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Body temperature of horses spending time in paddocks in various weather conditions during the summer

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The aim of the study was to determine the internal and surface temperature of selected body parts of horses during their stay in paddocks in various weather conditions in the summer. The study was conducted on 10 adult thoroughbred mares. The experiment was carried out on horses spending time in the paddock in four eight-hour stages with differing weather conditions in summer (sunny, cloudy, rainy and windy). Measurements of internal temperature (Veterinär SC 12 veterinary thermometer) and surface temperature of the head, rib area and croup (Thermal Imagers Ti9 FLUKE infrared camera and SmartView 4.1 software) were carried out at rest and again after four and eight hours in the paddock. It was concluded that the time horses spend in the paddock in summer should depend on weather conditions. Many hours spent outside the stable during sunny weather accompanied by high air temperature can contribute to overheating. On the other hand, rain and wind can cause hypothermia. Therefore, it is worth considering leaving horses in the stable or limiting their stay in the paddock to no more than four hours.

KEYWORDS: horses, weather, paddock, body temperature, thermography

Providing horses with access to free movement is one of the primary factors affecting their welfare (Cooper and McGreevy, 2007). This is because horses are herbivores, whose dominant activity in free living conditions is continuous wandering (Corrigan, 2012). According to Hampson et al. (2010), wild horses spend a significant part of their day wandering. This norm is disturbed by life in the stable, which does not ensure sufficient movement, particularly free movement on paddocks and pastures (Cooper and Albentosa, 2005).

This is mainly due to the limitations of the infrastructure of equestrian centres and the limited range of services they offer (Klychova et al., 2014). Centres located in urban areas, with a small total area, including paddock area per horse, are currently very popular.

Moreover, in many cases there are no pastures at all. In addition, the standard services of a boarding stable for horses often do not include letting them outside, which means that the animals are solely dependent on their handlers. As a consequence, healthy horses may stand in boxes for days or even weeks without being released into the paddock.

The problem of insufficient time in paddocks is also associated with horses' specific use or in some cases with their owners' mentality (Mills and Clarke, 2007). For example, the life of a sport horse often completely revolves around competitions, training, transport to competitions, and treatment of injuries (Neuberg-Zuchowicz and Geringer de Oedenberg, 2010). Due to the increasing popularity of indoor competitions, the season lasts year round, with no long periods when the horses can relax in paddocks or pastures. The mentality of horse owners may include excessive, misguided solicitude for their charges. In consequence the horses are raised in a manner that is incompatible with the biology of the species and they become fragile (Visser and Van Wijk-Jansen, 2012). One manifestation of the solicitude of contemporary horse owners is limited access to paddocks and pastures, which they explain by the possibility of injury, chill, or overheating (Hotchkiss et al., 2007). Sometimes the horses are not able to move freely on the paddock at all, or their stay outside the stable is limited to training or to a brief period spent most often alone in a small paddock adjacent to the stable. Overprotective owners keep the horses in their boxes in weather conditions that they consider harmful. Lack of movement in horses, combined with inadequate nutrition and grooming (often making them fragile and reducing their adaptability) increases susceptibility to disease, mainly respiratory and gastrointestinal disorders, but also tendon and joint injuries, including serious ones (Popescu et al., 2019). Limiting social contact between horses, which are herd animals, also negatively affects their welfare and leads to various types of emotional and behavioural problems (Janczarek et al., 2019). Various psychological disorders are increasingly observed and are becoming one of the major problems of the modern domestic horse (McBride and Long, 2001).

Body temperature is the best indicator of the body's thermoregulatory processes. The first symptoms of overheating or hypothermia are manifested first by changes in surface temperature, and only then by changes in internal temperature (Čebulj-Kadunc et al., 2019). On the assumption that thermoregulation of the horse's body depends on the surrounding atmospheric conditions, a study was undertaken to determine the internal temperature and surface temperature of selected body parts of horses during their stay in paddocks in various weather conditions in the summer.

