The effect of Protechmasta Infrared rug on the skin temperature of the performance horse at rest.

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Abstract:

Despite the high incidence of temperature related conditions and heat associated injuries (*e.g. rhabdomyolysis also known as tying up*) in the modern sport horse, there is little application in the every-day and competition management of prevention of these conditions. In contrast to other large domestic species where the skeletal comprises 30-40% of total body weight, half the total body weight of the working equine is the muscle. The mass-specific heat load for the exercising horse is three-fold higher compared to that of a human. (1. *Hodgson et.al 1993*). Despite this higher rate of heat production in the equine, the body mass is in the region of 50% less than that of humans. This results in a smaller surface area to dissipate a large metabolic heat load, the disadvantage of this smaller surface area to body mass ratio is partially offset by higher rates of cutaneous and respiratory heat loss.

An excessive elevation in core body temperature in the equine can seriously hinder performance capacity, it can also lead to heat stress in the resting equine when over rugged. Horses often train and compete in hot weather, ambient conditions that substantially increase the risk of temperature related injury. A lack of understanding of the thermoregulatory response in horses at rest, during exercise & competition, post exercise and post competition, during transportation, warming up and cooling down is responsible for heat and stress related conditions. Another big contributor to heat stress, is improper management of the process of rugging up.

Metabolic heat production is dependent on the job that the Equine does, at what level and for how long. Therefore, effective regulation of temperature mechanisms for the equine are crucial and serve to regulate temperature per its present condition, surroundings & environment and minimise injuries to the muscles, metabolism and cells. These mechanisms will allow proper management of horses in training and competition. It is concluded that regulating temperature of the Equine under working and resting conditions is a thermoregulatory challenge to the horse and its owner.

It was this challenge that resulted in the development of the Protechmasta Infrared rug of which it's Far infrared properties prove here to support the regulation of the equines temperature during rest.

Introduction

Protechmasta Infrared Rug

This study investigates the beneficial effects of the Protechmasta Infrared (IR) rug when applied to horses at rest. The Protechmasta IR Equine rug contains a special ceramic powder (filaments) that is blended with the yarns of the lining fabric, these filaments are impregnated with Far InfraRed (FIR) emitting nanoparticles designed to deliver thermal radiation effects. The rug's air mesh fabric is designed to take away moisture and to regulate temperature by circulating warm air around the horse at a constant rate and in keeping with the equines present temperature and environmental temperature. [Masta 2017}

Far Infrared (FIR)

Far infrared (FIR) radiation (λ = 3–100 μm) is a subdivision of the electromagnetic spectrum that has been investigated for biological effects. [2. Vatansever F, PubMed]

FIR transfers energy purely in the form of heat which can be perceived by the thermoreceptors in Equines skin as radiant heat.

Not only is Far Infra-red (FIR) absorbed by the Equines body but it is also emitted by the body in the form of black body radiation. FIR also can be described as “biogenetic radiation” Its therapeutic effect is the result of local hyperemia (excessive blood flow) and the positive heating impact which reduces muscle tension and, favourably, pain perception (due to increase of endorphin secretion), immunological reactions, acceleration of metabolism, and regulation of activity of autonomic nervous system in the aspect of controlling muscle tension. At the cellular level the mechanism of infrared radiation is based mainly on the interactions with water molecules

An especially interesting part of IR is far infrared (FIR) which is alternatively called biogenetic radiation or biogenetic rays. This is the part of the IR which has the pure heating effect on the human cells due to marked sensitivity of our thermoreceptors. It penetrates up to 5 cm beneath the skin surface. [3. Michael R. Hamblin. PubMed.]

Materials and Methods.

Preparation of horses and environment.

This study was performed in an American Barn selected for its enclosed and controlled environment and to minimise external artefacts such as wind, sunlight and distraction from other elements. The horses were scanned on a hard, dry, and level surface.

Eight adult event horses with no known abnormalities on physical examination of the shoulders, barrel, hindquarters, dorsal and lumbar region were used. Horses in this study were all close in competition level, height, age and weight. All horses are ridden by the same rider and have the same daily routine. All Horses for this study were housed in 12' x 12' stalls on the same yard and cared for by the same grooms. All horses had their coats clipped excluding the saddle region pre-scanning, the horses were not exercised for 24 hours before hand, this was to ensure no artefacts from rider & equipment, wind, sunlight, mud, water, sweat, and to prevent conduction, convection and solar radiation from exercise and environment.

The horses were fasted for 2h prior to and during the imaging procedure to avoid postprandial thermal variation.

The ambient temperatures during this study were recorded and stayed constant at 9 degrees Celsius. Horses were rugged overnight prior to the research; These overnight rugs were removed 60 minutes prior to scanning. As the horses were fully clipped and the ambient temperature at only 9 degrees, an hour was all that was required to bring their superficial skin temperature to normal and to prevent excessive cooling.

