Acta Scientiae Veterinariae, 2012. 40(2): 1035

SHORT COMMUNICATION
Pub. 1035

ISSN 1679-9216 (Online)

Pattern of Rectal Temperature in Sheep Affected by Foot Rot

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ABSTRACT

***Background*:** Circadian rhythms are biological rhythms generated by an organism or group of organisms that have an intrinsic period of 24 h. Among the many variables that exhibit circadian rhythmicity, body temperature has received considerable attention. The circadian rhythm of body temperature is a well-documented physiological phenomen. Also, it has been shown that changes in heat loss via convection and radiation are primarily caused by variations in skin blood flow, with consequent changes in skin temperature. For this reason, foot temperature assumes a great importance both as indicator of equine laminitis and foot-and-mouth disease in sheep. Particularly, the foot rot, term loosely used to describe lameness associated with the bovine foot, is characterized by acute inflammation of the skin and adjacent soft tissue of the interdigital cleft or space in which the modifications of temperature assume a great importance. In fact, the regulation of body temperature is an essential component of the process of fever, which plays an important role in an organism's response to infection and disease, and its manipulation is a standard procedure in various surgical and therapeutic procedures. In this regards, the aim of this study was to evaluate the pattern of rectal temperature (RT) both in healthy Comisana sheep and in Comisana sheep affected by foot rot.

***Materials, Methods & Results*:** This experiment was carried out on 10 clinically healthy and not pregnant female sheep, and 10 not pregnant female sheep affected by foot rot. During the experimental period, all animals were kept under a natural photoperiod (sunrise 06:30, sunset 19:00). RT was measured every 3 h intervals for 24 consecutive hours starting at 11:00 on day 1 and ending at 11:00 on day 2. A trigonometric statistical model was applied to the average values of each time series, so as to describe the periodic phenomenon analytically, by characterizing the main rhythmic parameters according to the single cosinor procedure. Four rhythmic parameters were determined: mean level, amplitude (the difference between the peak, or trough, and the mean value of a wave), acrophase (the time at which the peak of a rhythm occurs), and robustness (strength of rhythmicity). The application of the periodic model showed a circadian rhythm of RT in healthy subjects and no circadian rhytmicity of RT was observed in ill sheep.

***Discussion*:** The analysis of the results obtained under experimental conditions used in the present study indicated the existence of a circadian periodicity of rectal temperature in healthy sheep whereas no circadian oscillations of rectal temperature were revealed in sheep affected by foot rot. A simple and coherent explanation for these pathological alterations is that the set point is elevated during the rising phase and returned to normal during the later phase. Taking together, the findings of the present study, along with those of others, emphasize the concept that RT exhibits a circadian rhythm that reflect the familiar circadian patterns of endogenous source and the existence of circadian oscillations around a set point with changes in mean body temperature and an absent rhythm when temperature is modified to a new set point, as observed in sheep affected by foot rot.

Keywords: foot rot, rectal temperature, rhythmicity, sheep.

Received: September 2011 www.ufrgs.br/actavet Accepted: December 2011

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INTRODUCTION

Circadian rhythms are biological rhythms generated by organisms that have an intrinsic period of 24 h. Circadian rhythmicity is a ubiquitous and pervasive property of the mammalian physiology and behaviour [14]. Among the many variables that exhibit circadian rhythmicity, body temperature has received considerable attention. Its circadian rhythm is a well-documented physiological phenomen [5,6,15]. It consists of spontaneous and regular periodic oscillations over different periods of time, which are the result of complex mechanisms that witness the existence of endogenous and exogenous factors [7,8].

Moreover, since the thermoregulatory system utilizes behavioral and autonomic processes in integration with other physiological systems, the regulation of body temperature in relation to these systems is essential for panting, salivary discharge, grooming, control of heat loss through peripheral vasodilation and vasoconstriction, and thermogenesis through shivering in striated muscle [9]. It has been also demonstrated that changes in heat loss via convection and radiation are primarily caused by variations in skin blood flow, with consequent changes in skin temperature. For this reason also the foot temperature assumes a great importance both as indicator of equine laminitis [10] and foot-and-mouth disease in sheep [2,11].

