Veterinary Sciences and Medicine

RESEARCH ARTICLE

Development of an Equine Non-Contact Thermography Device

HC Collins[1], JL Leatherwood[2*], F Yildiz[1], MJ Anderson[1], N Walker[3] and MM Beverly[1]

[1]Department of Agricultural Sciences and Engineering Technology, Sam Houston State University, USA
[2]Department of Animal Science, Texas A&M University, USA
[3]Louisiana State University Agricultural Center, Louisiana State University, USA

Abstract

Fever is a common indicator of infectious disease in animals. However, collection of a rectal temperature can be difficult and stressful on the animal. New technologies, such as thermal imaging cameras, have recently become more prevalent to collect the body temperature of animals at other, less invasive sites. The objective of this research was to compare a first generation prototype non-contact thermography device (NCTD) to a traditional FLIR® thermal imager (FLIR® Systems Inc., Austin, TX) as well as determine the relationship between rectal and thermographic temperatures as an indicator of health status. The study was conducted in three phases, with Phases I and II focused on correlating ocular globe temperatures to an industry standard of rectal temperature. Following data collection, Phase III evaluated multiple sites on mature sedentary horses. Data were analyzed using the PROC CORR and PROC REG procedures of SAS. A moderate relationship was found at the ocular globe of the eye ($r=0.51$; $P \leq 0.01$) for NCTD: FLIR®, along with weak relationships being found between NCTD: Rectal ($r=0.42$; $P \leq 0.01$) and FLIR®: Rectal ($r=.031$; $P \leq 0.01$) at this location. Weak relationships were also found using a combination of knee, girth, and flank measurements on the horse, where an R- squared value was found with both the FLIR® ($r^2 = 0.19$) and NCTD ($r^2 = 0.15$) in relation to rectal temperature. Additional phases will need to be executed, where environmental factors are heavily emphasized, in order to determine these devices true effectiveness for body temperature detection in a production setting. Still, utilization of this technology shows potential to greatly reduce risk for spread of diseases, and allow for a healthier and better maintained population of horses within the industry.

Keywords: Equine, Thermography, Fever, Eye

Abbreviations: MC: Medial Canthus, **OG:** Ocular Globe, **LC:** Lateral Canthus, **IRT:** Infrared Thermography

Introduction

Fever is a common indicator of infectious disease in animals [1]. Specifically in horses, fever is defined as being a rise in body temperature above the normal range of 37.5 to 38.6°C [2]. The equine industry is heavily dependent on the gathering of mass numbers of animals in the form of races, shows, rodeos, fairs, and other educational and competitive functions. These large assemblies of horses run a high risk for spread of infectious diseases [3], and an effective method of temperature collection can be opportune for prevention. If, upon arrival to an event, animals could be screened for illness prior to admittance into the facility, the biosecurity of the event would be enhanced, allowing for a greater population of animals with sound health. Currently, the industry standard for determining body temperature involves the use of a rectal thermometer [4]. Unfortunately, this method may be a safety risk for handlers and unfavorable to the animal. While the use of a rectal thermometer is widely regarded as the most effective industry practice, more modern methods are being developed and tested including Infrared Thermography (IRT) devices. In ovine, the eye and surrounding skin appears to be the anatomical choice for the measurement of temperature. The highest face temperature is often found in the eye and has been shown to reflect internal body temperature. Diego et al. [5] demonstrated that thermography was a fast and non-invasive method for fever detection in sheep and could greatly reduce the stress caused by the capture, management, and manipulation of animals during clinical examination [5]. The study was able to successfully distinguish between febrile and non-febrile sheep by measuring temperatures of the eye, and found a positive, moderate overall correlation of rectal temperatures to IRT ocular temperatures.

