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RELIABILITY OF SURFACE INFRARED THERMOMETRY IN HORSES

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ABSTRACT
Core body temperature is indispensable in the assessment of the health status, as well as diagnosis and management of febrile conditions in patients. However, taking temperature in veterinary practice using conventional rectal thermometry could be challenging as most animals like horses often resent it. In this report, the reliability and accuracy of non-contact infrared thermometry in measuring temperature in horses is evaluated. Body surface infrared temperature readings of 40 horses were measured from three different sites (forehead, shoulder point, and anal verge regions) and compared with rectal thermometry as gold standard, the mean temperature differences, spearman's correlation and reliability coefficients were calculated for each measurement site. Bland-Altman plot was used to assess the agreement and systematic differences between the non-contact infrared and rectal thermometry. All the analyses were evaluated at α0.05. The body surface temperatures were slightly lower and correlate poorly with rectal temperature ($p>0.05$). The Bland-Altman analysis showed low mean bias ± SD between infrared and rectal thermometry as forehead (1.06 ± 0.48℃), shoulder point (0.77 ± 0.48℃), and anal verge (0.32 ± 0.63℃); and high reliability with clinical potentials (Intraclass correlation and Cronbach's Alpha coefficients (r) ≥ 0.98). Based on this data, with the high consistency and agreement, as well as the low mean biases below 1oC, the non-contact infrared thermometry of the anal verge and shoulder point demonstrated the greatest clinical potentials as an alternative to rectal thermometry in horses.

KEYWORDS: Infrared thermometry, equine practice, body temperature, rectal thermometry, health status, reliability.

INTRODUCTION
Precise temperature determination is important in the diagnosis and management of febrile conditions, as well as in the assessment of health status in many animal species including equines. Because core body temperature mimics that of the internal organs, it is considered as the gold standard (Allegaert *et al.*, 2014). An incessant increase above the normal reference body temperature limits signifies fever. Fever is one of the most commonly reported clinical parameters during physical examination of the horses (Ramey *et al.*, 2011). In animals, body temperatures are usually taken using the conventional rectal thermometry technique. This is because rectal thermometers are inexpensive and easy to use (Kreissl and Neiger, 2015; Kahnq and Brundage, 2020). Rectal thermometry is a minimally invasive means of taking temperature from the rectal mucosa to gain insight into the core body temperature (Kreissl and Neiger, 2015). During the process of taking rectal horse temperature, the individual taking the temperature is prone to kicks from the horse. This method often takes time and can be exhausting for horses. As a result, non-contact infrared thermometry, which has more benefits than rectal thermometry, is becoming increasingly relevant in veterinary practice. Its benefits include speed (about 2 sec), convenience, reduction of animal stress, and occupational risk of bites, as well as scratches during restraint (Omobowale et al., 2017). Infrared thermometers measure the radiation in the infrared range released by the body (Ramey et al., 2011). Different types/models with specific applications on alternative areas (e.g. auricular, ocular, etc.) are available (Kahng and Brundage, 2019).

Infrared thermometry was first investigated in human medicine in 1985 for the estimation of body temperature without contact with the body and proved to be very accurate, reliable and accessible (Hughes et al., 1985; Osio and Carnelli, 2007). It is now gaining more attention in other species of animals (Jara et al., 2016). Existing studies have compared rectal and non-contact infrared thermometry in veterinary practice using different sites such as axilla, auricular canal, ocular, nasal planum, forehead, gum, interdigital spaces, and inguinal regions, etc. but have reported contradictory findings in some animals (Ramey et al., 2011;

Omobowale et al., 2017; Kahnq and Brundage, 2019; Muhammed et al., 2019; Cugmas et al., 2020). Therefore, consistency and agreement between non-contact infrared thermometry and conventional rectal thermometry must be validated in body temperature estimation in horses. Hence, this investigation compares the performance of a non-contact infrared thermometer designed for human use with glass mercury thermometer (rectal) in 40 apparently normal stable horses.