Material and methods

Horses

The study was conducted on 10 thoroughbred mares aged 8-10 years. The mares were born and had remained at the same stud since birth. At the time of the study they were 4-6

months pregnant, with no foal at their sides. All mares were healthy and had not been ridden for three months prior to the study. They were kept in a stable of the open-barn type, where they could be released directly into the paddock adjacent to the stable or a pasture located 500 m from the stable. The barn was equipped with a set of feeding troughs and automatic drinkers, and salt licks were placed in holders in the corners. The floor was covered with straw twice a day. Excrement was collected on an ongoing basis. The straw was removed and replaced completely once a month.

At each feeding trough there was a tether, which each mare was tied to when the concentrate feed was given. Feeding, which additionally included meadow hay, took place twice a day. Between feeding times, the mares stayed on the paddock or pasture, with the possibility of entering the stable building.

Experiment

The experiment was carried out on the paddock adjacent to the stable in four eight-hour stages during the summer. The horses were familiar with the paddock from time they spent there every day. The ground was of earth and sand. The paddock had an area of 1500 m², with no shaded places. Each stage of the experiment consisted of two four-hour phases. The date of the stages depended on the atmospheric conditions included in the experimental design. The horses' behaviour was not interfered with during the experiment. Their locomotive behaviour was negligible.

In each stage of the experiment, measurements were made four hours after the horses were released from the stable, i.e. at 12:00, which was the first phase of the experiment. The second phase was after another four hours, at 16:00, when measurements were made again.

During the experiment, the mares were not able to enter the stable on their own; in each research phase they were brought from the paddock to the stable, where the measurements were made. The measurements took five minutes, during which the mares were held on tethers by the grooms.

Research methods

Weather conditions

Weather conditions during each stage of the experiment were determined from the website www.mojapogoda.com/uslugi/homepage-weather.html, with the GPS location for the site of the research. These parameters were updated every two hours. Table 1 shows the means and standard deviations of air temperature, relative humidity, atmospheric pressure, and wind speed from five successive updates for each stage (type of weather). These results serve only as a detailed description of the experimental conditions, but are not part of the research.

Body temperature measurements

Internal temperature was measured rectally using a Veterinär SC 12 veterinary thermometer. The measurement time was 60 s. The surface temperature was measured using

Table 1
Atmospheric conditions during each stage of the experiment

Stage of experiment	Name and date of stage	Characteristic atmospheric phenomena	Air temperature (ºC)	Relative humidity (%)	Atmospheric pressure (hPa)	Wind speed (m/s)
1	sunny weather (12.08.2019)	sunny, slightly cloudy in places	28.34 ±3.34	67.45 ±2.34	987.00±2.56	1.03 ±0.22
2	cloudy weather (25.07.2019)	moderately or very cloudy with mainly low clouds	20.14 ±1.12	86.04 ±6.76	946.47±10.05	1.17 ±0.34
3	rainy weather (14.07.2019)	overcast, intermittent rain	19.36 ±0.58	98.00 ±0.54	952.44±2.45	1.54 ±0.15
4	windy weather (23.08.2019)	moderately or slightly cloudy, windy	22.13 ±1.04	57.47 ±1.46	998.05±1.99	6.16 ±4.05

a Thermal Imagers Ti9 FLUKE infrared camera with an uncooled microbolometer array, activation in the focal plane at a resolution of 120/160 pixels, and an infrared spectrum in the 7.5-14 μm range. The camera was placed 230 cm from the horse's left side. Thermographic images, lasting about 60 s, were taken according to applicable procedures, in a darkened room at a constant temperature (van Hoogmoed and Snyder, 2002). The open barn used for this purpose ensured appropriate conditions for thermographic testing by sufficiently limiting the influence of external factors (Soroko and Morel, 2016). After the images were taken, the data were transferred from the camera to computer memory and analysed using SmartView 4.1 software.