Benefits of this technology include rapid temperature detection and a lack of invasiveness. IRT is a technology that detects infrared energy on the surface of an object and Produces a temperature and depending on the specific device, an image displaying temperature distribution. While this technology has the advantage of being non-invasive, as it does not require contact with the subject being measured, it is limited to reading only surface temperatures. Valera et al. [6] evaluated

Correspondence to: JL Leatherwood, Department of Animal Science, Texas A&M University, College Station, 22 TX 77843, Mobile: 979-862-3654 23, Email: leatherwood [AT] tamu [DOT] edu

Received: April 26, 2018; **Accepted:** April 30, 2018; **Published:** May 04, 2018

changes in eye temperature and stress in horses during show jumping competitions and suggested that eye thermography measurements correlate to both salivary and plasma cortisol and may constitute an effective method for detecting stress in performance horses [6]. Investigators of this study affirm IRT as a useful technology to determine stress levels in horses. Further, a study involving febrile ponies was performed using a FLIR® EX320, a device that differs from the FLIR® E60 by having a lower thermal sensitivity and fewer extraneous features due to its older age [7]. This study produced data that indicates the devices ability to detect rises in body temperature, but is not accurate enough to be effective as a primary fever diagnostic tool. Still it has shown potential for the ability to detect rises in body temperature, although additional evidence is needed to show its effectiveness in this matter. Therefore, the objectives of the current study are to develop a portable noncontact thermography instrument that could be readily available to consumers, and validate the use and efficacy of a novel instrument for equine and determine appropriate anatomical locations to complete the scans to produce the most reliable indication of body temperature.

Materials and Methods

The Sam Houston State University Institutional Animal Care and Use Committee (13-10-94 25-1027-3-01) approved all care, handling, and sampling of horses. This study was divided into multiple phases to access accuracy of the device as well as the correlation between thermographic measurements of different parts of the horse and rectal temperatures. In addition to the novel device (Figure 1), that has recently been developed, a FLIR® E60 Thermal Imaging camera (FLIR® Systems Inc., Austin, TX) was utilized in order to validate the new devices ability to detect infrared thermal temperatures as effectively as the devices of which it was modeled after. Phase I evaluated the efficacy of the first generation prototype NCTD in its first field testing in order to validate its use against a traditional FLIR® thermal imager and determine both devices correlation with rectal temperature. Measurements were obtained in the following areas: medial canthus (MC), ocular globe (OG), and lateral canthus (LC) (Figure 2).

Measurements were taken by both the FLIR® and NCTD at a 1 m distance of each location on the eye. Rectal temperatures

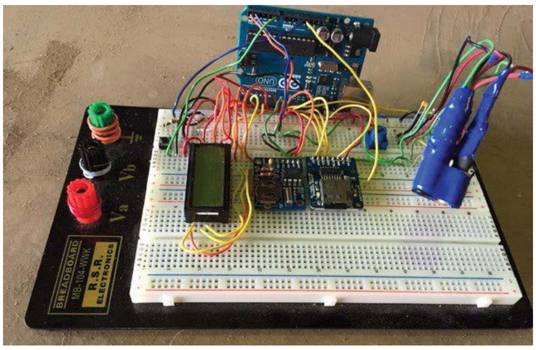

Figure 1: Prototype Non-Contact Thermography Device (NCTD) development board.

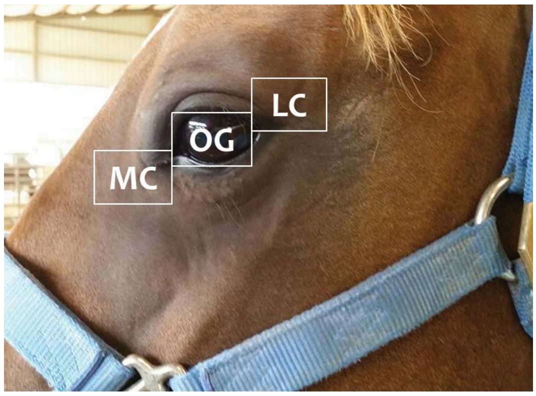

Figure 2: Illustrates each sector of the eye (MC; Medial Canthus, OG; Ocular Globe, LC; Lateral Canthus) that was measured using a FLIR® E60 Thermal Imaging camera (FLIR® Systems Inc., Austin, TX) and a new Non-Contact Thermography Device.