2. MATERIALS AND METHOD

Animals

Forty (40) adult horses in Ibadan, Oyo State, Nigeria were examined. They were sampled irrespective of breed, age and sex. The horses were apparently normal on physical examination. Consent of the owners was sought before the readings were taken. As a routine clinical procedure, no ethical approval was unnecessary for this study.

Temperature measurement

A standardized glass mercury thermometer was used in assessing the rectal temperatures of the horses. Within the two minutes of rectal temperature reading, the surface temperatures were also taken using non-contact infrared thermometer. Temperature measurements were taken at the cranial border of the inter-orbital space of the forehead, shoulder point, and at the base of the tail about the anal verge. Average of triplicate measurements obtained at distances of 10 cm apart were recorded. The non-contact infrared thermometer was used according to the manufacturer's instructions. The readings of both thermometers were on the Celsius scale.

Statistical Analysis

Data obtained were analyzed using SPSS version 20 at $\alpha_{0.05.}$ Using the rectal thermometry as gold standard, the mean differences and spearman's correlation coefficient to determine the strength of the linear relationship with non-contact infrared thermometry were calculated. Also, reliability analysis (Cronbach's Alpha and Intraclass correlation (ICC) coefficients) was done to assess the contrast and consistency between the two measurement methods. One-sample t-test was performed to assess the extent of the mean bias with assumption that the mean value difference between both measurements are not significantly different from zero. Bland-Altman (B-A) plot was used to analyzed the agreement and systematic differences between the two types of measurements. Agreement limits was defined within two standard deviations; followed by linear regression analysis to assess the statistical significance of any proportional bias where present. Measurements exhibiting significant biases after linear regression were Log-transformed and reassessed before accepting or rejecting the null hypothesis that there is a significant bias in the mean values of the measurements (Bland-Altman, 1986; Bunce, 2009).

RESULTS

Result of analysis

Table 1 showed that the mean temperature measurement of the rectal thermometry was slightly higher than that of surface thermometry. The mean bias ± SD between the rectal temperature and the forehead, shoulder point, and anal verge temperatures were 1.06 ± 0.48, 0.77 ± 0.48, and 0.32 ± 0.63, respectively. There was a weak negative correlation between the two measurement methods with no statistical significance ($p>0.05$). Figures 1-3 represent frequency distributions of the mean temperature measurements of the non-contact infrared thermometry. Table 2 showed that the non-contact temperature readings are consistent and positively correlated discretely; with both the ICC and Cronbach's Alpha (r) ≥ 0.98. In Figure 4a-c of the B-A analysis visual inspection showed proportional biases in the plots; while linear regression revealed no significant proportional mean bias between rectal and forehead infrared ($r = 0.55$; $t = 1.65$; $p = 0.108$), and shoulder point infrared ($r = 0.33$, $t = 1.02$, $p = 0.315$), except with anal verge thermometry ($r = -0.70$; $t = -2.58$; $p = 0.014$). Figure 5a-c showed an irregular variability trend of the non-contact infrared temperature measurements in comparison with the rectal temperatures.

Table 1: Correlation and one-sample t-test for non-contact infrared temperature measurements and rectal temperature readings.

Temperature Measure (℃)	Rectal	Forehead	Shoulder	Tail
Mean ± SD (95% C.I)	36.92 ± 0.37 (36.80, 37.03)	35.86 ± 0.28 (35.76, 35.95)	36.20 ± 0.31 (36.05, 36.25)	36.71 ± 0.55 (36.42, 36.78)
Mean bias ± SD (95% C.I)	-	1.06 ± 0.48 (0.12, 1.99)	0.78 ± 0.48 (-0.18, 1.71)	0.32 ± 0.63 (0.91, 1.54)
Correlation (R2)	-	-0.068*	0.002**	0.112***
p-value	-	0.678	0.989	0.492

*Correlation between rectal and forehead temperatures; **Correlation between rectal and shoulder point temperatures; ***Correlation between rectal and tail temperatures

Table 2: Intraclass correlation between rectal temperature measurements and non-contact infrared temperature readings.

