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SERIAL TEMPERATURE MONITORING AND COMPARISON OF RECTAL AND MUSCLE TEMPERATURES IN IMMOBILIZED FREE-RANGING BLACK RHINOCEROS (*DICEROS BICORNIS*)

Peter vdB. Morkel, B.V.Sc., Michele Miller, D.V.M., Ph.D., Mark Jago, D.V.M., Robin W. Radcliffe, D.V.M., D.A.C.Z.M., Pierre du Preez, Francisco Olea-Popelka, D.V.M., Ph.D., Jennifer Sefton, B.S., Arthur Taft, Ph.D., R.R.T., Daryl Nydam, D.V.M., Ph.D., and Robin D. Gleed, B.V.Sc., M.R.C.V.S., D.A.C.V.A.

Abstract: Control of body temperature is critical to a successful anesthetic outcome, particularly during field immobilization of wild animals. Hyperthermia associated with exertion can lead to serious and potentially life-threatening complications such as organ damage (including myopathy) and death. Methods for monitoring core body temperature must accurately reflect the physiologic status of the animal in order for interventions to be effective. The goal of this preliminary study was to compare serial rectal and muscle temperatures in field-immobilized black rhinoceros (*Diceros bicornis)* and evaluate a possible association. Twenty-four free-ranging black rhinoceros were immobilized between February and March of 2010 in Ethosha National Park, Namibia. Pairwise comparisons showed a correlation of 0.73 (95% CI; 0.70–0.75) between rectal and muscle temperature measurements. Results from a multivariable model indicate that muscle temperature readings were, on average, 0.46°C (95% CI; 0.36–0.57°C) higher than rectal temperatures while adjusting for repeated measurements on the same rhinoceros, effect of duration of immobilization, and effect of ambient temperature on rhinoceroses' temperature readings. As immobilization time increased, muscle and rectal temperature values within an individual rhinoceros tended to equilibrate. The overall temperatures decreased by an average of 0.00059°C/min (95% CI; –0.0047 to –0.0035°C/min; $P = 0.779$). As the ambient temperature at time of immobilization increased by 1°C, the average rhinoceros temperature increased by 0.09°C (95% CI; 0.06–0.11°C, $P < 0.0001$). Higher body temperature creates a potential for cellular damage leading to complications that include myopathy. Methods for monitoring rectal, muscle, and ambient temperatures should be incorporated into anesthetic monitoring protocols for large ungulates, particularly under field conditions.

Key words: Black rhinoceros, *Diceros bicornis*, muscle temperature, rectal temperature.

BRIEF COMMUNICATION

Temperature monitoring is critical in anesthetized animals and allows for interventions that minimize complications. Hyperthermia has been implicated in the development of capture myopathy and increased morbidity and mortality in wild animals.[14] Traditional methods of temperature monitoring (rectal thermometry) may not always reflect actual core or localized changes in temperature (i.e., muscle).[7] The objective of this preliminary study was to compare two methods for assessing body temperature under field conditions in free-ranging black rhinoceros (*Diceros bicornis*).

Between 24 February and 2 March 2010, 24 black rhinoceros were captured as part of a larger study on ventilation in eastern Etosha National Park, Namibia (19°0′0″S, 16°0′0″E). The research protocol was approved by the Cornell University Institutional Animal Care and Use Committee (Protocol #2006-0170) and by the Namibian Ministry of Environment and Tourism. All animals were immobilized using etorphine hydrochloride (M99, Novartis, Kempton Park, 1619 South Africa; 3.5–5.5 mg total dose), azaperone (Stressnil, Janssen Pharmaceutical Ltd., Halfway House, 1685 South Africa; 60–80 mg total dose), and hyaluronidase (Hyalase, Kyron Laboratories, Benrose, 2011 South Africa; 1,750–2,500 IU total dose) administered i.m. by dart

From Frankfurt Zoological Society, 42 Kinnersley Street, Newton Park, 6045, South Africa (Morkel); the Palm Beach Zoo, 1301 Summit Boulevard, West Palm Beach, Florida 33405, USA (Miller); the Namibia Ministry of Environment and Tourism, Private Bag 13306, Windhoek, Namibia (Jago, du Preez); the Cornell Conservation Medicine Program, Cornell University, College of Veterinary Medicine, C2-508 Clinical Programs Center, Tower Road, Ithaca, New York 14853, USA (Radcliffe, Nydam, Gleed); the Colorado State University, College of Veterinary Medicine and Biomedical Science, Department of Clinical Sciences, Animal Population Health Institute, 300 West Drake, Fort Collins, Colorado 80523, USA (Olea-Popelka, Sefton); and the Medical College of Georgia, Department of Respiratory Therapy, 487 St. Sebastian Way, EC-4318, Augusta, Georgia 30912, USA (Taft). Correspondence should be addressed to Dr. Miller (mmiller@palmbeachzoo.org).