The average surface temperature of three parts of the left side of the horse's body was analysed – side view:

– head: masseter muscle, caninus muscle, and cutaneus labiorum muscle

– rib area: latissimus dorsi muscle, external intercostal muscles, and abdominal external oblique muscle

– croup: *gluteus superficialis* muscle, *gluteus medius* muscle, *semitendinosus* muscle, and semimembranosus muscle

All measurements were made at rest (before releasing the horses into the paddocks at each stage, i.e. during each type of weather) and in the first and second phase of each stage.

Statistical methods

The data were tested for normality of distribution using the Shapiro-Wilk test, which confirmed a normal distribution. The results were analysed using the GLM procedure in the SAS software package. The statistical model included the random effect of the horse (Dytham, 2011) and the fixed effect of the stage of the experiment (n = 4: sunny weather, cloudy weather, rainy weather, windy weather) and the phase (n = 3: rest, phase I – after 4 hours, phase II – after 8 hours) and the interaction between these factors. The differences between levels of the factors were tested by Duncan's post-hoc for least squares means (LSM). The significance level of $P \leq 0.05$ was adopted.

Results and discussion

Significant differences were noted in the average internal body temperature of horses staying in the paddocks in different weather conditions (stages of the experiment) as well as during different phases of the experiment (Table 2). In both the first and the second phase, i.e. four and eight hours after the horses were released from the stable, the highest internal temperature was noted during sunny weather and the lowest during rainy and windy weather. There were no significant differences between mean internal temperatures at rest. Only during cloudy weather were there no significant differences noted between phases. During sunny weather, the average was lowest at rest and highest in the second phase; these differences were statistically significant. During rainy and windy weather, the average internal temperature gradually decreased; it was significantly higher at rest and in the first phase than in the second phase.

The average surface temperature of the heads of horses staying in paddocks during different types of weather differed significantly in many cases (Table 3). In the first phase of the experiment, this parameter was significantly lower during rainy and windy weather compared to sunny and cloudy weather. The values during the second phase were lowest in rainy and windy weather and differed significantly from the temperature in cloudy weather (intermediate value) and sunny weather (highest value). No significant differences for measurements at rest were found between stages. Differences between phases were noted during sunny, rainy and windy weather. Only in the first of these cases was the value from the second phase higher than the value from the first

Table 2
Internal body temperature of horses during each stage and phase of the experiment (°C)

Stage of experiment	Sunny weather			Cloudy weather			Rainy weather			Windy weather		
Phase of experiment	rest	phase 1	phase 2	rest	phase 1	phase 2	rest	phase 1	phase 2	rest	phase 1	phase 2
LSM	38.07^{ax}	38.71^{ay}	39.29^{az}	38.11^{ax}	38.17^{bx}	37.34^{bx}	37.97^{ax}	37.51^{cx}	36.74^{cy}	38.15^{ax}	37.69^{cx}	36.86^{cy}
SE	0.29	0.44	0.49	0.48	0.41	0.38	0.37	0.48	0.35	0.43	0.57	0.41

LSM – least squares mean, SE – standard error
Means with different letters (a, b, c – between stages in the same phase of measurement; x, y, z – between phases in the same stage) differ significantly at $P \leq 0.05$

phase, which in turn was higher than the value at rest. In the case of rainy and windy weather, the value from the second phase was lower than the resting and first-phase values, which were similar.

In the first phase of the experiment, the average surface temperature of the horses' rib area during successive stages of the experiment differed significantly in all cases (Table 4). Beginning with the lowest value, the averages in different types of weather were ordered as follows: rainy, windy, cloudy, and sunny. In the second phase, the differences between means were similar. In contrast, no significant differences were found between stages when the surface temperature was measured at rest. Significant differences between the phases occurred in all cases. During sunny and cloudy weather, the temperature from the second phase was higher than the value from the first phase. During sunny weather, however, the resting surface temperature near the ribs was the lowest among all phases. In the second case, the resting value was similar to that obtained in the first phase. During the other two types of weather, the average values showed the reverse pattern. During rainy weather, the resting value was the highest among the phases, while the value from the second phase was the lowest. During windy weather, the value from the second phase was lower than the other values, which were similar to one another.