Particularly, the foot rot, term loosely used to describe lameness associated with the bovine foot, is characterized by acute inflammation of the skin and adjacent soft tissue of the interdigital cleft or space in which the modifications of temperature assume a great importance [1]. For this purpose the pattern of rectal temperature (RT) both in healthy sheep and in sheep affected by foot rot was evaluated.

MATERIALS AND METHODS

The study was conducted in Padua (Italy) on 10 clinically healthy and not pregnant female sheep (Comisana breed, 2-6 years old, mean body weight 55 ± 2 kg) and 10 not pregnant female sheep (Comisana breed, 2-4 years old, mean body weight 47 ± 2 kg) affected by foot rot. In all sheep, foot temperature was measured at the right front of the interdigital area (FTRFIA), at the left front of the interdigital area (FTLFIA), at the right rear of the interdigital area (FTRRIA), at the left rear of the interdigital area (FTLRIA), at the right front of the interdigital line (FTRFIL), at the left front of the interdigital line (FTLFIL), at the right rear of the interdigital line (FTRRIL) and at the left rear of the interdigital line (FTLRIL) by means of Infrared Thermal Camera[1] (Table 1).

As concerning feeding conditions, all animals were fed daily on hay (2 kg), wheat straw (1 kg), wheat concentrate (0.5 kg) and water ad libitum. General animal care were carried out by professional staff not associated with the research team.

During the trial period, all animals were kept under a natural photoperiod (sunrise 06:30, sunset 19:00) and environmental temperature and humidity (18-22 ºC; 70 Rh%). Thermo-hygrometric recordings were conducted inside the pen throughout the entire study by means of a data logger[2] placed in the middle of the boxes at 1.5 m height from the floor.

RT was measured every 3 h intervals for 24 consecutive hours starting at 11:00 on day 1 and ending at 11:00 on day 2. On all subjects, RT was recorded

Table 1. Mean values (±SD) of foot temperature at the right front of the interdigital area (FTRFIA), at the left front of the interdigital area (FTLFIA), at the right rear of the interdigital area (FTRRIA), at the left rear of the interdigital area (FTLRIA), at the right front of the interdigital line (FTRFIL), at the left front of the interdigital line (FTLFIL), at the right rear of the interdigital line (FTRRIL) and at the left rear of the interdigital line (FTLRIL), obtained in 10 healthy sheep and in 10 sheep affected by foot rot.

Foot temperature (ºC)	Healthy Sheep	Ill Sheep
FTRFIA	30.87±1.58	29.00±1.99
FTLFIA	30.77±1.40	29.80±2.01
FTRRIA	30.92±2.73	29.22±2.35
FTLRIA	31.19±2.23	32.40±2.63
FTRFIL	31.32±1.46	30.10±1.96
FTLFIL	31.42±1.34	30.83±1.95
FTRRIL	31.58±2.89	30.47±2.20
FTLRIL	31.71±2.14	33.92±2.21

with a calibrated electronic thermometer with resolution of 0.1°C[3] with the probe being inserted to a depth of 9 cm.

A trigonometric statistical model was applied to the average values of each time series, so as to describe the periodic phenomenon analytically, by characterizing the main rhythmic parameters according to the single cosinor procedure [4]. Four rhythmic parameters were determined: mean level, amplitude (the difference between the peak, or trough, and the mean value of a wave), acrophase (the time at which the peak of a rhythm occurs), and robustness (strength of rhythmicity). For each parameter, the mean level of each rhythm was computed as the arithmetic mean of all values in the data set (9 data points), the amplitude of a rhythm was calculated as half the range of oscillation, which in its turn was computed as the difference between peak and trough. Rhythm robustness was computed as a percentage of the maximal score attained by the chi-square periodogram statistic for ideal data sets of comparable size and 24 h periodicity [13]. Robustness greater than 40% is above noise level and indicates statistically significant rhythmicity.

RESULTS

The application of the periodic model showed a circadian rhythm of RT in healthy subjects. No circadian rhytmicity of RT was observed in sheep affected by foot rot. The statistical analysis of cosinor enabled us to define the periodic parameters and their acrophases during the 24 h of monitoring (Table 2).