from a helicopter. A 3-ml stainless steel dart (Joubert Capture Equipment, Kimberley, 8306 South Africa) was consistently placed in the gluteal muscle. Most capture procedures were conducted during morning hours when ambient temperatures ranged from 23.9°C to 33.7°C, as measured by a Kestrel® 4300 weather meter (Nielsen-Kellerman, Boothwyn, Pennsylvania 19061, USA). Rhinoceros temperatures were recorded immediately upon reaching the animal and, subsequently, at variable intervals depending on the individual (every 1–2 min up to every 5 min with the longest interval being 13 min during repositioning of the animal). Rectal and muscle temperatures were measured by inserting dual output thermistor probes (Fluke Corporation–Hart Scientific Division, American Fork, Utah 84003, USA) into the rectum and dart site (112 mm probe into the gluteal muscle), respectively. The concordance correlation coefficient (ccc) was used to evaluate agreement between temperature readings from rectal and muscle thermometers (using rectal temperature as the reference). Generalized linear latent and mixed models analysis was used to account for repeated measurements (lack of independence in observations) on the same rhinoceros over time and to evaluate the effect of immobilization time and ambient temperature on both rectal and muscle temperature readings. The mean, standard deviation, and number of observations for each site are reported in degrees Celsius (Table 1). Descriptively, when comparing to the rectal temperature standard, muscle temperatures were, on average, higher than rectal temperatures.

The ccc (agreement) between rectal and muscle temperature was 0.73 (ccc 95% CI: 0.70–0.75). Figure 1 shows the positive relationship between paired measurements. For readings above 37°C, muscle temperatures were generally higher than rectal temperatures. This correlation was stronger at higher body temperatures, i.e., when muscle temperatures increased a greater difference was observed between rectal and muscle temperatures (Fig. 2). After controlling for the effect of ambient temperature at immobilization, and for the time after darting (minutes) at which each temperature reading was obtained, muscle temperature was, on average, 0.46°C higher than rectal temperature (Table 2, $P < 0.001$). As the ambient temperature at time of immobilization increased, the average rhinoceros temperature increased by 0.09°C per each 1°C ambient temperature increase (95% CI; 0.06–0.11°C/each 1°C increase in the ambient temperature; $P < 0.0001$; Table 2). Rhinoceros temperature, on average, decreased by 0.00059 °C every minute after immobilization ($P = 0.779$; Table 2).

Table 1. Overall temperature mean (°C), standard deviation (SD), and total number of observations for each measuring device for 24 black rhinoceros.

Thermometer	Mean	SD	Number of observations
Rectal	37.74	0.90	158
Muscle	38.24	1.33	183

Because field capture of black rhinoceros involves both chasing and darting from a helicopter, animals experience varying degrees of exertion prior to immobilization. Blood lactate in black rhinoceroses in this study ranged from 1.49 to 11.6 mmol/L with higher levels generally observed in animals undergoing longer induction periods and running further distances (CG4+ cartridges, iSTAT®1 Handheld Clinical Analyzer, Heska Corporation, Loveland, Colorado 80538, USA).[10] An association between hyperthermia and exertion has been observed in multiple species, leading to increased risk of developing capture myopathy, acidosis, and other physiological derangements.[2,14] Incremental increases in muscle temperature resulted in lower incremental increases in rectal temperature in individual rhinoceroses (Fig. 2). As the average temperature (mean of rectal and muscle) increased, the difference between the two readings also increased. For example, for average temperatures above 39°C the difference between muscle and rectal readings ranged from 0.5–3.0°C. Figure 2 also shows that when the average temperature exceeds 39°C, all muscle readings were higher than the rectal values. Local muscle temperature differences associated with dart trauma was considered unlikely, as pilot comparisons between gluteal muscle dart and nondart sites was not significant. In addition, muscle temperature was lower than rectal values when the rectal temperature was below 37°C. A body temperature of 41°C has been proposed as a critical threshold under field conditions, above which an animal should be immediately reversed (capture drugs antagonized) if the temperature cannot be controlled using shade, water misting, and fanning.[1] Therefore, temperature monitoring in field-immobilized rhinoceros is crucial to determining trends that may help prevent conditions leading to a poor capture outcome.

