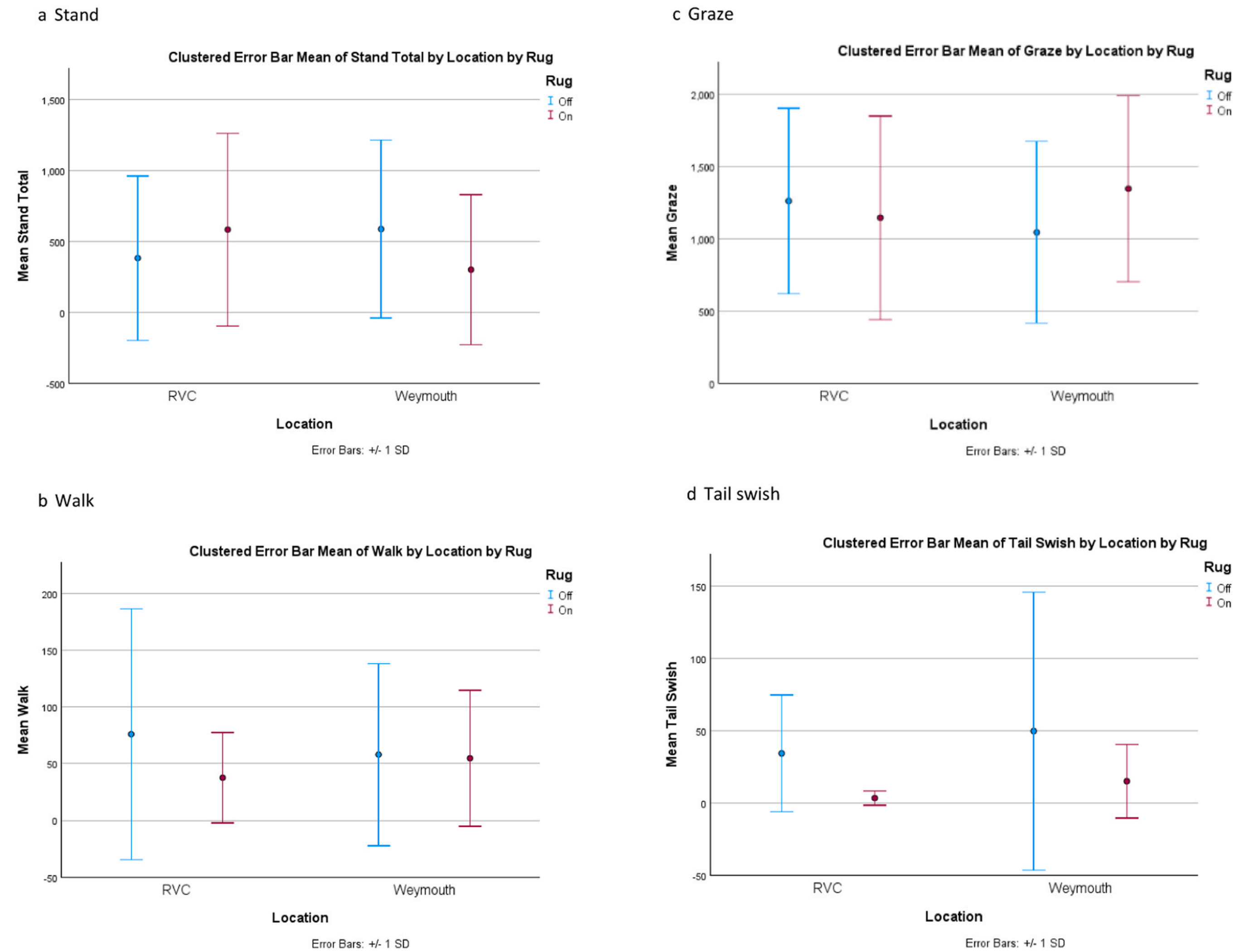

Fig. 1. Significant interactions between location and rug status illustrated with descriptive data. The unadjusted mean and standard deviation are shown for each behaviour at each location, separated by rug status. (a) Standing; (b) Walking; (c) Grazing; and (d) Tail-swishing.

Table 6
Rate Ratios with their 95 % confidence intervals (CI) for independent variables with significant effects on behaviour obtained using the GEE*. Baseline condition is also known as the reference category of the model.