Rugs:

8 Size 6.3 Protechmasta rugs were used in this study.

Handling during research:

A designated handler restrained the horses with a halter and rope during each stage of image capture. In between the 30 minute stages the horse were tied up in their stables.

Equipment used.

Research was conducted using thermal imaging cameras to discern the rugs ability to induce physiological changes in horses at rest and to ascertain the thermal effects of the Protechmasta rug. The wavelength of the FIR is too long for human eyes therefore an Infrared camera’s special filters will allow us to visualise the Infrared radiation and to measure it.

Equipment that was used included one Flir T440 (320 x 240) 18Hz, and one Flir T1030 Thermal Imaging cameras.

The infrared image analysis required the Flir Tools software to download the final scan to and interpret the scans for their quantitative data.

The final temperature data was transferred to an excel sheet created to calculate the maximum. Minimum and average temperatures within each single scan at the different stages of analysis.

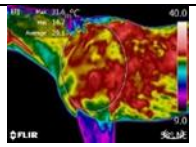
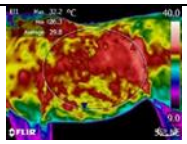
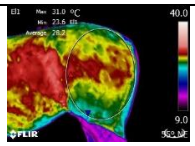
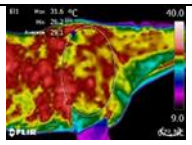
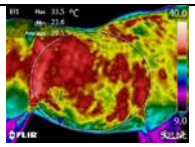
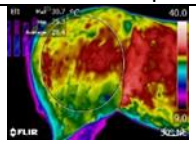
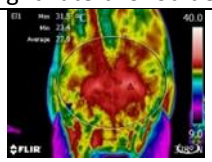
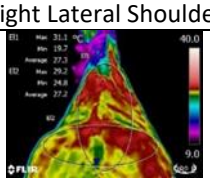
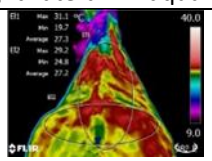
Image capture:

A designated highly qualified thermographer was used to capture all scans for all horses and at all stage of this study.

Anatomical Regions scanned:

Chest Left lateral Shoulder Left Lateral Barrel Left lateral Hindquarter	Right lateral shoulder Right Lateral Barrel Right Lateral hindquarter Dorsal spine Lumbar spine

Table 1.0 Images of anatomical regions scanned with a thermal Imaging camera for phase 1 and 3.

 Left Lateral shoulder	 Left lateral Barrel	 Left lateral Hindquarter
 Right Lateral Shoulder	 Right Lateral Shoulder	 Right Lateral Hindquarter
 Chest	 Dorsal Spine	 Lumbar

Extrinsic factors:

Emissivity = 0.98
Ambient temperature = 9ºC
Relative humidity = 40%
Distance from target = 2 meters
Reflective temperature = 19 ºC

Protechmasta rug In Situ.

When the Protechmasta IR rug is in-situ, the lining fabric is positioned over regions of the chest, shoulders, dorsal spine, including cervical, lumbar and sacro-Iliac region, hindquarters lateral and cranial. The absolute temperatures of both rug and horse were recorded prior to application and post application.

The study

Phase one:

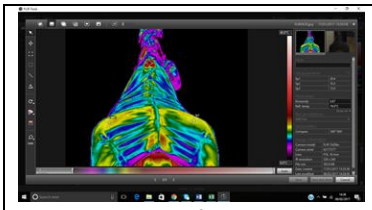
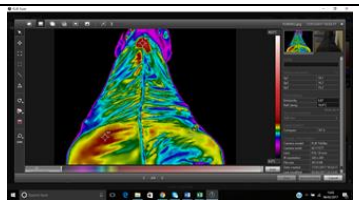
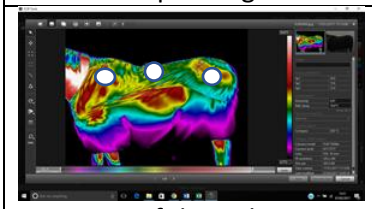
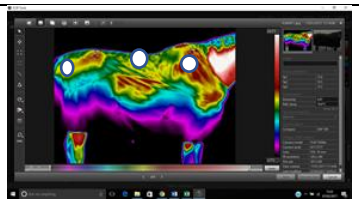
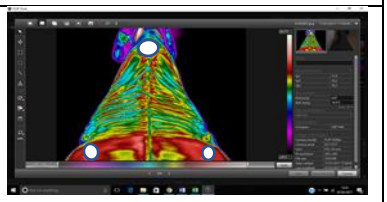
All 8 horses were scanned at rest to establish baseline temperatures prior to rug application. Thermal images (thermograms) of the skin temperature of nine anatomical regions were taken of each horse in an ambient temperature of 9 ºC to ascertain their normal thermal patterns and temperature at 9 ºC. Two minutes was given to capture 9 anatomical regions of each phase of this study. (***See Table 1.0***)

Phase two:

(a) Before application, the Protechmasta IR rug was scanned inside and outside at 9 ºC to ascertain a baseline temperature. Three regional measurement points were selected on each three views of the rug. (***see Table 2.0***). These were taken prior to the rug being placed in situ on the horse.

