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Study of circadian rhythmicity of physiological response and skin temperature of sheep during summer and winter in semi-arid tropical environment

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HIGHLIGHTS

- Under semi-arid region, ambient temperature varies between summer and winter.
- Respiration rate, heart rate and skin temperature showed daily circadian rhythm during summer and winter in sheep.
- The ambient temperature throughout the day of both summer and winter influences the physiological variables.

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ABSTRACT

The present study aimed to evaluate the circadian rhythmicity of some physiological variables, including rectal temperature (RT), respiration rate (RR), heart rate (HR) and skin temperature (ST) in sheep during the summer and winter in semi-arid tropical environment. Eight Malpura rams of 3–4 year of age with an average body weight of 37.1 ± 1.99 kg were selected for the study. All the animals were fed individually for a maintenance requirement on a body weight basis. The RT, RR, HR and ST values were measured in each animal at 3 hour intervals for 24 consecutive hours. Ambient temperature (DBT) and relative humidity (RH) was also recorded inside the shed at the time of physiological parameter study. The cosinor analysis showed a daily circadian rhythm ($P < 0.01$) in RR, HR and ST values during the summer and winter in sheep under semi-arid environment. The RR, HR and ST differ significantly ($P < 0.05$) between summer and winter. The amplitude of RR, RT and ST differ significantly ($P < 0.05$) between the seasons. The results indicate that the circadian rhythmicity of RR, HR, RT and ST during summer and winter changed as expected in compliance to the seasonal requirements of animal's adaptability.

1. Introduction

Homoeothermic animals regulate their physiology and behavior to maintain a balance between their heat production and the physical processes of heat exchange with the environment. An animal's temperature is the result of the balance between heat produced by the basal metabolism and muscular activity of the body, and the heat lost from the body [8,11]. The actual regulation of body temperature is accomplished mainly through thermoregulatory centers located in the brain. In mammals, respiration is directed to accomplish the tissue oxygenation and removal of CO_2 under thermo-neutral conditions, but also mediate the dissipation of heat by evaporative heat loss under thermo-challenging environmental conditions. Sheep dissipates approximately 20% of total body heat via respiratory moisture in a neutral environmental temperature (12 °C) which accentuates to 60% of the total heat loss at high ambient temperatures (35 °C) [34]. The heart rate reflects primarily the homeostasis of circulation along with the general metabolic status. It increases in exposure to high environmental temperature [1], thus bringing about the increase in peripheral blood flow to venules leading to increased heat loss through sensible (loss by conduction, convention and radiation) and insensible (loss by diffusion water from the skin) means. Since, it is quite well established fact that changes in peripheral blood flow affects cutaneous temperature [4], it is essential to evaluate if these cutaneous temperature changes are affected by the circadian pacemaker, controlled by circadian processes.

In mammals circadian rhythmicity is most common physiological property [4,22]. The animals maintain their body temperature within physiological limits for survival and maintaining productivity [14]. In sheep also, the nychthemeral variation of the deep body temperature is evident [5]. In fact, it is well known that to maintain a constant body temperature, animal has to satisfy the condition of "stationary

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equilibrium", in which the metabolic production of heat is equal to its loss [21]. The mechanisms involved in, the temperature regulation and the synchronizers responsible for rhythmicity variations were also evaluated in sheep [23,24,7] and along with that probably the respiration rate, heart rate, cutaneous temperature variation also co-evolved. The change in the metabolism allows the animal to adapt itself to different environmental conditions. Probably, circadian rhythmicity is an adaptive mechanism of an animal for environmental changes with the day night cycle [27]. In endotherms heat passes from the core to the periphery that leads to changes in skin temperature in relation to core temperature. In addition to that, the ambient temperature also affects the oscillation of skin temperature [25,2].

Circadian rhythmicity of key control physiological parameters does give an opportunity to relate things to the animal's prevailing environment and does reflect on its ability to counter the offensive environmental conditions. Most of living organisms, including ruminant species, show circadian rhythms, synchronize a wide range of physiological and behavioral functions with the temporal pattern of the geophysical cycles in their environment [26]. In hot arid and semi-arid region, sheep husbandry is a sustainable livelihood resource since ancient time [18]. High temperature and solar radiation of this region severely affects the animal production [20]. There have been a few studies on the effect of ambient temperature on the oscillatory pattern of core temperature [12,16,24]. Da silva and Minomo [5] also showed a nychthemeral variation of core body temperature in sheep under tropical environment. However, still, there is a need to relate the changes in body temperature to the other physiological variables like HR, RR and cutaneous temperature. The aim of this study was to evaluate the effect of ambient temperature changes on the daily oscillatory pattern of RR, HR, rectal and skin temperature in Malpura sheep during the summer and winter under semi-arid tropical environment.