Independent variable	Baseline condition	Behaviour	Rate ratio (95 % CI)
Rug status	Rug on	Stand	RVC: 0.6 (0.5–0.7); Weymouth: 2.3 (1.9–2.7)
		Tail Swish	RVC: 11.0 (5.3–22.9); Weymouth: 4.0 (2.3–7.2)
		Graze	RVC: 1.1 (1.0–1.3); Weymouth: 0.8 (0.7–0.9)
		Walk	RVC: 2.3 (1.7–3.1); Weymouth: 1.2 (0.8–1.6)
Rug status	Rug on	Head Shaking	2.0 (1.2–3.2)
		Grooming Self	1.8 (0.4–7.4)
Time of day	Afternoon	Grooming Self	2.1 (1.1–4.2)

* Variables included in the model were Rug status, Location, Rug x Location interaction, Time of the Day, Temperature, Wind Speed and Cloud Cover.

Table 7
Rate Ratios with their 95 % confidence intervals (CI) for environmental covariates with significant effects on behaviour obtained using the GEE*.

Behaviour	Significant Effect	Rate Ratio (95 % CI)	Interpretation
Tail Swishing	Temperature	1.33 (1.22–1.46)	Counts increase by rate ratio with every 1° C increase in temperature.
Tail Swishing	Wind Speed	0.84 (0.77–0.91)	Counts decrease by rate ratio with every 1 mph increase in wind speed.
Walking	Cloud Cover	0.99 (0.99–1.00)	Counts decrease by rate ratio with every 1 % increase in cloud cover
Active (Trot, Canter, Gallop, Roll)	Cloud Cover	0.98 (0.97–0.99)	Counts decrease by rate ratio with every 1 % increase in cloud cover

*Variables included in the model are Rug status, Location, Rug x Location interaction, Time of the Day, Temperature, Wind Speed and Cloud Cover.
*No parameter estimates were available for the effect of wind speed on Grooming Self.

irritation to horses (e.g. Hartmann et al., 2015; Christensen et al., 2022). However, suspected midges were informally observed flying on both sites throughout the study, particularly at the Weymouth site along the hedgerows that surrounded the study paddocks, observations that inform interpretation of the current results.

Horses respond to insect nuisance in many ways, including moving to areas of lower insect prevalence e.g. hills with greater windspeed (Rubenstein and Feinstein, 2021), seeking shelter (Proops et al., 2019; Christensen et al., 2022) and increasing the rate of behaviours such as tail swishing, skin twitching, head shaking and stamping (Keiper and Berger, 1982; Christensen et al., 2022). It has been shown experimentally that lightweight cotton rugs can offer protection and reduce signs of irritation and reactivity from flying insects (Padalino et al., 2019) and owners report using a range of lightweight cotton and mesh rugs for this purpose (Cox et al., 2023).

It seems likely that the lower frequencies of *Tail Swishing and Head Shaking* that we observed in rugged horses were due to reduced irritation from midges, and reduced irritation may also have facilitated more time spent Grazing at the Weymouth site where we informally observed more midges. This interpretation is supported by data on how the behaviour of our study horses was affected by the environmental variables that influence midge activity. We found no tail swishing below a temperature of 5 °C, while counts of this behaviour increased linearly at higher temperatures. In addition, tail swishing counts were also lower when wind speeds were greater. These behavioural observations map very well with the field data showing that, in Southern England during the autumn season, midge species are generally inactive below 5 °C, with increasing activity observed across a temperature spectrum 6 °C to 12 °C (Tugwell et al., 2021). Midges are also not strong fliers and their flight appears to be inhibited by wind speeds as low as > 3mph (Blackwell, 1997; Carpenter et al., 2008; Sanders et al., 2011). The wind speeds obtained from a commercial forecasting site in our study exceeded this level, but horses often take shelter from wind, standing against hedges where wind speeds are lower and where midges are better able to fly. Protection from insects, even in autumn, could have many welfare benefits as insect nuisance is associated with raised salivary cortisol levels, indicating an increased arousal and likely negative affective state (Christensen et al., 2022). Protection from midges may be especially important as some horses can develop a debilitating insect-bite hypersensitivity (IBH) which can dramatically reduce quality of life. One study found that IBH horses with rugs had more severe skin lesions than horses without rugs, but this part of the study was correlational and it is likely that rugs were provided for the more severely-affected horses (Söderroos et al., 2023).