(b) Once in Situ a scan of the inside and the outside of the rug was taken at each temporal increment (30,60,90,120,150,180) in an ambient temperature of 9ºC. This was to ascertain the thermal reaction of the rug material and its properties.

Table 2.0 Images of anatomical regions scanned with a thermal Imaging camera for phase 2 (*Note white dots represent the central part of each measured region.*)

 Top of Rug	 Under Rug	 Captured images.
 Left lateral	 Right Lateral	 Dorsal

Phase three:

The Protechmasta IR rug was placed in situ on each horse initially for 30 minutes and then removed for 2 minutes while scan capture of the nine anatomical regions selected for this study were taken. The rug was immediately re-applied post scan capture for a further 30 minutes and then repeated at the following temporal increments for all three phases, **30, 60, 90, 120, 150 and 180 minutes**

Sequence: Thermal images were taken at the following temporal increments for all three stages: 30, 60, 90, 12, 150 and 180 minutes.

Storage:

The thermograms were stored on high-resolution SD card and transferred to a HP laptop for post imaging processing and evaluation. Flir Tools, analytical software was used to analyse each scan (Table 3.0). Each thermograms level and span was change to 9 and 40 (Table 4.0) to ensure standardisation of the qualitative analysis of each thermogram. Effective mean average anatomical surface temperature (MAST) for the targeted anatomical region was calculated from an approximately 3000-pixel (each pixel contains an individual temperature) area selected over the regions of the chest, left

shoulder, barrel and hindquarter and the right shoulder, barrel and hindquarter and the region of the dorsal and lumbar areas. (**See Table 1.0**)

Table 3.0: *Flir Tools analysis software used to measure high, Low and average temperatures of each scan.*

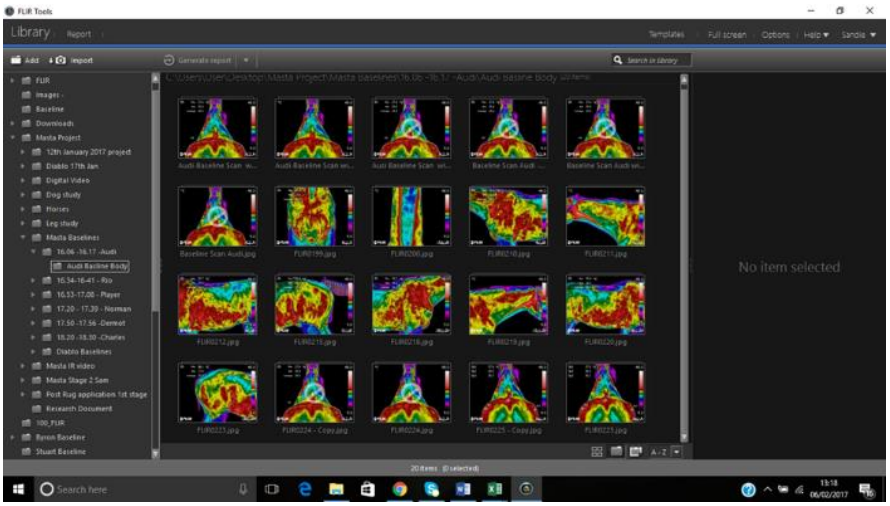
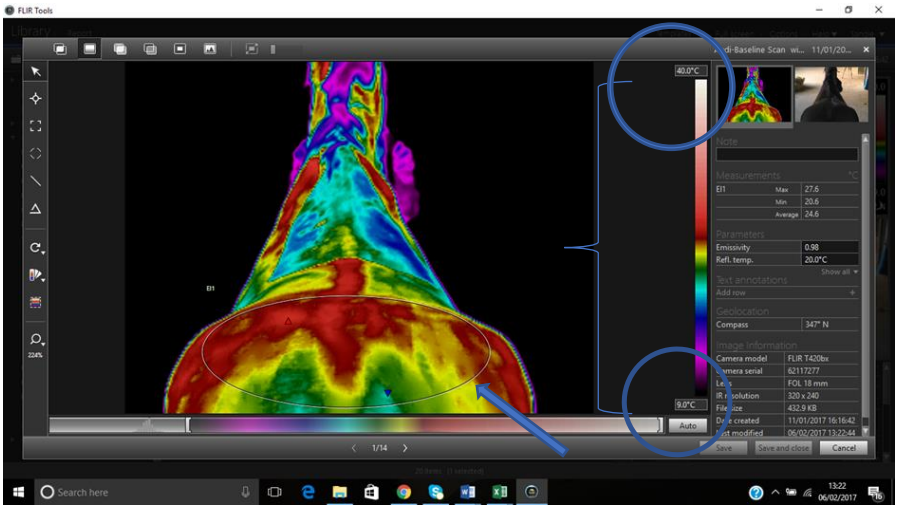


Table 4.0*: Level and span values 9 – 40 (Circled) and the target area measured in this case the lumbar region (arrowed)*



The analytical software utilizes the mean temperature of the pixels, composing the targeted area within each image to determine the surface temperature of each anatomical region. Effective mean average temperature for these anatomical regions was calculated to allow comparison of changes in MAST, as affected by the timing of each stage (30, 60, 90, 120, 150, 180) of Protechmasta rug application protocol.