were also collected to serve as the standard to determine body temperatures. Measurements were taken on 20 sedentary horses (2-9 years; 357 to 540 kg) over 5 days for 100 measurements. Each measurement was taken within a singular covered stall barn, with each horse measured within their own stall. Relative humidity and ambient temperatures were recorded in order to evaluate the impact of environmental effects on the devices. Following phase I, modifications were made to the NCTD that included the angle of the sensor was narrowed to 5 degrees and a laser was added to improve the accuracy of temperature readings. Additionally, the device was programmed to produce an average value along with the individual values previously utilized. The average is produced using every 5 values collected, which allowed for a more consistent evaluation of temperature in a specific location. Following the improvements made to the device measurements were taken using both the FLIR® and NCTD at a 1 m distance from each location of the eye (MC, OG, and LC).

Rectal temperatures were also recorded to serve as the standard measurement of body temperature. From this secondary round of data, further evaluation of the device to the established FLIR® model was assessed, as well as to further observe the ocular temperatures relationship to rectal temperature. For this phase, 100 measurements were taken on sedentary horses (2-15 years; 357 to 540 kg). There were notable differences however, in the setting of which these measurements were taken. In the beginning of Phase II, 20 measurements were obtained within a single stall barn, while the remaining 80 measurements were evaluated at a similar event facility (Ike Hamilton Expo Center, West Monroe, LA) over the course of two days. This created greater variability in terms of light and air exposure, time of day, and other various environmental factors. Relative humidity and ambient temperature were recorded at the time of each measurement in order to determine if these factors affected thermal measurements. The purpose of the third phase was to test the NCTD and FLIR® at additional locations on the horse in order to compare them back to rectal temperature. Additional areas of the horse were selected based on accessibility, a relative lack of fat coverage, and possible presence of viable superficial veins that may allow for better thermal expression. The following locations were measured on each horse: eye, muzzle, lower lip, throatlatch, forehead, back of the ear, bridge of nose (side), front face of the knee, front leg cannon bone (side), where the neck and chest meet, girth, hock, flank, and tail head. All measurements were taken using both the FLIR® and NCTD from a 1 m distance as described previously. Rectal temperatures were also collected through this phase of the trial. For Phase III, 100 measurements were taken at each location on sedentary horses (2-15 yr. 357 to 540 kg). The location in which horses were measured remained constant throughout this phase of the data collection; horses were kept in an unenclosed but covered facility when measurements were taken. Relative humidity and ambient temperatures were recorded for each horse at the time each of their individual measurements was taken. All data were analyzed using the PROC CORR procedure of SAS to determine the relationship between measurements and the PROC REG procedure of SAS to determine the relationship between rectal temperature and temperatures at multiple locations on the body.

Results

A moderate relationship was observed between the NCTD: FLIR® at the ocular globe ($r=0.53$; $P<0.01$) and the LC ($r=0.65$; $P<0.01$) locations during phase I (Table 1). There was a minimal relationship at the MC with NCTD: FLIR® ($r=0.05$; $P \leq 0.05$); however, the FLIR® had a higher correlation at the LC ($r=0.44$; $P \leq 0.01$) to rectal temperature when compared on the NCTD ($r=0.18$; $P \leq 0.05$). The same is true at the OG for the FLIR® to rectal relationship ($r=0.45$; $P < 0.05$) as well as the NCTD to rectal relationship ($r=0.37$; $P < 0.05$), although both relationships did strengthen. The relationship between ocular temperatures were found to have a weak correlation ($r \leq 0.37$; $P \leq 0.06$), illustrating that the ocular temperature alone with either device is not a good substitute for traditional rectal temperature measurements.