Non-contact measurements	Cronbach's Alpha	Intraclass Correlation	95% Confidence Interval		F - test			
			Lower boundary	Upper boundary	Value	df1	df2	p-value
Forehead	0.982	0.982	0.970	0.990	57.090	39	78	<0.0001
Shoulder	0.991	0.991	0.984	0.995	106.128	39	78	<0.0001
Tail	0.997	0.997	0.995	0.998	311.356	39	78	<0.0001

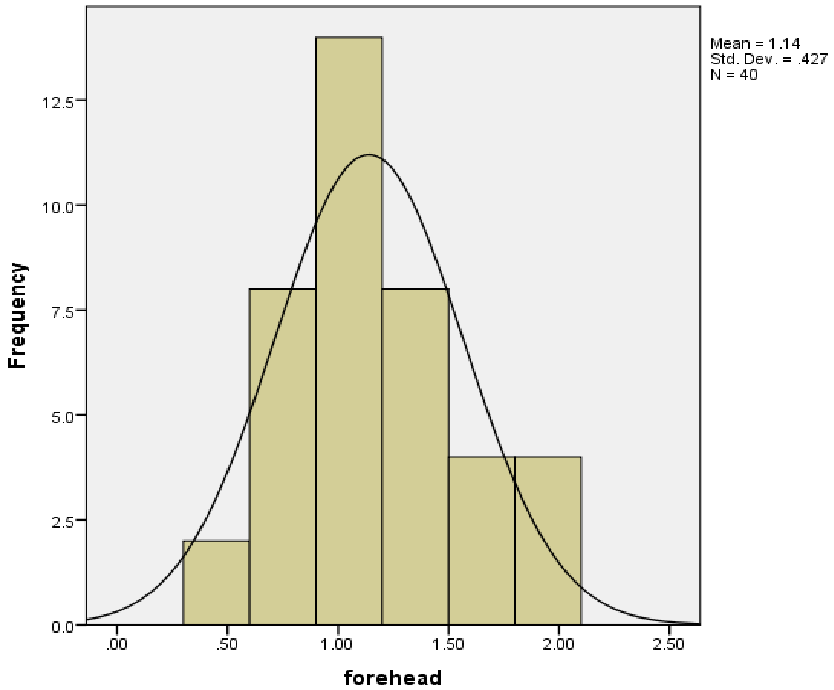

Figure 1: Frequency distribution of forehead non-contact infrared temperature measurements.

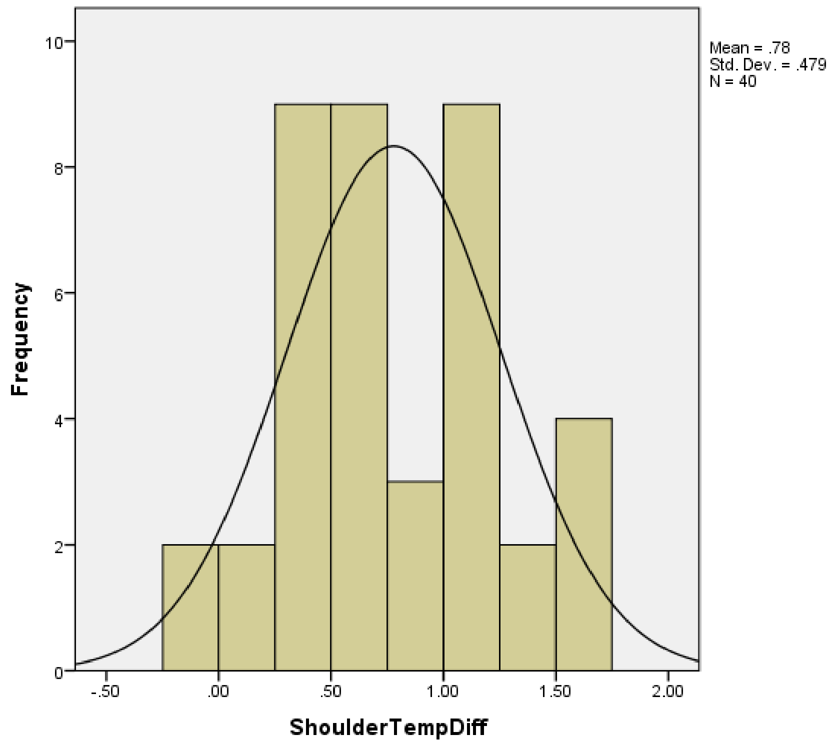

Figure 2: Frequency distribution of shoulder non-contact infrared temperature measurements.