Regional surface temperature changes of each anatomical region in relation to the baseline images were noted and recorded. The mean temperature of the baselines was then compared to the mean values of the 9 scans of each horse from each temporal increment (30,60,90,120,150,180).

Statistical analysis.

Stage 1 & 3 results are the mean average surface temperature (MAST) of 9 replicated thermal images, of each horse's selected anatomical regions after the Protechmasta IR rug application. Each timed Protechmasta IR rug application was initially considered a separate application for purposes of analysis. The mean values of the 9 scans taken of each horse at each temporal increment were calculated and recorded. The final mean values from each temporal increment (timings)

were then compared together to acquire the final mean values and results of the research. We have then compared the baseline MAST's of all the horses with the maximum 180-minute application.

Stage 2. All Temperature data from the inside and outside of the Protechmasta rug baseline and temporal increments post application were calculated in the same way and MAST from each temporal increment were compared to acquire their mean values. At the end of this study an overall MAST was acquired.

Data analysis was completed by using a the Flir Tools analysis software that captured the high, low and average temperature of the anatomical regions measured in this research. Excel electronic software was used to store and calculate this data from the Thermograms and tables were used to plot and evaluate the data and achieve significance of the results.

STAGE 1 & 3

Table 5.0 Average high/low/Average temperatures both temperatures of each whole horse

Column:	**1.**		**2.**		**3.**	
Baseline	**HIGH Temp**		**LOW Temp**		**Average temp**	
Audi	30		15		26	
Rio	31		22		28	
Player	30		21		27	
Norman	30		20		27	
Dermot	27		16		23	
Charles	29		19		26	
Diablo	27	**Mean**	17	**Mean**	23	**Mean**
	203	**29**	**131**	**19**	**180**	**26**
30 mins						
Audi	30		17		26	
Rio	28		18		28	
Player	31		23		28	
Norman	30		24		28	
Dermot	28		21		25	
Charles	32		23		28	
Diablo	28	**Mean**	19	**Mean**	24	**Mean**
	207	**30**	**145**	**21**	**186**	**27**
60mins						
Audi	31		17		27	
Rio	32		23		29	
Player	30		24		28	
Norman	31		22		27	
Dermot	28		20		25	
Charles	32		22		28	
Diablo	26	**Mean**	21	**Mean**	23	**Mean**
	210	**30**	**149**	**21**	**187**	**27**

90 mins

Audi	31		18		27		
Rio	32		24		29		
Player	31		23		28		
Norman	31		22		27		
Dermot	30		20		26		
Charles	31		22		28		
Diablo	27	**Mean**	19	**Mean**	23	**Mean**	
	212	**30**	**148**	**21**	**189**	**27**	

120mins

Audi	30		18		27		
Rio	34		24		30		
Player	31		23		28		
Norman	29		22		27		
Dermot	30		19		25		
Charles	31		23		28		
Diablo	27	**Mean**	20	**Mean**	23	**Mean**	
	213	**30**	**148**	**21**	**187**	**27**	

150mins

Audi	31		15		25		
Rio	33		24		30		
Player	32		32		32		
Norman	31		21		27		
Dermot	32		20		27		
Charles	32		23		25		
Diablo	27	**Mean**	19	**Mean**	28	**Mean**	
	217	**31**	**153**	**22**	**194**	**28**	

180 mins

Audi	31		19		26		
Rio	34		24		32		
Player	33		20		29		
Norman	27		19		25		
Dermot	30		19		25		
Charles	30		21		26		
Diablo	25	**Mean**	18	**Mean**	22	**Mean**	
	210	**30**	**139**	**20**	**185**	**26**	

Results of Stage 1 and 3.

Column 3 Average Temperature (*Translated the average temperature represents the average of 3,000 pixel temperatures of each 9 anatomical regions measured within the thermogram for each horse. This figure equates to 189,000 temperatures measured to achieve the overall **average** result*). (See Table 5.0)

- When comparing the MAST (*mean average surface temperature*) of the Baselines Average temperatures for all horses with the 30-minute temporal stage, there was an initial increase of 1 degree Celsius - from 26 ºC to 27 ºC.
- Between 30 minutes and up to 150 minutes the MAST for the average temperature of these temporal stages stayed consistent at 27 ºC and did not increase or decrease across all horses.
- At 150 minutes, we saw an increase in MAST of the average temperature of all horses of 1 degree from 27 ºC to 28 ºC degree across all horses.
- After 150 minutes and up to 180 minutes, we saw a decrease in MAST of the average temperature of 2 degrees back to the baseline temperature of 26 degrees.