Increased body temperature results in higher oxygen consumption by mitochondria.[7] Addition-

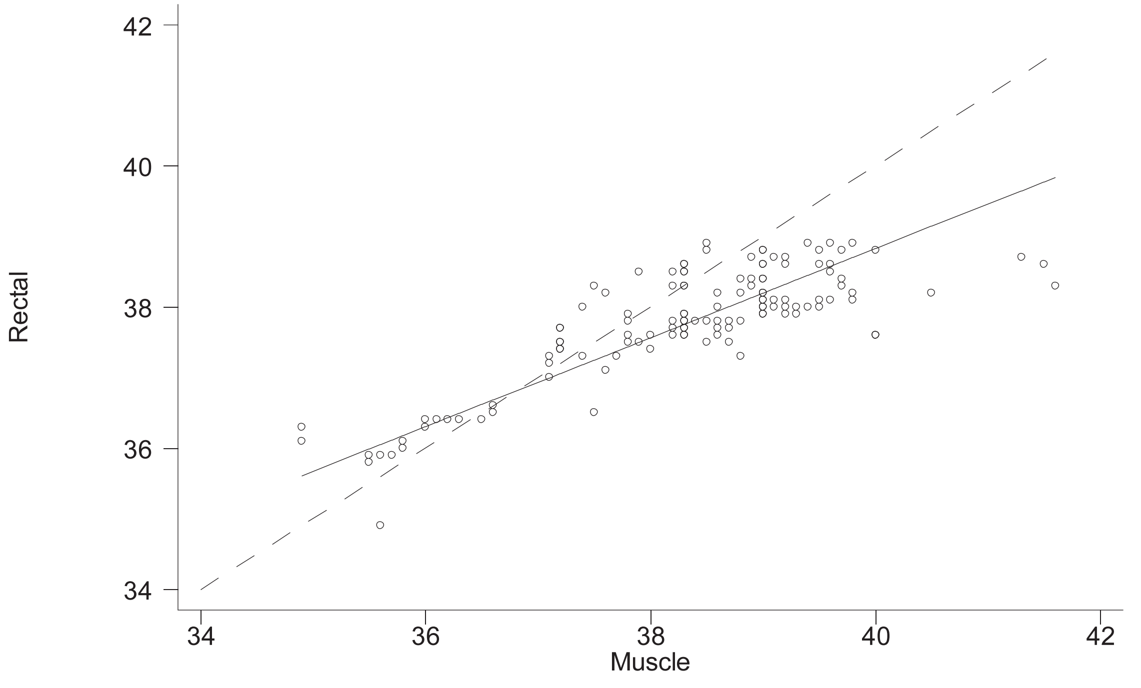

Figure 1. Relationship of paired muscle and rectal temperatures (°C) in immobilized black rhinoceros. Note: Data must overlay dashed line for perfect concordance between muscle and rectal temperature readings.