In the first phase, the surface temperature of the croup during sunny weather was significantly higher than that obtained during the other three types of weather (Table 5). The values were intermediate during cloudy weather and lowest during rainy and windy weather. The surface temperatures of the croup in the first phase during rainy and windy weather did not differ statistically. In the second phase, all means differed significantly from one another. In successive stages of the experiment they were ranked as follows, in ascending order: rainy, windy, cloudy, and sunny weather. In contrast, no significant differences were found between stages in measurements at rest. Differences between phases were found during each type of weather. During cloudy and windy weather, the resting values were significantly higher than the other two. During sunny weather the lowest value was noted at rest and the highest in the second phase. The reverse pattern was shown during rainy weather.

The weather was shown to have a marked effect on the internal temperature and surface temperature of horses staying in the paddocks in the summer. Changes in surface temperature, which are the first symptom of disturbed thermoregulation (Godyń, 2013), appeared on the head during three of the four types of weather. The surface temperature was significantly lower during rainy and windy weather than when it was sunny or cloudy. Hodgson et al. (1994) showed that the blood supply system of the head is highly developed, in part to prevent the brain from overheating. Despite this protection, however, during sunny weather the surface temperature of the head increased relative to the temperature at rest after just four hours in the paddocks. Furthermore, there was an additional significant increase after another four hours. It should be noted that the values obtained both at noon

Table 3
Surface temperature of horses' head during each stage and phase of the experiment (°C)

Stage of experiment	Sunny weather			Cloudy weather			Rainy weather			Windy weather		
Phase of experiment	rest	phase 1	phase 2	rest	phase 1	phase 2	rest	phase 1	phase 2	rest	phase 1	phase 2
LSM	31.67^{ax}	32.45^{ay}	34.89^{az}	31.89^{ax}	32.06^{ax}	32.11^{bx}	31.77^{ax}	31.23^{bx}	30.28^{cy}	31.45^{ax}	31.56^{bx}	30.56^{cy}
SE	0.36	0.56	0.66	0.56	0.34	0.45	0.39	0.58	0.49	0.56	0.57	0.51

LSM – least squares mean, SE – standard error
Means with different letters (a, b, c – between stages in the same phase of measurement; x, y, z – between phases in the same stage) differ significantly at $P \leq 0.05$

Table 4
Surface temperature of horses' rib area during each stage and phase of the experiment (°C)

Stage of experiment	Sunny weather			Cloudy weather			Rainy weather			Windy weather		
Phase of experiment	rest	phase 1	phase 2	rest	phase 1	phase 2	rest	phase 1	phase 2	rest	phase 1	phase 2
LSM	34.56^{ax}	35.67^{ay}	36.78^{az}	34.51^{ax}	34.12^{bx}	35.32^{by}	33.34^{ax}	32.34^{cy}	31.56^{cz}	33.56^{ax}	33.24^{dx}	32.08^{dy}
SE	0.51	0.56	0.62	0.46	0.56	0.66	0.47	0.49	0.67	0.39	0.49	0.56

LSM – least squares mean, SE – standard error
Means with different letters (a, b, c – between stages in the same phase of measurement; x, y, z – between phases in the same stage) differ significantly at $P \leq 0.05$

Table 5
Surface temperature of horses' croup during each stage and phase of the experiment (°C)