Column 1. Highest Temperature.

- Of the seven horses in the study five saw an increase in their mean average **highest** temperature point of between 1 and 3 degrees from baseline to 180 minutes.
- Two of the horses saw a decrease of 2 degrees of their **highest** mean average point from baseline to 180 minutes.

Column 2. Lowest Temperature

- Of seven horses in the study five saw an increase in their average mean **lowest** temperature point of 1 and 4 degrees from baseline to 180 minutes.
- Two of the horses saw a decrease of 1 degree in their **lowest** mean temperature point from baseline to 180 minutes.

Points to note:

It is not possible to get all horses at the exact starting baseline temperature for several factors these are due to the following:

- Level of musculature.
- Adipose fat levels.
- Length of coat. Although all horses were clipped some were clipped later than others.
- Illness – although all horses were deemed as healthy and fit.
- Level of activity in their boxes between increments.

Stage 2.

Table 6.0

Protechmasta IR Rug Results						
	Dorsal	**Lateral left**	**Lateral right**	**+3**	**MAST**	**MAST Whole Rug**
Baseline						
Exterior	15	14	14	43	**14**	
Interior	14	13	13	40	**13**	13.5
30 mins						
Exterior	19	17	17	53	**18**	
Interior	18	16	16	50	**17**	17.5
60 mins						
Exterior	18	17	17	52	**17**	
Interior	17	15	15	47	**16**	16.5
90 mins						
Exterior	19	18	18	55	**18**	
Interior	19	15	15	49	**16**	17
120mins						
Exterior	18	16	16	50	**17**	
Interior	16	16	16	48	**16**	16.5
150 mins						
Exterior	19	16	16	51	**17**	
Interior	18	16	16	50	**17**	17
180 mins						
Exterior	18	16	16	50	**17**	
Interior	17	15	15	47	**16**	16.5

Total Collective MAST	
Exterior	**17**
Interior	**16**
Total MAST	**16.5**

Total MAST of all 7 rugs
16.5

Results of stage 2

A.

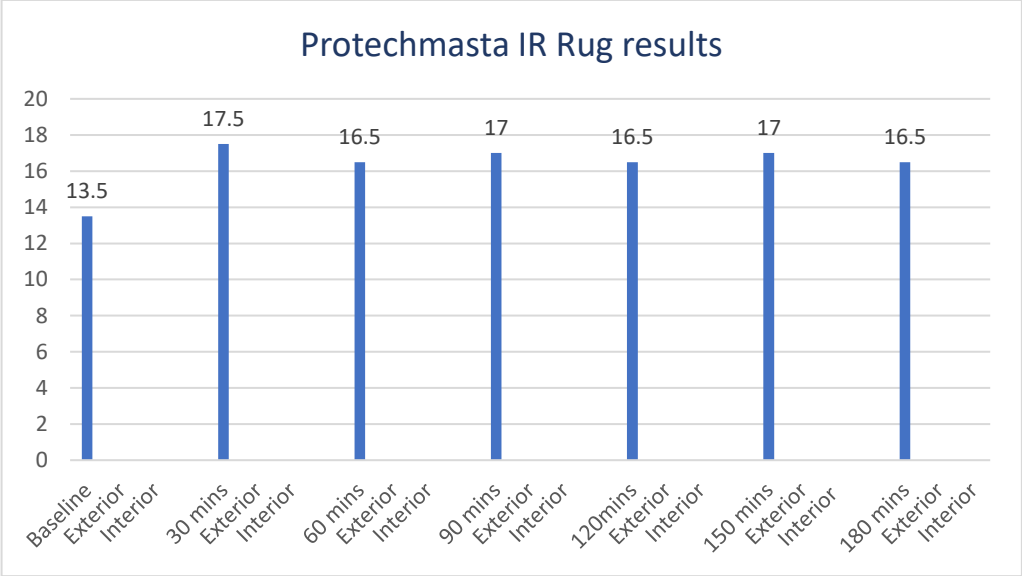
- When comparing the MAST (mean average surface temperature) of the rugs **Baselines Exterior** temperatures with the exterior temperature of the **30-minute** temporal stage, there was an initial increase of **4 ºC** across all rugs.

- When comparing the MAST (mean average surface temperature) of the **Baselines Interior** temperatures with the interior temperatures of the **30-minute** temporal stage, there was also an initial increase of **4 ºC across** all rugs.

B.