Ambient temperatures during this phase had a minimum of 22°C and a maximum of 26.1°C, with 22.8°C being the average ambient temperature and an average relative humidity of 96%. Data collected during phase II, demonstrated a weak correlation of NCTD: FLIR® at the MC ($r=0.08$; $P \leq 0.05$). A moderate relationship was again found at the OG ($r=0.51$; $P \leq 0.01$) and LC ($r=0.53$; $P \leq 0.01$) for NCTD: FLIR® (Table 2). In terms of the NCTD: FLIR® relationship, these measurements are consistent with the results of the first phase. However, the correlation between NCTD: Rectal improved at the OG and LC ($r=0.41$, $r=0.28$; $P \leq 0.01$), while the FLIR® remained constant at both OG and LC ($r=0.31$, $r=0.32$; $P \leq 0.01$). Ambient temperatures during phase II had a minimum of 30.6°C, a maximum of 32.8°C, an average of 31.7°C, and an average relative humidity of 81%. During phase III, the individual correlation found to be highest in relationship to rectal temperature was the girth for NCTD ($r=0.34$; $P \leq 0.01$) and at the Flank for FLIR® ($r=0.40$; $P \leq 0.01$; Table 3). Strong correlations were also found between both thermography devices at the knee, hock, and tail head, with correlations above $r=0.71$ ($P \leq 0.01$). Additionally, at the chest, a correlation of $r=0.64$ was observed, and the cannon, girth, and flank all produced correlations greater than $r=0.55$ ($P \leq 0.01$) for this relationship (Table 4).

A stepwise regression was also performed to determine if any combination of sites on the horse would give a reasonable estimate of body temperature when compared to rectal temperature. Utilizing all 14 points produces the highest R-squared value being $r^2=0.30$ for FLIR®: Rectal, and $r^2=0.24$ for NCTD: Rectal. However, 14 measurements per horse is not necessarily practical, especially for a design with the intent of being more efficient than obtaining a rectal temperature. The highest R-squared values using 3 points were found using the muzzle, knee, and flank in the FLIR® ($r^2=0.23$) and the eye, flank, and tail head for the NCTD ($r^2=0.18$). With the addition of the lower lip to the FLIR® regression, the R-squared value is raised ($r^2=0.26$) as was the NCTD regression with the addition of the girth ($r^2=0.22$). Additionally, the only combination of three locations where an R-squared value was found with both the FLIR® ($r^2 = 0.19$) and NCTD ($r^2 = 0.15$) was using the knee, girth, and flank (Table 5).

Temperature Detection Methods	Medial Canthus	Ocular Globe	Lateral Canthus
NCTD: FLIR®	0.06	0.18	0.34
NCTD: Rectal	0.54	0.37	0.45
FLIR®: Rectal	0.55	0.18	0.44

Table 1: Correlation coefficients (r) between various temperature detection methods used on horses. Devices used include a rectal thermometer, a FLIR® E60 Thermal Imaging camera (FLIR® Systems Inc., Austin, TX), and a newly developed Non-Contact Thermography Device (NCTD). Temperatures were obtained with the FLIR® and NCTD from a 1 m distance at 3 locations of the eye (Medial Canthus, Ocular Globe, and Lateral Canthus).

Temperature Detection Methods	Medial Canthus	Ocular Globe	Lateral Canthus
NCTD: FLIR®	0.08	0.02	0.42
NCTD: Rectal	0.51	0.41	0.31
FLIR®: Rectal	0.54	0.28	0.33

Table 2: Correlation coefficients (r) between various temperature detection methods used on horses. Devices used include a rectal thermometer, a FLIR® E60 Thermal Imaging camera (FLIR® Systems Inc., Austin, TX), and a newly developed Non-Contact Thermography Device (NCTD). Temperatures were obtained with the FLIR® and NCTD from a 1 m distance at 3 locations of the eye (Medial Canthus, Ocular Globe, and Lateral Canthus).

Measured Areas of Horse	NCTD	FLIR®
Eye	0.23	0.31
Muzzle	0.10	0.36
Chin	0.17	0.34
Forehead	0.07	0.20
Throatlatch	0.19	0.14
Side of Nose	0.09	0.18
Behind Ear	0.10	0.07
Chest	0.16	0.29
Knee	0.13	0.21
Cannon	0.12	0.16
Girth	0.34	0.35
Flank	0.32	0.40
Hock	0.27	0.28
Tail head	0.05	0.24

Table 3: Correlation coefficients (r) between rectal temperature measurements on horses and two infrared thermography devices. The two thermography devices being a FLIR® E60 Thermal Imaging camera (FLIR® Systems Inc., Austin, TX) and a newly developed Non-Contact Thermography Device (NCTD). These thermography devices were used to measure the surface temperature of horses at 14 locations on the body.

