Field testing two animal specific non-contact thermometers on healthy horses.

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Abstract

This study investigated the accuracy of two animal specific non-contact infra-red thermometers (Rycom and Thermofocus), when compared to rectal temperature in healthy horses. 100 rectal and eye temperatures were measured in 22 horses. Fewer than 50% of the readings taken with the Thermofocus device were within ±0.5ºC of RT. Over 80% of eye temperature readings taken with the Rycom device were within ±0.5ºC of rectal temperature measured from the medial canthus region. The Rycom thermometer also appears to detect hyperthermia when measuring the left eye temperature, however, clinical patient testing is needed before its use can be recommended.

Keywords:

Infra-red thermometer, body temperature, non-contact thermometer, equine.

Introduction

Measurement and interpretation of body temperature form an essential part of any clinical examination. True core temperature can be measured in the urinary bladder, oesophagus or a major blood vessel (Miller, 2009), however in many patients these methods are too invasive to be justified for routine use. Rectal thermometry remains the current gold standard for measuring body temperature in conscious patients (Johnson, Rao, Hussey, Morley, & Traub-Dargatz, 2011) even though rectal temperature is known to differ to blood temperature in dogs (Greer, Cohn, Dodam, Wagner-Mann, & Mann, 2007) and horses (Green, Gates, & Lawrence, 2005). Measuring rectal temperature from an anxious equine patient, or within a confined space such as a trailer can place the veterinary professional at risk of being kicked or injured. There is therefore, on-going interest in developing non-invasive safer methods of measuring body temperature in horses.

Infrared thermometry detects heat radiation from the body surface to measure temperature. Both infrared thermography cameras (Johnson et al., 2011) and human non-contact infrared thermometers (NCIT) have been investigated as alternatives to rectal temperature measurement in horses (Ramey, Bachmann, & Lee, 2011). Skin temperatures measured at the axilla were up to 15^{o}C lower than RT so deemed not clinically useful, but gum temperature was reported to reliably identify elevated body temperatures in febrile horses (Ramey et al., 2011). However, gum temperature measurement relies on the horse tolerating lip retraction, which not all horses allow, and the gingival temperature can be affected by drinking cold water.

Figure 1 near here

The temperature of the eye varies by anatomical location as demonstrated in Figure 1, with the medial canthus typically used for temperature measurement (Soroko et al., 2016). So far equine eye temperature has been measured by thermography, with Johnson et al. (2011) reporting eye temperature ≥38°C to be a reliable indicator of fever in ponies. In contrast, Soroko et al. (2016) suggest thermography of the eye should not be used to estimate body temperature as eye temperature was found to differ to rectal temperature in exercising racehorses. Further evaluation is therefore needed before eye temperature can be used in a clinical setting.

Two NCIT devices designed for use in animals are now readily available to both veterinary professionals and animal owners. Both devices suggest they can report core body temperature when used on the eye, or other anatomical locations such as the skin of the rectum, gingiva or inner ear. Both devices suggest animal owners use the NCITs to monitor their animal's health when deciding if veterinary treatment should be sought, yet to date there is no published literature supporting the use of either device in horses.

The aim of this study was to investigate the accuracy of two animal specific NCIT devices, when compared to rectal temperature in healthy horses. Additionally, the study aimed to investigate the impact of poor operator technique on the accuracy of the device, including incorrect device distance from measurement site, and use outside the operators recommended ambient temperature range.

Methods

Animals

The study population consisted of 22 horses housed at Nottingham Trent University Equestrian Centre, Brackenhurst Campus, Nottingham, United Kingdom. The study population included 14 geldings and 8 mares, representing 11 breed types (including Thoroughbreds, Cobs and Irish Sports Horses) aged 2-23 years old (mean age 12 years ± 5).

Temperature Measurements

Rectal temperature was recorded using a V966F Vicks Comfortflex Digital Thermometer (KAZ Incorporated, New York, USA). This thermometer measures temperatures between 32-42.9°C with an accuracy of ±0.2°C at room temperature. The thermometer was lubricated using K-Y jelly (Johnson & Johnson, France), inserted at least 5cm into the rectum and held against the rectal wall until the alarm sounded. A head collar and lead rope were used to restrain all horses within their stable, with the same equine technician performing the rectal thermometry on all occasions. Rectal temperature was taken first in all cases.