- When comparing the MAST temporal stages between 60, 90, 120, 150 and 180 minutes (**see table 6.0**) there was a very consistent rise and fall of 0.5 degrees between each stage. **(see table 7.0**)

Table 7.0



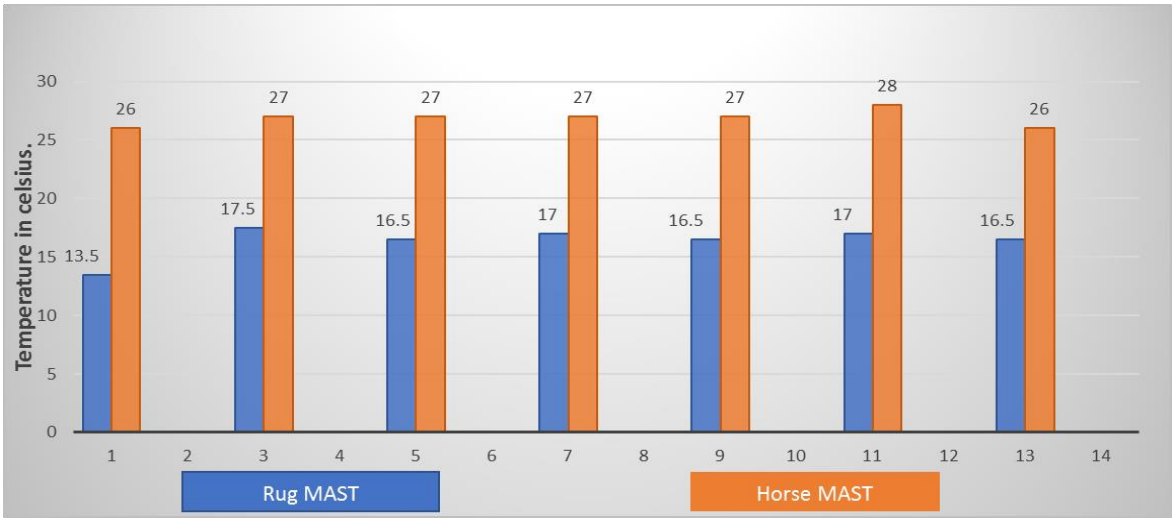
Note: *The conclusion here is that the rug is maintaining and regulating its temperature while in Situ.*

Conclusion of stage 2.

The conclusion for stage 2 is that an even stable temperature increase for both the rugs interior and exterior temperature was achieved.

The highest increase of 4 ºC in MAST (mean average surface temperature) of the rugs on all the horses was seen at the 30-minute temporal stage. This increase in temperature will be because the rugs initial insulating response was activated, absorbing radiation falling on it as it contacted the horses skin surface. At the 60 minute stage the temperature dropped by 1 ºC as the rug adjusted and stabilised to the horse's body and ambient room temperature. Post this fall at the 60 minute stage the rug regulated and maintained a consistent 0.5 degree rise and fall between the temporal stages from 60,90,120,150,180 minutes. An object in thermal equilibrium with its surroundings radiates as much as it absorbs hence why this yoyo temperature response was triggered.

It would therefore appear that this would suggest that the ceramic filaments which are impregnated with Far Infrared partials are absorbing and reflecting the radiation at a consistent rate and thus following the features of a blackbody which is a perfect absorber as well as a perfect emitter of radiation.



Overall Conclusion.

From the data collected from both Horse MAST and Rug MAST the conclusion would indicate that between the initial baseline to the 3O minute temporal stage the rug absorbed 3% of the radiation emitting from the superficial skin temperature of the horse. The rug in the 60-minute temporal stage dropped by 1 ºC which would indicate, as the horse's temperature did not increase but stayed at 27 ºC, that this 1 ºC was lost to the atmosphere. At the 30-minute temporal stage the horses MAST stabilised at 27 ºC and maintained this temperature until the 150-minute temporal stage when it peaked by 1 ºC to 28 ºC. From the 90-minute temporal stage and up to the 180 temporal stage the rug maintained an absolute stable temperature. This would indicate that the rugs properties can help to regulate the increases and decreases of the radiation emitting from the surface of the object that the rug is in contact with, in this case the Horses skin surface. At the final 180-minute temporal stage the horses MAST decreased by 1 ºC taking it back down to the original baseline temperature.

During the study all temperature measurements showed some level of increasing at the 150-minute mark before reducing back to baseline temperatures.

Individual average high and low temperature fluctuations were consistent:

- 5 increasing from baseline to 180 minutes
- 2 decreasing from baseline to 180 minutes.

Higher increases are seen in low temperature areas than in higher temperature areas, demonstrating signs of better temperature regulation.

Horses are not just increasing in heat but are also decreasing which indicates the rugs ability to absorb heat and emit heat allowing a more regulated temperature, therefore preventing the horses from cooling down too quickly and heating up beyond that of a safe level.

Study results:

The study results indicated that the Protechmasta IR rug had a positive effect on the maintenance and regulation of the equines skin temperature, this is an important factor to the well-being of the equine.