Stage of experiment	Sunny weather			Cloudy weather			Rainy weather			Windy weather		
Phase of experiment	rest	phase 1	phase 2	rest	phase 1	phase 2	rest	phase 1	phase 2	rest	phase 1	phase 2
LSM	33.65^{ax}	34.24^{ay}	36.67^{az}	33.29^{ax}	32.45^{by}	32.67^{by}	33.23^{ax}	30.81^{cy}	29.89^{cz}	33.26^{ax}	31.25^{cy}	31.09^{dy}
SE	0.38	0.56	0.51	0.44	0.60	0.58	0.39	0.59	0.54	0.36	0.57	0.56

LSM – least squares mean, SE – standard error
Means with different letters (a, b, c – between stages in the same phase of measurement; x, y, z – between phases in the same stage) differ significantly at $P \leq 0.05$

and in the afternoon (first and second phase) were higher than those specified by Marlin (2008) as normal.

As changes in the surface temperature of the head may be indicative of disturbances in thermoregulation (Eaton-Evans, 2019), this parameter seems particularly important for assessing the impact of weather on the health of horses. It is thus worth emphasizing that keeping horses in paddocks during sunny weather can lead to an excessive increase in temperature in this part of the body, even after a relatively short period. Our results are consistent with those published by Lindinger (1999).

Time spent in the paddocks also caused changes in the surface temperature of the head during rainy and windy weather. In this case, however, the temperature at noon was the same as the temperature at rest, and only decreased significantly in the afternoon. Cloudy weather proved to be neutral in terms of changes in surface temperature, which was additionally confirmed by the internal temperature measurements. This suggests that even in the summer the body can be cooled down during rain or strong wind, causing colds, respiratory disease or even rhabdomyolysis (Cymbaluk, 1994). Our results indicate that the horse's body temperature decreases much more slowly than it increases. Therefore it is recommended to limit the horses' stay outside the stable during the summer to four hours (in rainy or windy weather, i.e. wind speed above 5 m/s), or even to keep them inside (sunny and very warm weather, i.e. about 30°C).

Analysis of the surface temperature of selected parts of the body, including the croup and especially the rib area, enabled even more accurate determination of the impact of weather on the surface temperature of horses in paddocks. It is interesting that during rainy or windy weather these parts of the body cooled down more than the head. The blood circulation system of the head evidently helps not only with heat dissipation, but with warming as well. According to McKinley et al. (2017), in this manner the body ensures optimal temperature conditions for the brain. It is possible, however, that if the weather conditions in rainy or windy weather chilled the body more, the muscles would shake, which would automatically heat up the body (McCutcheon and Geor, 2008).

Analysis of the surface temperature of all tested body parts suggests that it is worth considering limiting horses' time outside the stable to a maximum of four hours during adverse weather conditions, which according to the results of our study are sunny, rainy or windy weather. Only cloudy weather may signal that the horses' stay in the paddock can be safely extended. Snoeks et al. are of a similar opinion (2015). On the other hand, Visser et al. (2008) stress that horses today often become fragile by spending most of the day in the stable. This means that keeping them in the paddock in adverse weather conditions may be harmful. Therefore, it seems that they should be gradually accustomed to unfavourable weather conditions. Similar studies should be conducted using horses of other breeds to confirm the impact of weather conditions on the internal and surface temperature of these animals.

It is particularly important that this suggestion was confirmed by the analysis of our own results regarding internal temperature. It is worth noting that rainy and windy weather were accompanied by lower internal temperature than cloudy weather, and especially sunny weather. According to Čebulj-Kadunc et al. (2019), disruptions of thermoregulation of the body due to external factors are first manifested by changes in surface temperature, and only then by internal temperature. Thus it should be emphasized once again that the weather conditions analysed in our own research, despite occurring during the summer, most often had a destabilizing effect on maintenance of body temperature in the optimal range.

Conclusions

The amount of time horses spend in the paddock in summer should depend on weather conditions. Many hours spent outside the stable during sunny weather accompanied by high air temperature can contribute to overheating. On the other hand, rain and wind chill the body. Therefore, it is worth considering leaving horses in the stable or limiting their time in the paddock to a maximum of four hours.

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