2. Materials and methods

2.1. Site of study

The present study was conducted at the experimental animal farm of Physiology and Biochemistry Division at ICAR-Central Sheep and Wool Research Institute, Avikanagar. The institute is situated under semi-arid tropical region, located at a longitude 75°28′E, latitude of 26°26′N and at altitude of 320 m above mean sea level.

2.2. Animals, handling and feeding

The study was conducted on eight adult (3–4 year of age) Malpura rams of average body weight 37.1 ± 1.99 kg. Malpura is a triple-purpose, hardy and adapted sheep breed native from hot arid and semi-arid areas of Western tropical India. The animals were housed in well ventilated sheds made up of asbestos roofing and chain link sides, and were maintained under proper hygienic conditions. All the animals were fed individually for a maintenance requirement on a body weight basis. The animals were stall fed with a diet consisting of 70% roughage (*Cenchrus ciliaris* hay) and 30% concentrate feed (barley 650 g/kg, groundnut cake 320 g/kg, minerals 30 g/kg including 10 g/kg NaCl, with crude protein = 180 g/kg and total digestible nutrients = 650 g/kg). All the animals were kept inside the same experimental shed and same feeding regime in similar condition 15 days before the starting of the experiment for adaptation.

2.3. Data collection/experimental procedure

The respiration rate (RR), heart rate (HR), rectal temperature (RT) and skin temperature (ST) were measured from each animal at 3 h intervals for 24 consecutive hours on two occasions: during summer and winter. All the data were recorded inside the shed. The animals were kept inside the shed throughout the day and night periods. Day time data were collected in natural day light whereas, dim light was used for collection of data at night time. The RR, HR, RT and ST were measured from individual animals. Dry bulb temperature (DBT), wet bulb temperature (WBT) and relative humidity (RH) were also recorded in the shed at the time of physiological parameter study (3 hour interval). The temperature and humidity during summer ranges from 23 °C to 40 °C and 16% to 62%, respectively. During winter the temperature and humidity ranges from 7 °C to 25.5 °C and 41% to 93%, respectively. The variation in ambient temperature in different time point of the day during summer and winter is depicted in Fig. 1. The respiration rate (RR) was recorded by observing the flank movement for 1 min in which each inward and outward movement of the flank was counted as one complete respiration. Heart rate was recorded by counting the number of pulses (beats) in the femoral artery using the middle finger. Rectal temperature was recorded using a digital clinical thermometer (Model No KFT-04, Microgene diagnostic systems pvt Ltd., India; Accuracy: ±0.1 °C) that gently inserted about 3 cm deep into the rectum, so that probe remained in contact until the reading become stabilized. The skin temperature was taken by using an infrared laser thermometer (DT-8550 Handheld Non-Contact Laser Infrared Thermometer, France; Accuracy: ±2%) at pre-scapular region. Before taking a reading of skin temperature 1 cm^2 area of the pre scapular region was clean shaved. The recording was done at 0600 h, 0900 h, 1200 h, 1500 h, 1800 h, 2100 h, 2400 h and 0300 h of the day. All the reading was taken by the trained veterinarian.

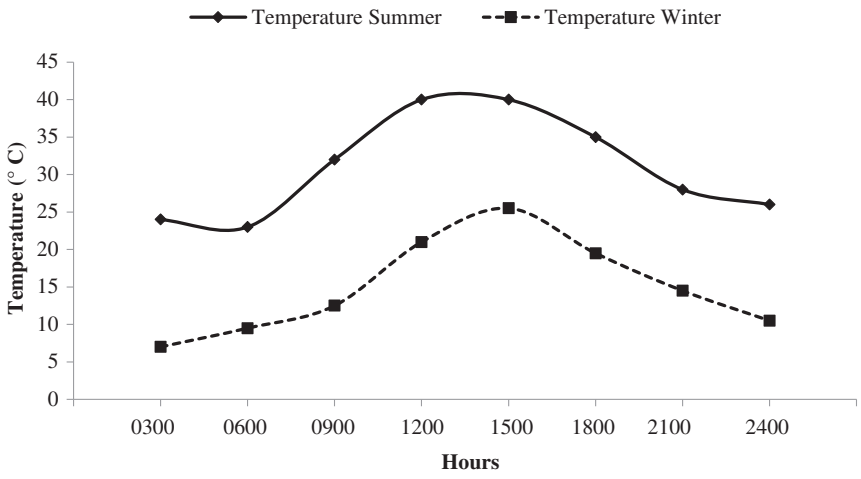

Fig. 1. Temperature and humidity of summer and winter during different hours of the day in semi-arid tropical environment.