For optimal function, the equine needs to keep the body regulated at a constant temperature. The equines body can only do this if the heat it generates is balanced with the heat that it loses, the Protechmasta rug clearly does this based on the research evidence of the give and take of heat at regulated and constant rates.

This heat which is transported to the surface of the skin through the blood circulation can be influenced by the ambient air temperature in touch with the skin's surface and will lose heat or gain heat by conduction, convection, radiation and evaporative sweating. The blood flow below the skin surface is influenced by temperature receptors and will increase or decrease metabolic activity responsible for effective muscle function and cellular activity. Initially, the temperature receptors at the surface of the equines skin detect changes in the external temperature, they then pass information to the processing centre in the brain, called the hypothalamus. This Hypothalamus has temperature receptors (nerve impulses) that detect changes in the temperature of the blood which is circulating initially at the skin surface, it will automatically trigger changes to the sweat glands and muscles (receptors) initiating a response to ensure the equines body temperature remains constant, at 37°C ensuring equilibrium.

Based on this study the Protechmasta IR rug maintained and regulated the temperature of the equine. Given that the ambient temperature was as low as 9 degrees and the horses were stood tied up in their boxes, they did not lose heat to the atmosphere by convection or conduction as would be expected of a horse without a rug and that is in contact with the cold ground and in contact with the low air temperature. They also did not sweat while wearing the rug. When a horse is insulated by wearing a rug the danger is overheating, this can lead to heat stress from poor dissipation and poor evaporation of heat. In all the horses, there was an even and maintained regulation of temperature in keeping with an optimum healthy function. This would appear to have been encouraged by the application of the Protechmasta IR rug.

Both sweat glands and muscles, need to be able to generate and release heat not only to keep the equilibrium of temperature but to also ensure better muscle function, metabolism and cellular efficiency. The benefits of the FIR heating elements of the Protechmasta rug lie in its ability to increase the blood flow of the equine by vasodilation and keep it constant, this widening of the blood vessels will improve metabolic rate, oxygenation of blood and cells.

Improved metabolic efficiency will allow better cellular respiration, a set of metabolic reactions that take place in the cells of the horse improving the conversion of biochemical energy from nutrients into ATP(energy) and encouraging the release of waste product for e.g. toxins in the body. With improved circulation comes improved oxygen availability, generally supplied to a cell by passive diffusion. This Improved circulation encourages better transportation of nutrients (such as amino acids and electrolytes), oxygen, carbon dioxide, hormones. It also improves circulation of blood cells to and from the cells in the body to provide nourishment and help in fighting diseases, stabilise temperature and pH, and maintaining homeostasis.

The heat generated from increased blood flow also makes connective tissue more flexible as it's extensibility will increase, allowing for improved suppleness and prevention of injury. It temporarily decreases joint stiffness, pain, and muscle spasms. Heat reduces inflammation and the build-up of fluid in tissues (oedema).

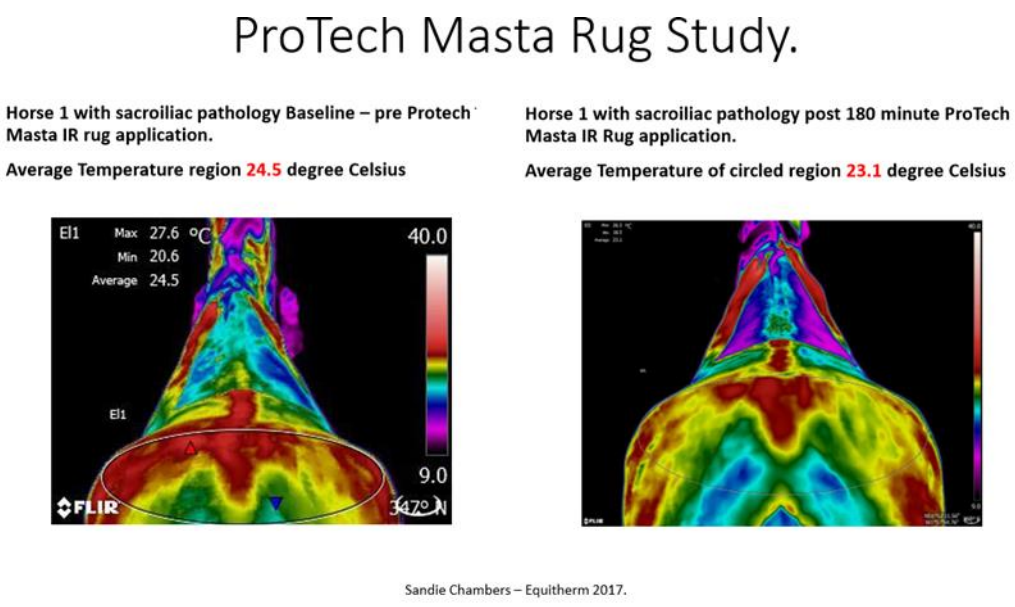
Observation.