Figure 2 near here

Eye temperature was then measured using the two NCIT devices, the Thermofocus Animal non-contact thermometer (Technimed, Vedano, Italy), and the Rycom non-contact infrared thermometer for pets model RC004T (Guangzhou Jinxinbao Electronic Co. Ltd, Guangzhou, China). The Thermofocus thermometer uses LED light guides to indicate the ideal distance for temperature measurement (see Figure 2) and can be used in ambient temperatures of 1-55°C. The Rycom thermometer should be held between 2-5cm away from the surface being measured (see Figure 3) and can be used in ambient temperatures of 10-40°C.

Figure 3 near here.

The Rycom thermometer was used first as this device does not emit any light or sound, with the Thermofocus used second as the guide light emitted by the device as it may be considered a potential source of aversion. The eye temperature was measured using both devices at the medial canthus, lateral canthus and central globe area of both eyes. Additionally, the eye temperature was recorded for the central globe area deliberately holding each thermometer too far away (Figure 4). This distance was approximately 10cm beyond the recommended position from the eye, aiming to simulate poor operator technique to allow investigation of the impact this had on accuracy of the device.

Figure 4 near here.

The Rycom device was also used to measure internal ear temperature by inserting the device into the folds of the pinna. Additionally, the surface temperature of the rectum was measured using the NCIT device. Temperature readings were performed during routine health checks, with four repeated measurements recorded spanning two seasons to include both winter and summer ambient temperatures. Additionally, temperature readings were taken once following exercise to obtain an elevated body temperature to compare measurements from hyperthermic horses. Hyperthermia was defined as a rectal temperature >38^{o}C (Baxter, 2001).

A ‘lo’ reading is given when the NCIT devices record a temperature below 32.0°C. In the event of a ‘lo’ reading, the measurement was repeated, if the subsequent reading was also ‘lo’, this was recorded as a missing data point due to “lo” reading. If a horse did not tolerate a temperature measurement, this was recorded as a missing data point due to intolerance.

Ambient Conditions

The study was conducted over a seven-month period, from December 2016 to June 2017, on 10 separate days. Ambient conditions were measured using a HI 9564 Thermo Hygrometer (Hanna Instruments Lid, Bedfordshire, UK). All equine temperature measurements were performed in a stable, out of direct sunlight and sheltered from any wind. The ambient temperature ranged from -0.1-25.5^{o}C (mean = 13.9 ^{o}C, SD = 9.77). This included ambient temperatures outside the recommended operating range of both NCIT devices, to simulate year round use of the devices in a normal UK yard environment.

Statistical Analysis

Statistics were calculated using SPSS 24.0 (SPSS Inc., Chicago, USA). In line with previous studies an acceptable limit of difference between the two temperature recording sites – rectal versus eye temperature - was set at ±0.5°C (Greer et al., 2007; Hall & Carter, 2017; Lamb & McBrearty, 2013; Smith, Lamb, & McBrearty, 2015; Watson, Brodbelt, & Gregory, 2015). Repeated temperature readings were performed on different days under different ambient temperature conditions, therefore each individual temperature monitoring event was treated as a separate data point (Hartnack, 2014). The percentage of readings falling within this limit of agreement was calculated for each device at each measurement site. Only measurement sites with >75% agreement with RT were further analysed, as greater than 25% of readings falling outside this limit of agreement is considered to be clinically unacceptable (Lamb & McBrearty, 2013; Sousa, Carareto, Pereira-Junior, & Aquino, 2011). Data were non-parametric when tested for normality using the Shapiro-Wilks test. The effect of environmental temperature on accuracy of the device was investigated using Spearman rank correlation between ambient temperature and rectal temperature minus eye temperature, and the effect of operating the device outside the manufacturer's instructions was investigated using a Mann-Whitney test. Scatter plots were used to provide a visual assessment of the difference between the two sites (rectal versus eye temperature). The threshold for significance was set at $P \leq 0.05$ for all tests.

Ethics

This study was approved by the School of Animal Rural and Environmental Science, Nottingham Trent University ethics approval group.

Results

Resting rectal temperature ranged from 36.7-38.0°C (median = 37.7°C, SD = 0.244), post exercise rectal temperature ranged from 37.5-38.7°C (median = 38.0°C, SD = 0.2776). There was no significant difference between rectal minus eye temperature pre and post exercise using either device at any anatomical location ($P > 0.05$), therefore pre and post exercise readings were combined for analysis. The Thermofocus device reported one "lo" reading on the right eye globe region when measured too far away, otherwise all eye temperature readings were tolerated and reported a temperature reading.

Ear temperature measurement was not tolerated for 47/100 (47%) of the left and 58/100 (58%) of the right ear measurements. Additionally, the device recorded a "lo" reading for 12 of the 53 tolerated ear measurements (22.6%) for the left ear, and 6 of the 42 tolerated ear measurements (14.3%) for the right ear. Rectum surface temperature measurement was tolerated on all occasions by all horses.