Figure 1 shows circadian rhythm of RT in healthy sheep whereas the pattern of rectal temperature in ill sheep is shown in Figure 2.

Table 2. Mean values (±SD) of rectal temperature (RT), obtained during the 24 h of monitoring in 10 healthy sheep and in 10 sheep affected by foot rot.

Time (hours)	Rectal Temperature	
	Healthy Sheep	Ill Sheep
11	39.02±0.23	38.91±0.45
14	39.08±0.19	38.86±0.99
17	39.29±0.20	39.12±0.87
20	39.50±0.18	39.09±0.71
23	39.35±0.18	38.86±0.92
2	39.20±0.10	39.10±0.66
5	39.20±0.18	39.87±0.89
8	39.10±0.21	38.94±0.88
11	38.95±0.28	39.10±079

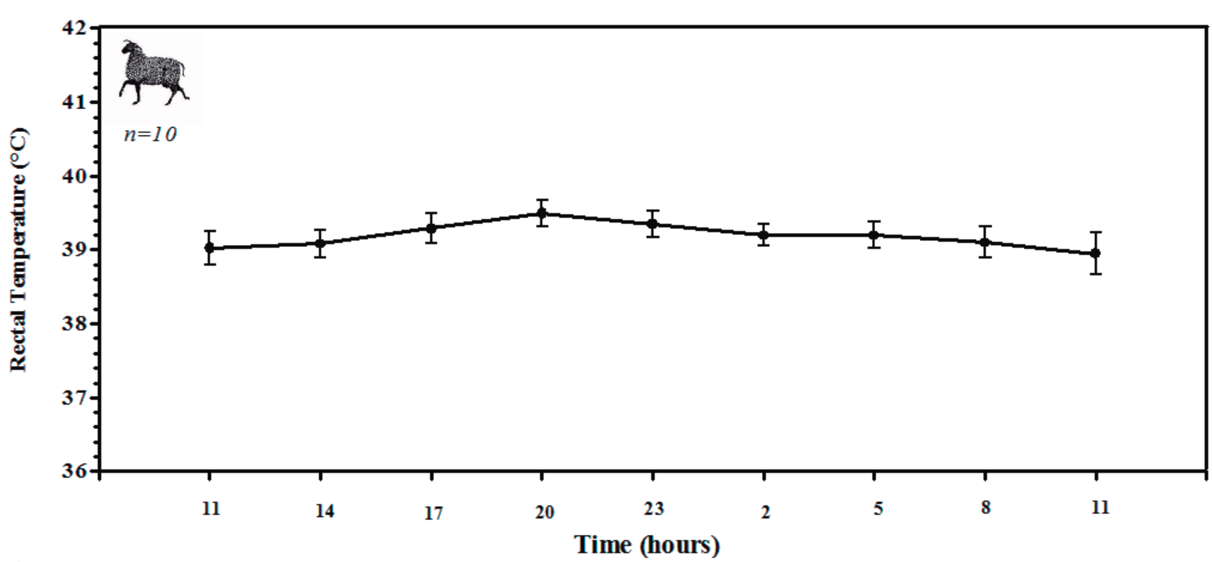

Figure 1. Circadian rhythm of rectal temperature (°C) in healthy sheep. Each point represents the obtained mean (n = 10) of rectal temperature.