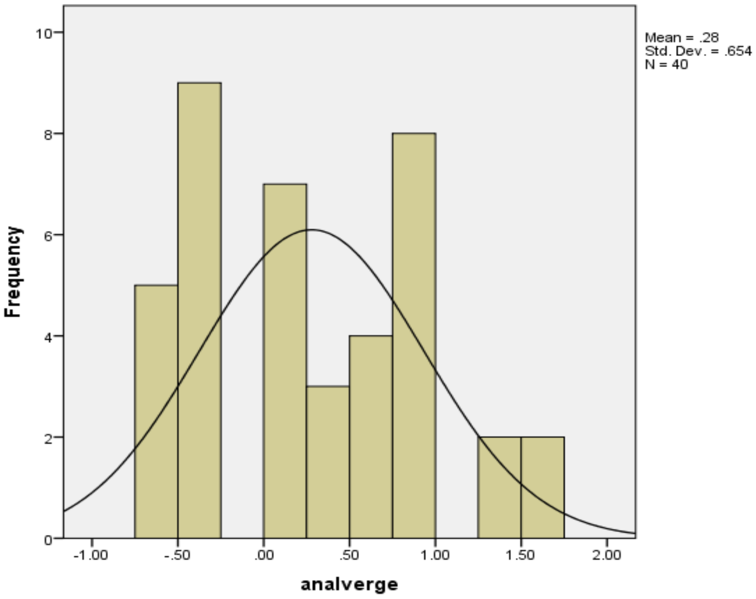

Figure 3: Frequency distribution of anal verge non-contact infrared temperature measurements.

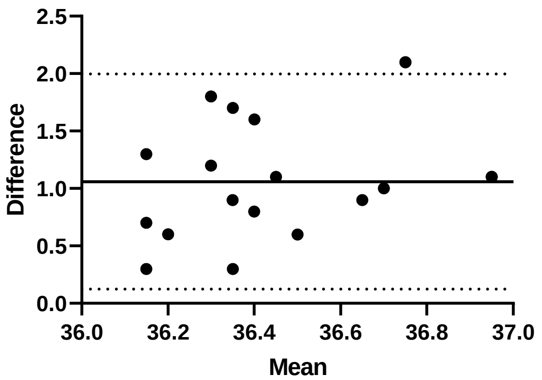

Figure 4a: Bland-Altman's plot of agreement between the forehead mean temperature and the rectal thermometry. There was no significant agreement between the mean forehead and rectal temperature measurements.

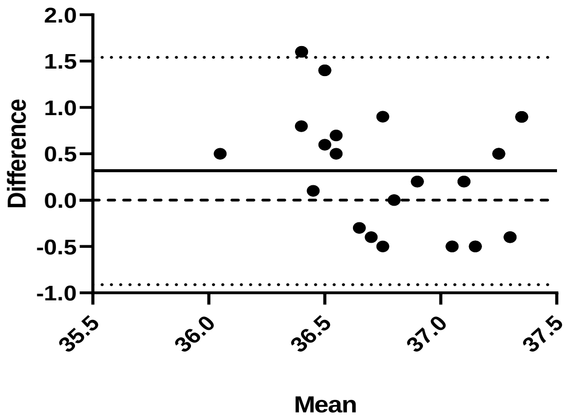

Figure 4c: Bland-Altman's plot of agreement between the tail mean temperature and the rectal thermometry.