Agreement Between Thermometers and Anatomical Locations.

Table 1 near here

Table 1 shows the agreement between rectal temperature and surface temperature measured at each anatomical location with both devices. Fewer than 50% of the readings taken with the Thermofocus NCIT were within ±0.5°C of rectal temperature at any anatomical location. Additionally, no clear bias was evident on visual assessment scatter plots of rectal temperature versus the rectal minus eye temperature at either the medial or lateral canthus of the left eye (Figure 5), therefore no further analysis was performed on this device.

Figure 5 near here.

Measured with the Rycom device, over 75% of eye temperature readings from the medial and lateral canthus regions of both eyes were within ±0.5°C of rectal temperature. These regions were therefore used for further analysis. Figure 5 shows how the rectal-eye temperature difference varies at different body temperatures.

Figure 6 near here

As reported in Table 1, improper positioning of the Rycom NCIT (holding the device too far away from the ocular surface) significantly reduced the agreement between rectal temperature and eye temperature measured at the globe (Z = -6.454, P<0.001). The median and range of temperatures recorded by the Rycom for medial and lateral canthus of each eye are shown in Table 2.

Table 2 near here

Detection of Hyperthermia

Eight horses were hyperthermic following a period of exercise. Medial canthus temperature measured with the Rycom NCIT identified all eight horses as hyperthermic when measured on the left side, however, 17 of the 92 normothermic horses were incorrectly identified as hyperthermic at the same location. The sensitivity and specificity of the Rycom device detecting hyperthermia is shown in Table 3.

Table 3 near here

Effect of Ambient Temperature

A weak negative correlation was found between ambient temperature and the rectal-medial canthus temperature difference (Rs = -0.168, P = 0.018) and rectal-right eye lateral canthus temperature difference (Rs = -0.215, P = 0.032) measured with the Rycom. No correlation between ambient temperature and the difference between rectal and left eye lateral canthus temperature was found (Rs = -0.121, P = 0.231). There was no significant difference between rectal-eye temperature difference measured in ambient temperatures within (n=40) or outside the manufacturer's recommended operational ambient temperature range (n=60) for the Rycom device (Z = -1.798, P = 0.72).

Discussion

The results of this study suggest that only the Rycom device measuring eye temperature, specifically in the medial or lateral canthus regions, could provide an alternative method of measuring equine body temperature. In contrast, at all anatomical locations measured, the Thermofocus reported fewer than 50% of readings within ±0.5°C of rectal temperature so this device cannot currently be recommended for use in horses. The other anatomical sites measured (rectal skin surface and ear) reported temperatures up to 5.4^{o}C lower than rectal temperature, with fewer than 30% of readings within ±0.5°C of rectal temperature. These sites cannot currently be recommended for temperature monitoring. This reflects the findings of a study measuring eye, ear and neck temperature in exercising horses; only eye temperature was found to reliably detect a temperature increase following exercise and exposure to stressful stimuli (Hall, Burton, Maycock, & Wragg, 2011).

Surprisingly, all the horses tolerated the use of the NCITs to measure their eye temperature. The population of horses used are well handled and used for teaching and research purposes, so this may not be reflective of the wider equine population. In contrast, the Rycom device was neither well tolerated when used in the ear nor accurate, despite the manufacturer's instructions suggesting this as an appropriate measurement site. Incorrect positioning of the Rycom device significantly and negatively impacted the accuracy of the temperature reported, meaning inaccurate results are likely if the thermometer is not positioned appropriately, for instance by an inexperienced operator. A weak negative correlation between ambient temperature and the rectal to eye temperature difference was found, which could be due in part to using the device outside the manufacturer's recommended operating conditions.

Further research is needed to investigate the Rycom device's accuracy detecting hypothermia and hyperthermia, ideally using both healthy exercising animals and clinical patients with pathological temperature changes. Despite demonstrating a high level of agreement with rectal temperature, Figure 4 highlights a possible limitation of the device. At lower rectal temperatures the device appears to over-report body temperature. It is therefore possible that the device would not be able to accurately detect hypothermia. Both non-contact thermometers have also been tested in cats and dogs, where neither thermometer reliably detected hypothermia in anaesthetised cats, or hyperthermia in exercising dogs (Hall, Fleming & Carter, In Press). This highlights the importance of undertaking further research with NCITs before adopting them for clinical use.