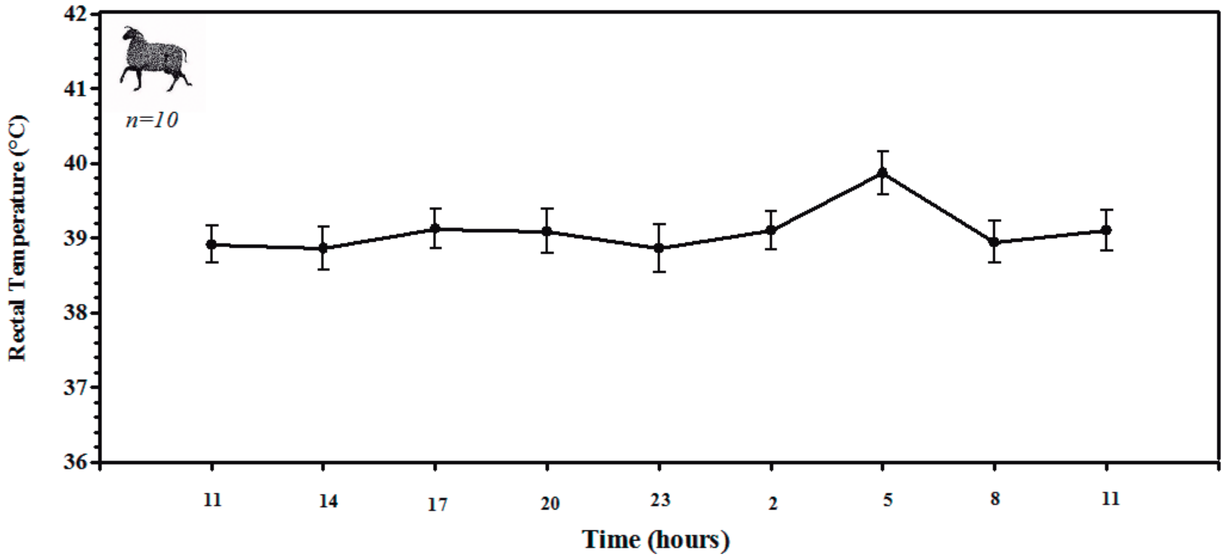

Figure 2. Pattern of rectal temperature (ºC) in sheep affected by foot rot. Each point represents the obtained mean (n = 10) of rectal temperature.

DISCUSSION

The analysis of the results obtained under experimental conditions used in the present study indicated the existence of a circadian periodicity of rectal temperature in healthy sheep whereas no circadian oscillations of rectal temperature were revealed in sheep affected by foot rot.

These data confirm the conclusion of previous studies carried out on body temperature in mammals, in which RT changed with time of day [5,6]. Particularly, in according to studies conducted on sheep's body temperature that reveal a daily rhythm with an ascent phase during the day and a descend phase during the night [7,9], our results indicated the presence of a robust daily rhythm of RT (75.60%) with acrophase during the dark phase (21:38) of the light-dark cycle. Body temperature of the sheep under a light-dark cycle started its daily ascent at the time of sunrise, which is an agreement with the findings in different species of diurnal mammals [12]. These circadian changes are probably due to a rhythmic input from the suprachiasmatic nucleus acting upon the hypothalamic thermoregulatory centres, modulating the set point [14].

In thermal physiology set point is an important concept that explains the complex physiological processes involved in diseases providing changes of temperature. During the rising of temperature, various thermoregulatory responses are activated to increase heat production and reduce heat loss (thus leading to a temperature elevation), and various responses are also activated later to reduce heat gain and increase heat loss (leading to a return of temperature to its initial, nonfebrile level).

A simple and coherent explanation for these pathological alterations is that the set point is elevated during the rising phase and returned to normal during the later phase [14]. This support our results about the pattern of rectal temperature in sheep affected by foot rot in which temperature changes involving set point modifications that probably modify the familiar circadian oscillations of RT [14]. In fact, as previously demonstrated body temperature changes in farm animals may act as a stress indicator for welfare and productivity [3] and a chronic and acute stress may also alter temperature rhythms for several days following the stressor [16].

In conclusion, typically RT exhibits a circadian rhythm, around a set point, that reflects the familiar circadian patterns of endogenous source with changes in mean body temperature and unusual or absent rhythm when temperature is increased to a new set point, as observed in sheep affected by foot rot.

SOURCES AND MANUFACTURERS
[1]Model ThermaCam P25, Flir System, Italy.
[2]Gemini, Chichester, West Sussex, UK.
[3]Model HI-92740, Hanna Instruments, Bedfordshire, UK.

***Ethical approval*.** All housing and care followed the standards recommended by the Guide for the Care and Use of Laboratory Animals and Directive 86/609 EEC.

***Declaration of interest*.** The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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