The rugs in the current study were fabricated from heavier material than bespoke fly rugs and were designed primarily to protect horses from adverse weather not insects. It is therefore possible that turnout rugs might have impacts on behaviour unrelated to reduced insect nuisance. For example, horses performed less self-grooming when they wore rugs in the current study which could be due to reduced irritation or conversely because rugs cover skin, effectively preventing horses from using their teeth to scrape areas that are itching or irritated. Horses also performed less walking when rugged, more so at the RVC than at Weymouth. Reduced walking could reflect additional effort required to move when carrying extra weight or if leg straps inhibit movement. Rug weights are most often described in terms of the insulation they provide (e.g. 200 g of fill) but total weight can be between 3 and 5 kg. This represents around 1 % of the weight of a normal pony. Although this is less than the 1.6–2.98 % of body mass upper threshold advocated to avoid harm when tagging animals for wildlife studies (Wilson et al., 2021) it cannot be assumed that this additional weight will have no effect when rugs are worn for long periods. That said, the difference between rug and no rug conditions in walking counts (seconds) was relatively modest in the current study (median 46 s (IQR 9–96) with rug off; 33 s (IQR 5–63). If rugs were having major inhibitory effects on self-grooming or walking, one might expect rebound levels of these comfort and locomotory behaviours (Nicol, 1987; Chaplin and Gretgrix, 2010; Bibiano et al., 2022) during periods when rugs were removed, leading to far greater differences between conditions. Specifically examining whether rebound behaviour occurs when rugs are removed would be a useful next step.

The ambient temperature prevailing during this study (1–15 °C) was mild, below the 20 °C level where horses tend to seek shelter from heat (Proops et al., 2019), and above temperatures where horses tend to seek shelter from cold (if combined with wind and rain) (Jorgensen et al., 2016) or request to wear rugs (Mejdell et al., 2019). Indeed, within the temperature range 1–15 °C there is individual variation as to whether horses choose to wear rugs or not (Mejdell et al., 2019). Padalino et al. (2019) raised concerns about the effects of rug wearing but in a context where ambient conditions were either 31.7 °C and 22.5 % humidity, or 26 °C and 33.2 % humidity. Thus, while it is likely the turnout rugs increased the thermal load of our horses, this did not seem to cause discomfort or to outweigh the benefits of reduced insect nuisance under these conditions.

An alternative to using rugs on horses is to provide shelters, but horses cannot stay in shelters all day. Free-ranging horses spend between 50 % and 66 % of their time foraging or grazing, with intervals between grazing rarely exceeding 2–4 h (reviewed by Auer et al., 2021). Rugs therefore have a role in allowing normal grazing and walking behaviour while reducing insect nuisance, even outside of summer periods when that nuisance is most apparent to owners. The need for waterproofing may depend on expected rainfall.

There were a number of study limitations. The current study examined horses from just two geographical locations and found strong interactions between location and the effects of rug wearing on behaviour. It is thus not possible to generalise the results obtained here to other locations. Future systematic investigation of the influence of wind direction, shelter and insect presence would be important. In the current study insect numbers were not recorded formally. Future work could consider the use of automated monitoring systems to estimate insect numbers and to classify active species (e.g. Kalfas et al., 2023). If this could be achieved it would be particularly interesting to apply methods, similar to those pioneered by Mejdell et al. (2016), to establish the levels of insect activity at which horses would request to wear rugs, and to establish the trade-offs that may exist between thermal comfort and insect avoidance. In the current study there was variation between study horses (in size, breed, age and sex) and minor variation in rug design and insulation level, which varied between 0 and 200 g. This is at the lower end of horse-rug insulation which can be as much as 550 g for some heavyweight rugs. However, in the current study it was not possible to control the variation in horse and rug characteristics and the potential impact of these factors could not be analysed. Despite the variable sample, significant effects were obtained, indicating the results may be applicable to a wide range of horses but this should be examined systematically in future studies. The best approach may not be to standardise every aspect, thus limiting generality and reproducibility, but to systematically vary each parameter of interest (Richter et al., 2010).

Referring to our original predictions we found no evidence under the mild autumn conditions of this study that horses with or without rugs were either (i) too cold or (ii) too hot. We also saw no signs of discomfort associated with rug wearing (iii). We did however find support for predictions (iv) - that rugs might lead to reduced activity, and (v) - that rugs might reduce behaviours associated with insect nuisance.

To conclude, when weather conditions are relatively mild (above 5 °C), horse welfare may be improved more by the use of lightweight turnout rugs for fly protection rather than heavyweight rugs designed primarily for warmth. Further study using bespoke fly rugs, rather than waterproof turnout rugs, under mild autumn conditions is required to test this prediction.

CRediT authorship contribution statement

Yu-Mei Chang: Writing – review & editing, Supervision, Methodology, Formal analysis, Conceptualization. **Charlotte Burn:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Frederick Daw:** Writing – review & editing, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Christine Nicol:**

Writing – original draft, Supervision, Methodology, Funding acquisition, Conceptualization.

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.

Acknowledgements

The authors gratefully acknowledge study funding from the Horse Trust, a UK based charity (number 231738).

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