Conclusion

For a thermometer to be clinically useful it should be accurate, fast and well tolerated by the patient. The NCIT devices examined in this study were tolerated well by all the horses measured when used on the eye, with results provided within seconds. The Thermofocus device showed poor agreement with rectal temperature. The Rycom device was found to be most accurate when used to measure eye temperature in the region of the medial canthus, with over 80% of all readings measured within ±0.5°C of rectal temperature. Whilst the Rycom thermometer appears to detect hyperthermia when measuring the left eye medial canthus, this study included only eight hyperthermic horses. This device should therefore be tested on clinical patients, specifically including hypothermic patients, and more hyperthermic patients prior to routine use in clinical practice.

Acknowledgements

The authors would like to thank the NTU Equestrian Centre technician team, particularly Anna Gregory for her support and facilitation of the project and Amy Hazlehurst for her assistance with equine handling and rectal thermometry. The authors have no conflicts of interest to declare.

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Table 1. Agreement between rectal temperature (RT) and surface temperature measured with the non-contact infra-red thermometer (NCIT) for two animal NCIT devices.

NCIT Device	**Thermofocus animal**		**Rycom**	
Anatomical location	Number of readings within ±0.5^{o}C of RT / total number of readings	Range of rectal to NCIT temperature differences (^{o}C)	Number of readings within ±0.5^{o}C of RT / total number of readings	Range of rectal to NCIT temperature differences (^{o}C)
Left eye medial canthus	44/100	-2.1 -1.3	80/100 *	-1.3 - 2.0
Left eye lateral canthus	45/100	-2.2 - 2.0	78/100 *	-1.4 - 2.4
Left eye globe	34/100	-1.2 - 2.8	63/100	-1.3 - 3.2
Left eye globe (NCIT too far away)	28/100	-0.6 - 4.2	26/100	-1.0 - 5.8
Right eye medial canthus	39/100	-2.5 - 2.6	83/100 *	-1.4 - 1.9
Right eye lateral canthus	44/100	-2.1 - 2.1	75/100 *	-1.4 - 3.0
Right eye globe	43/100	-1.5 - 3.3	68/100	-1.3 - 2.5
Right eye globe (NCIT too far away)	31.3/99	-1.1 - 4.7	26/100	-1.4 - 6.5
Rectum	(not measured)		20/100	-3.8 - 0.1
Left ear	(not measured)		12/41	-2.5 - 5.4
Right ear	(not measured)		7/36	-1.7 - 4.8

*Indicates 75% or more surface temperature within ±0.5 ^{o}C of RT.

Table 2. Median and range of temperatures measured at each anatomical location for all horses both pre and post exercise (eye temperatures measured with Rycom NCIT).

Anatomical location	Median temperature (ºC)	Minimum temperature (ºC)	Maximum temperature (ºC)
Rectal temperature	37.8	36.7	38.7
Left eye medial canthus	37.9	35.7	38.2
Left eye lateral canthus	38	35.3	38.3
Right eye medial canthus	38	35.8	38.2
Right eye lateral canthus	37.9	34.9	38.2

Table 3. Sensitivity and specificity of eye temperature for detecting hyperthermia at different anatomical locations.

Anatomical location	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)
Left eye medial canthus temperature	100	81.5	32	100
Left eye lateral canthus temperature	87.5	75	23.3	98.6
Right eye medial canthus temperature	75	81.5	26.1	97.4
Right eye lateral canthus temperature	75	85.9	19.5	92.2

Figure legends

Figure 1. Thermographic image of an equine eye, highlighting the warmest areas at the medial and lateral canthus regions.

Figure 2. The Thermofocus Animal NCIT device being used to measure medial canthus (left), central globe (centre) and lateral canthus (right) ocular surface temperature on the left eye. The red LED guide lights form a closed circle at the optimal distance from the surface to be measured.

Figure 3. The Rycom NCIT device being used to measure medial canthus ocular surface temperature on the right eye.

Figure 4: The Thermofocus NCIT device being used incorrectly, with the LED guide lights overlapping to confirm the thermometer is being held too far away.

Figure 5. Scatter plots of rectal temperature versus rectal minus eye temperature (ºC) measured at the medial canthus of the left eye (A) and lateral canthus of the left eye (B) using the Thermofocus device. The horizontal lines illustrate the limits of agreement where eye temperature measures within ±0.5°C of rectal temperature.

Figure 6. Scatter plot of rectal temperature versus rectal minus eye temperature (°C) measured at the medial canthus of both eyes using the Rycom device. The horizontal lines illustrate the limits of agreement where eye temperature measures within ±0.5°C of rectal temperature.