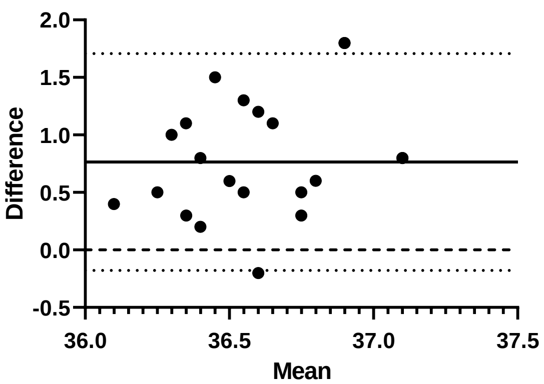

Figure 4b: Bland-Altman's plot of agreement between the shoulder mean temperature and the rectal thermometry.

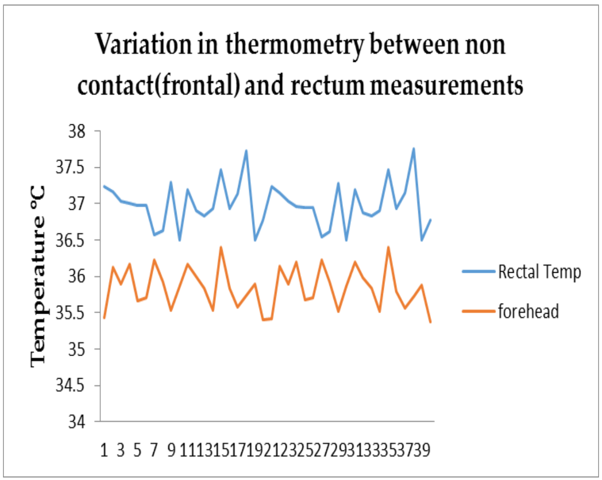

Figure 5a.

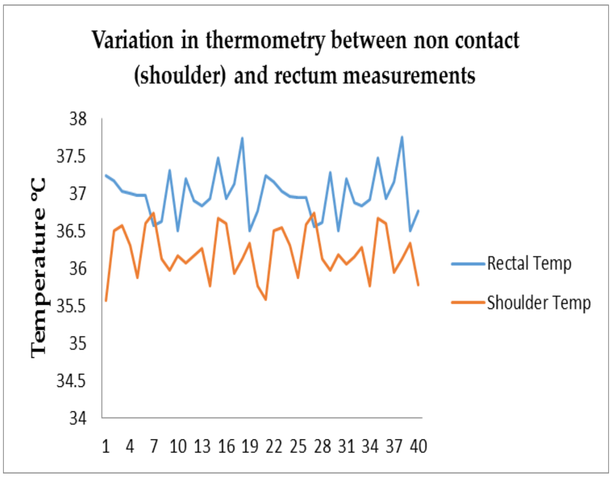

Figure 5b.

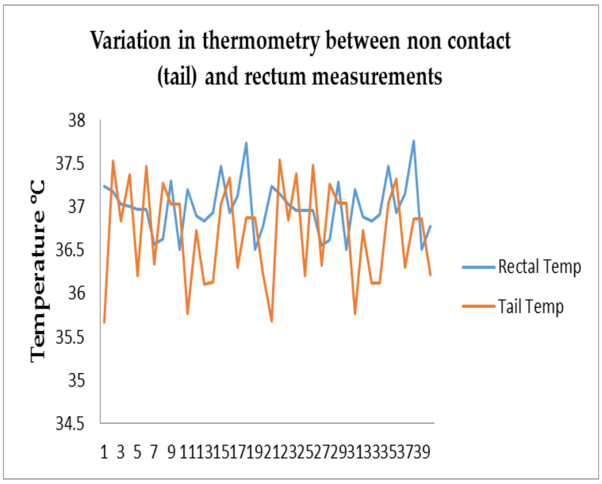

Figure 5c.