Measured Areas of Horse	NCTD:FLIR®
Eye	0.38
Muzzle	0.44
Chin	0.14
Forehead	0.53
Throatlatch	0.16
Side of Nose	0.07
Behind Ear	0.42
Chest	0.64
Knee	0.71
Cannon	0.55
Girth	0.58
Flank	0.58
Hock	0.71
Tail head	0.73

Table 4: Correlation coefficients (r) between a FLIR® E60 Thermal Imaging camera (FLIR® Systems Inc., Austin, TX) and a newly developed Non-Contact Thermography Device (NCTD). These thermography devices were used to measure the surface temperature of horses at 14 locations on the body.

Ambient temperatures during this phase had a minimum of 28.9°C, a maximum of 35.6°C, an average of 34.4°C, and an average relative humidity of 54%. The enhancements made to the NCTD device following the first phase showed improvements in performance throughout the second phase. The simple addition of the laser allowed for a much more accurate aim to the specific area being measured. However, the laser pointer would have been moot if not for the angle of the camera being narrowed. By reducing the scope of the sensor from 45 degrees to 5 degrees, it allowed for further accuracy when targeting a specific area of the horse, and therefore added confidence in values recorded. It should also be noted, that the new NCTD device is still in development, and still encounters minor errors when in use. Because the device remained on the development board throughout testing the components of the device were always exposed and susceptible to alterations. The statistical analysis of the measurements suggests the improvements made following Phase I may have allowed for enhanced relationships between temperature detection methods, however some concerning variability still exists. The results of Phases I and II show that the relationship between the FLIR® and the NCTD device decreased following Phase II but remain relatively consistent overall. However, the results of the second phase show a closer relationship between rectal temperatures and the NCTD device, increasing from r=0.37 ($P \leq 0.05$) to r=0.41($P \leq 0.05$) at the Ocular Globe and r=0.18 ($P \leq 0.05$) to r=0.28 ($P \leq 0.05$) at the Lateral Canthus. The improved relationships could very well be the product of the updated device; however, the improved correlations are not substantial and other factors should be considered when discussing differences in the data.

Combinations of Measured Areas of Horse	NCTD	FLIR®
Muzzle + Knee + Flank	ND	0.23
Girth + Flank + Tail head	0.18	ND
Knee + Girth + Flank	0.15	0.19
Muzzle + Chin + Knee + Flank	ND	0.26
Eye + Girth + Flank + Tail head	0.22	ND
Muzzle + Chin + Chest + Knee + Flank	ND	0.28
Eye + Chin + Girth + Flank + Tail head	0.22	ND
*All locations measured	0.24	0.3

*All locations measured include all 14 locations measured. However, the order of importance to which each location was included in the regression differs between the two devices. In addition, "ND" indicates no data was produced for that relationship.

Table 5: The coefficient of determination (r^2) between rectal temperature measurements on horses and two infrared thermography devices. The two thermography devices being a FLIR® E60 Thermal Imaging camera (FLIR® Systems Inc., Austin, TX) and a newly developed Non-Contact Thermography Device (NCTD). These thermography devices were used to measure the surface temperature of horses at 14 locations on the body. The R-square values shown are using combinations of 3, 4, 5, and 14 locations on the horse.