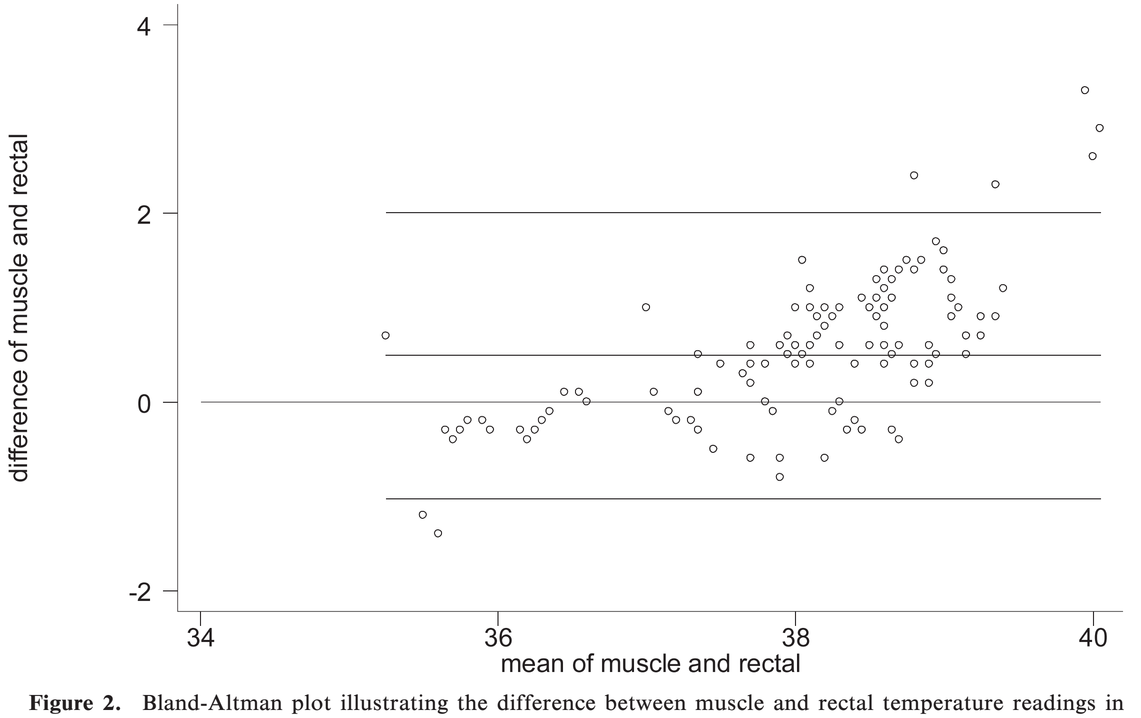

Figure 2. Bland-Altman plot illustrating the difference between muscle and rectal temperature readings in immobilized black rhinoceros. The difference in thermometry methods is plotted against the pairwise mean. The horizontal reference line at 0 represents no difference between muscle and rectal temperatures. The outer lines represent the 95% limits of agreement (mean ± 1.96 SD).

Table 2. Generalized linear latent and mixed models results, accounting for repeated temperature (T) measurements on the same rhinoceros and evaluating the effect of immobilization time and ambient temperature on muscle and rectal readings.

Measured T Parameter	Coefficient	SE	95% Conf.	Interval	*P*
Change in rhinoceros T over time (°C/min)	–0.00059	0.002	–0.0047	0.0035	0.779
Change in rhinoceros T per 1°C increase in ambient temperature	0.09	0.01	0.06	0.11	<0.0001
Muscle T compared to rectal T (°C)	0.46	0.05	0.36	0.57	<0.0001

ally, anaerobic muscle metabolism may occur after strenuous activity, during anesthesia if there is inadequate oxygen delivery to tissues, or in conditions that lead to decreased glycogen reserves (i.e., drought). Increased free radical production, muscle glycogenolysis, and lactate accumulation may lead to muscle cell damage.[8] Exertion and increased body temperature induce muscle damage through alterations in calcium metabolism in the sarcoplasmic reticulum similar to malignant hyperthermia.[3,11] Comparison of various temperature monitoring methods have been performed in other species. In anesthetized humans, mean esophageal temperatures were 0.6°C lower than rectal temperatures.[4] Comparison of rectal, esophageal, tympanic membrane, and central blood temperatures in hyperthermic cancer patients revealed that esophageal temperatures most accurately reflected central blood temperatures.[13] In contrast, tympanic membrane temperatures of intensive care patients most closely correlated with pulmonary artery measurements, with rectal temperatures being significantly warmer.[9]

The effect of exercise on muscle and core body temperatures has been investigated in humans and domestic species. In pigs that were handled aggressively for transport, concurrent stressors resulted in increased lactate, rectal temperatures, and metabolic acidosis.[12] Studies in exercising humans showed elevated muscle temperatures after exercise, although rectal temperatures remained unchanged.[7] Significantly higher muscle, compared to rectal or esophageal, temperatures were recorded in people undergoing various levels of exercise.[6] In one study, muscle temperatures remained elevated for 40 min after only 15 min of exercise.[6] An average muscle temperature difference of just 0.6°C resulted in lower glycogen and higher lactate in heated thigh muscles compared to the contralateral leg postexercise in humans. The researchers concluded that elevated muscle temperature increased glycogenolysis, glycolysis, and an increased rate of ATP turnover.[5] This small difference in muscle temperature resulted in significant metabolic changes in humans; an increase of 0.46°C in muscle compared to rectal temperatures in the rhinoceros could lead to similar changes. However, based on the variability in findings of previous studies, specific temperature monitoring methods should be tested and adapted for each particular species and application.

In summary, accurate temperature monitoring and intervention plans are crucial to minimizing complications associated with hyperthermia and, specifically, increased muscle temperature after capture. This preliminary study indicates that muscle temperatures are higher than those recorded by rectal thermometers (especially at higher body temperatures) and may be a more critical measurement in animals that have undergone exertion. Temperature trends are an important component for assessing exertion, potential muscle damage, and the risk of postimmobilization morbidity and mortality.

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