DISCUSSION

The result of this study showed that the non-contact infrared thermometry did not accurately measure the body temperature of the horses sampled even though the mean temperature bias between the two devices was not significant (p>0.05). Also, the surface infrared temperatures measured from the three different sites correlate poorly with rectal thermometry. This agrees with existing findings in horses (Ramey et al., 2011) and dogs (Kahng and Brundage, 2019). Again, the mean non-contact infrared temperatures were slightly lower than rectal temperature with the forehead, shoulder point, and anal verge exhibiting mean biases in the range of ≤2°C. These findings corroborate that of existing reports (Ramey et al., 2011; Brunell, 2012; Schmidt et al., 2013). In dogs, a considerably lower body surface temperature than rectal temperature; and a moderate correlation between both sites were reported (Cugmas et al., 2020). Similar observations were reported in other animal species (Shelton et al., 2006; Sikoski et al., 2007). Furthermore, the anal verge non-contact infrared thermometry showed the lowest mean temperature bias compared with forehead and shoulder non-contact infrared thermometry. In contrast, others have reported significantly higher body surface infrared temperatures from different sites compared to rectal thermometry in large animals including horses (Muhammed et al., 2019), and in felines (Kunkle et al., 2004). This variations between studies could be explained by the device models used and measurement site.

The Bland-Altman analysis of agreement also confirmed low mean proportional biases between the non-contact infrared and rectal thermometry, with mean differences of 1.06, 0.77, and 0.32°C for the forehead, shoulder, and anal verge, respectively. The closer the mean difference co-efficient is to zero the better the agreement and clinical relevance. This means the non-contact infrared temperatures satisfactorily agreed with rectal thermometry and has clinical potentials. According to Verchooten et al. (2001), differences in temperature of 2°C taken from two areas are clinically relevant. The levels of agreement in this study is far better than that reported in dogs (Sousa et al., 2011; Omobowale et al., 2017), and comparable to 2°C agreement reported in existing studies in Rhesus Macaques and cats (Brunel, 2012, Sousa et al., 2012). Some studies have reported unacceptable mean biases (Stephens 2005; Chen and White 2006; Shelton et al., 2006; Sikoski et al., 2007; Sousa et al., 2011; Omobowale et al., 2017).

Furthermore, test of reliability showed that the non-contact infrared temperatures at the different sites were consistent with absolute levels of agreement ($r \geq 0.98$) and narrower margin of errors. The acceptable range is ≥ 0.7. This again suggests that the forehead, shoulder, and the anal verge non-contact infrared thermometry studied have valuable clinical potentials in temperature measurement in horses; however, each clinic should validate the chosen non-contact infrared thermometry model.

Factors which could interfere with body surface infrared thermometry resulting in temperature variations or correlation within the area measured with rectal temperature are, the type of thermometers, animal species, measurement site, errors associated with uncalibrated thermometers (Pusnik and Drnovsek, 2005; Rushton et al., 2015); sampling of a relatively small area by infrared thermometers (Cugmas et al., 2020); external and body related factors such as air current and ambient temperature, body mass, hairiness, coat type, color and length, gender, age (Lamb and McBrearty 2013; Gomart et al., 2014; McNicholl et al., 2016; Kwon and Brundage, 2019), and user expertise (Mathis and Campbell, 2015). Variations in coronary band temperatures in healthy horses was positively associated with ambient temperature (Rosenmeier et al., 2012). However, variations in this study seem to be on account of anatomical sites measured.

One of the shortcomings of this study is the small sample size. This may have contributed to the low mean bias and reduced limits of agreement by the two methods compared. An adequate sample size is required in future studies to conclude that the effects are universally valid (Bunce, 2009).

CONCLUSION

This study has demonstrated the accuracy, precision, and reliability of a surface infrared thermometry in horses compared with rectal thermometry as gold standard. Even though it is weakly correlated with rectal thermometry, similar to existing reports; with high reliability coefficients (consistency and absolute agreement of ≥ 0.98) and proportional mean biases below 1^{o}C, the anal verge and shoulder temperatures showed the greatest clinical potentials alternatives to rectal thermometry in horses.

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