Additionally, it is important to note the changes in correlation between the FLIR® and rectal temperatures. From the first phase to the second, a decrease in strength of the relationship between the two temperature detection methods was observed at both the Ocular Globe and the Lateral Canthus. The relationship improved at the Medial Canthus, but additional data from Phases I and II has shown this area to be the least reliable of the ocular temperatures. Being that the use of the FLIR® remained consistent from the first phase to the second; the lack of uniformity of correlations cannot be explained through its utility. Although this may be the case for the NCTD, in the case of the FLIR® it is more likely environmental or other external factors caused the variability of results. Phase I showed a greater range of temperatures and a higher relative humidity than did Phase II, however the average temperatures of Phase I are well below that of Phase II. Additionally, the setting in which Phase I was conducted was more uniform, as the data for Phase II was collected at varying facilities. These environment related factors could possibly explain differences in results, but are not useful to explain why the FLIR® to rectal relationship weakened while the NCTD to rectal relationship strengthened. Still, the fact of the NCTD to FLIR® relationship remaining relatively consistent allows for some validation of the new NCTD devices' ability to detect infrared thermal temperatures. Therefore, the new device may hold some value to equine producers due to its ease of measurement, but without further investigations into the relationship of ocular temperature as a non-invasive means to evaluate health, its utility remains limited. While the results of the second phase show some promise for the efficacy of the new device, environmental factors may have caused inconsistencies in the third phase. There were, of course, differences in environmental factors (i.e. ambient temperatures, relative humidity, time of day, degree of precipitation, etc.) between Phases I and II, however conditions in Phase III were the most variable throughout the data collection process. In order to determine if these devices would have any efficacy in a production setting these environmental factors will need to be accounted for, and determination of their role in the use of IRT devices needs to be executed. Johnson et al. (2011) found a moderate relationship between ocular and rectal temperatures; however, their environment during the study was much less variable than this study from each phase. While a moderate relationship did exist, investigators of the study did note that IRT does not appear to be useful in its current state for determining body temperature, but may have the ability to indicate the possibility of a feverous horse.

Data collected from Phase III does give some insight into the functionality of these devices and their ability to indicate body temperature. The relationship of the FLIR® and the NCTD to rectal temperatures weakened some from Phase I, but remained consistent with the results of Phase II. This could indicate an expected range of correlations between ocular temperatures and rectal temperatures, within the given variations of ambient temperature and/or relative humidity. The reason for this being, while variation in environment did exist, ambient temperatures and relative humidity never met any kind of extreme throughout data collection. Ambient temperature was never below 22°C or above 32.8°C and relative humidity was never below 81% or above 96% for Phases I and II. Similarly for the NCTD device, the correlation to rectal temperature did weaken with the third phase, but not substantially. Dissimilar to Phases I and II, the relationship between the FLIR® and the NCTD device did not remain consistent and became significantly weaker (from r=0.54 and r=0.51 respectively to r=0.38). This weakened relationship between ocular temperatures of the thermography devices could be explained by environmental temperatures. Satchell et al. [8] performed a study to determine environmental effects on the repeatability of thermographic temperature measurements in horses and concluded that time of day, ambient temperature, and relative humidity all must be considered when using IRT in horses, as they can alter temperature readings [8]. However, other locations measured provided strong positive correlations between the devices under the same conditions. The tail head, hock, and knee all produced correlations above r=0.70, the chest produced a correlation of r=0.64, and the forehead, cannon bone, girth, and flank all produced correlations above r=0.50. Many of these areas, where strong correlations between the FLIR® and the NCTD device were found, have minimal fat coverage such as the forehead, cannon bone, knee, flank, hock, and tail head. It is possible that there is more uniformity of tissues in these areas amongst horses by conformation of the species, and would allow for more consistent readings by the thermography devices. However, the strongest correlations between these devices do not grant insight into their ability to detect body temperature. The forehead, cannon bone, knee, and tail head all had correlations lower than r=0.21 on both the part of the FLIR® and NCTD device in relation to rectal temperature. Furthermore, the hock had a slightly higher correlation than these areas, but remained weak being r=0.27 with NCTD device and r=0.28 with the FLIR® in relation to rectal temperature. The flank produced a slightly stronger relationship to rectal with both devices being r=0.32 with the NCTD device and r=0.40 with the FLIR®. While these correlations are still 268 considered weak, they are the second strongest for the NCTD and strongest for the FLIR® amongst all areas measured, and are relatively consistent between both of their relationships to rectal. Additionally, the flank has a strong correlation of r=0.58 in the relationship of FLIR® to the NCTD device. The flank of a horse is the slightly indented area found between the barrel and the stifle. The skin of this area is thinner than most other areas, and has less fat and muscle present near the surface.