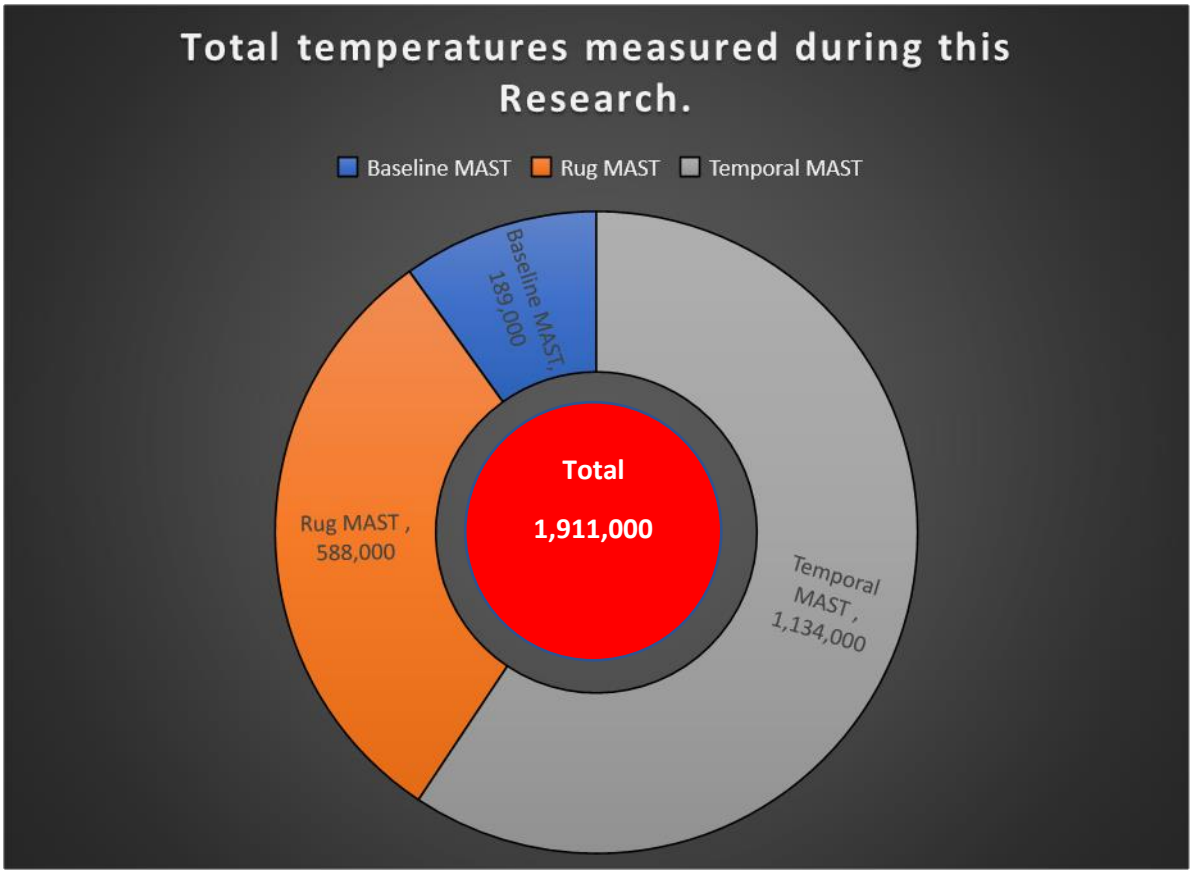
What was observed during this study was the reduction of inflammation post the Protechmasta IR rug application at the 180minute temporal stage, on two of the subjects.

On initial scanning with thermography of the baselines of these two horses, both had unusual thermal asymmetries in the left sacroiliac region spreading to the left hindquarter. On measuring the region's temperature (MAST 23.4 Celsius) there was a clear temperature asymmetry compare to the same region of the opposite side.

The reason that we saw this increase in temperature, is due to an inflammatory process. An injury causes various substances to be released and initiates a chain of reactions resulting in vasodilation and increased blood flow resulting in this thermal (heat) pattern and raised temperature associated with that pattern. Blood vessels become leaky allowing fluid to pass into the tissues which can cause swelling. The white blood cells (antigen) fight any pathogens involved to remove the causative stimulus and or bacteria and to prevent cell death. Tissue cellular repair can be helped along by encouraging blood flow and oxygen to the area initiating repair and reducing inflammation. In this case, the biological effects of the FIR vibrating particles provided by the Protechmasta rug appear to have irritated the inflammation increasing the blood flow and encouraging cellular activity and initiating repair.

On removal of the Protechmasta IR rug, we saw a visible reduction in thermal asymmetry and a reduction in heat of 1.4 degree Celsius. This is a very significant result.




Total temperatures measured during this Research.
Baseline MAST
Rug MAST
Temporal MAST
Baseline MAST, 189,000
Rug MAST , 588,000
Temporal MAST , 1,134,000
Total
1,911,000