Tong et al. [9] discussed the thermal expression of certain tissues in relation to surface temperature, outlining primarily the difference in temperatures between fat and muscle Coverage [9]. While the differences between thermal expression of fat and muscle do not offer much in the way of their abilities to indicate core body temperature, the information becomes useful when attempting to select areas to measure. The knowledge that areas with more fat coverage typically produce lower surface temperatures than areas with more muscle coverage can be instrumental when interpreting results such as these. Alternatively, it is possible that in a relative absence of both muscle and fat in a location such as the flank of a horse, surface temperature readings could be produced somewhat consistently. The peripheral veins of the flank may be better thermally expressed due to the lower tissue content and thinner skin of that area [10].

In addition, the remaining two areas where strong, positive correlations were found between thermography devices are unlike the other locations in regard to fat coverage. The girth and chest areas tend to have more fat coverage, and would be much more variable between individual horses. However, it is likely that due to their proximity to the heart, blood flow to these areas may be more regular and constant than other areas of the body, allowing for temperatures to be better maintained, and therefore detected more evenly. Furthermore, between the chest and the girth, the girth area is closer to the heart and has less variability of tissue composition than the chest. Also, the possibility that this location could better detect body temperature through thermal expression is reflected in the results of Phase III. The highest correlation to rectal temperature found by the NCTD device was at the girth being r=0.34 and second highest for the FLIR® with r=0.35. Additionally, a strong correlation was found between the NCTD device and the FLIR® of r=0.58. Additional statistical analyses from Phase III involved the use of a linear regression in order to determine if a combination of sites measured on the horse might allow for better Prediction of rectal temperature than would a singular site. Unfortunately, these relationships were found to be weak, and lack uniformity between the devices. The highest R-squared value, using all 14 sites measured, still produced weak relationships for both devices (NCTD; r^2=0.24 and FLIR®; r^2=0.30). While they are the strongest, these values are not significantly stronger than using only 3 or 4 sites on the horse. Furthermore, the only combination of sites that was uniform between both devices was the knee, girth, and flank, which still produced weak relationships for both the NCTD (r^2=0.15) and the FLIR® (r^2=0.19). While these values are weak, they do provide further validation of the devices' abilities to not only function similarly to one another, but also to predict rectal temperature similarly to one another at these specific sites.

The apparent inconsistencies within the data provide room for speculation in regard to the use of these devices. While it can be asserted that the new NCTD device is still in development, and lacks stability when in use, the same cannot be said for the FLIR®, which is an established and well manufactured device. The most logical factor to question then would be the environment, which in past studies has shown to affect the readings of thermography devices. Autio et al. [11] observed a thermography devices' (Therma Cam PM595, FLIR® Systems, Inc., Portland, OR) inability to detect a drop in body temperature when weanling foals were exposed to a below freezing environment [11]. Although the conditions of this study involved a much warmer environment, it can be inferred that weather related factors can alter an animal's core body temperature, which may not be accurately assessed by a thermography device. Due to the greater variability of environmental factors in Phase III, it is possible the temperature readings were uneven, causing weak relationships between measurements. The study performed by Okada et al. [12] found that areas of an animal where hair had been removed, a higher relative humidity, presence of wind, and a higher ambient temperature were all factors that produced higher overall temperature readings from the thermal imager [12]. These findings do not indicate whether or not these factors would alter core body temperature, but rather present insight into the functionality of a thermography device. If it is known that these particular factors tend to increase temperatures readings by these devices, then it is possible to better account for them, and possibly adjust readings depending on these factors in a particular setting.

To further support this, the study goes on to describe an infrared thermal imager as being most effective in an environment almost completely devoid of these factors. When ambient temperatures were constant and relative humidity was low, the measurements had a much higher reproducibility rate. Furthermore, when allowed time to acclimate to the given environment, the subjects being measured had much more consistent readings. This type of environment may not be practical in a setting where horses are involved, but this study does provide some additional knowledge of how environmental factors influence the function of various thermography devices. While this study does serve to reveal the utility of varying thermography devices' ability to detect body temperature, it also exposes the additional work needed to further validate their effectiveness. The results of this study show the NCTD and the FLIR® to operate similarly at not only the eye, but also multiple other sites on the horse. This new knowledge allows for additional possibilities of use, and confirms the novel devices' state as viable for use in infrared thermal temperature detection. However, the new NCTD device is in need of encasement, and perhaps further enhancements to solidify its accuracy in the way of an established model such as the FLIR®. The device has shown improvements thus far, and shows great potential as a valuable tool that is efficient and accessible within the equine industry. Currently, it seems the device may best serve its purpose as a preliminary screening tool to determine the potential for an animal harboring illness. In this case, a maximum temperature must be established, at which point animals meeting or exceeding this point would be removed for further evaluation. Utilization of this technology has the potential to greatly reduce risk for spread of diseases, and allow for a healthier and better-maintained population of horses within the industry.

Acknowledgements

This Office of Research and Sponsored Programs at Sam Houston State University provided financial support to conduct this research. The sponsor had no input in the study design, analysis, interpretation of data, or the decision to submit the article for publication.

References

1. Hart BL (1988) Biological basis of the behavior of sick animals. *Neurosci Biobehavioral Rev* 12:123-137. [View Article]
2. Goodwin SD (1998) Comparison of body temperatures of goats, horses, and sheep measured with a tympanic infrared thermometer, an implantable microchip transponder, and a rectal thermometer. *Contemp Top Lab Animal Science* 37: 51-55. [View Article]
3. Powell DG (1991) Viral respiratory disease of the horse. *Vet Clin North Am Equine Pract* 7: 27-52. [View Article]
4. Traub Dargatz JL, Dargatz DA, Morley PS, Dwyer R, Landry K (2001) Infection control strategies for horses in the new millennium. *Amer Assoc Equine Pract* 47: 36- 40. [View Article]
5. Diego AC, Sanchez Coron PJ, Pedrera M, Martinez-Lopez B, Gomez Villamandos JC, et al. (2013) The use of thermography as a non-invasive method for fever detection in sheep infected with bluetongue virus. *Vet J* 198:182-186. [View Article]
6. Valera M, Bartolome E, Sanchez MJ, Molina A, Schaefer A, et al. (2012) Changes in eye temperatures and stress assessment in horses during exercise. *J Equine Vet Sci* 827-830. [View Article]

7. Johnson, SR, Rao S, Hussey SB, Morley PS, Traub-Dargatz JL (2011) Thermographic eye temperature as an index to body temperature in ponies. *J Equine Vet Sci* 31: 63-66. [View Article]

8. Satchell G, McGrath M, Dixon J, Pfau T, Weller R (2015) Effects of Time of Day, Ambient Temperature and Relative Humidity on the Repeatability of Infrared Thermographic Imaging in Horses. *Equine Vet Journal* 47: 13-14. [View Article]

9. Tong, AK, Jones SD, Schaefer AL (1997) Method for detection of poor meat quality in groups of live animals. USA Patent 5595444. [View Article]

10. Bagavathiappan S, Saravanan T, Philip J, Jayakumar T, Raj B, Karunanithi, et al. (2009) Infrared thermal imaging for detection of peripheral vascular disorders. *J Med Phys* 34: 43-47. [View Article]

11. Autio E, Minna Liisa H, Jaakko M (2007) Thermographic evaluation of the lower critical temperature in weanling horses. *J Appl Anim Welf Sci* 10: 207-216. [View Article]

12. Okada K, Kei T, Sato S (2013) Investigation of Various Essential Factors for Optimum Infrared Thermography. *J Vet Med Sci* 75: 1349-1353. [View Article]

Citation: Collins HC, Leatherwood JL, Yildiz F, Anderson MJ, Walker N, Beverly MM (2018) Development of an Equine Non-Contact Thermography Device. Vet Sci Med 1: 001-007.