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Diurnal variation in some physiological parameters in the West African dwarf goats, as influenced by age, sex and pregnancy status

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Abstract

Diurnal variation in physiological parameters is an established phenomenon. However, the effects under various allostatic states have not been well established. Therefore, this study was carried out to determine the roles of age, sex and pregnancy status in the diurnal variations in heart rate, rectal temperature, and respiratory and pulse rates in West African Dwarf (WAD) goats. Twenty (20) healthy goats comprising 5 adult males, adult non-gravid females, gravid females and kids (less than 6 months old) were used in this study. The animals were sampled two hourly, at 08:00, 10:00, 12:00, 14:00, 16:00, 18:00 and 20:00 hours. The rectal temperature showed considerable diurnal variation. The values increased steadily until the peak was reached at 8 pm in the WAD goats. However, a significant increase was observed at 10 am in the male goats whereas the increases were not significant until 4 pm in the gravid and non-gravid females as well as in the kids. Significant diurnal changes were also demonstrated in the respiratory rates of the goats. Except for the young goats, the respiratory rate increased from 10 am and peaked at 2 pm before falling to the lowest values at 8 pm. However, the highest value of the respiratory rate in the young goats was observed at 8 am, from where it descended to its lowest value at 8 pm.

This study showed that diurnal variation in the rectal temperature, and respiratory rates may not follow the same sequence in both adult and young goats. The sex of the animal involved is also a source of influence on the diurnal fluctuations of these diameters, while pregnancy status did not appear to influence diurnal variation in the WAD goats studied.

Keywords: Diurnal variation, rectal temperature, heart rate, pulse rate, respiratory rate, goats.

Introduction

Body activities in man and animals have been observed to follow a synchronized daily rhythm of light and dark patterns. This oscillation has been used to classify animals into two broad categories - diurnal and nocturnal animals, depending on the period of the day in which the animals are particularly active (Piccione et al., 2003, Levy et al., 2019). Diurnal animals being

most active during the day, utilize the night for rest and sleep, while the nocturnal animals are active during the night using the day as their specific period of rest (Sanni et al., 2000). Most biological processes in the body fluctuate with this daily rhythm. For example, hormone levels, body temperature, blood flow, urine production, hair growth, heart rate, respiratory rates, blood pressure and general metabolic rate all fluctuate according to the daily rhythm (Piccione et al., 2003 and 2008; Habbal and Al Jabal, 2009). Diurnal variations have also been reported under different body conditions such as heart and pulse rates, blood pressure in the newborn foal (Piccione et al., 2008), body temperature during sustained exercise in men (Reilly and Garrett, 1998), body temperature, heart rate, arterial pressure, and other biological variables in horses (Piccione et al., 2009). Despite the varied conditions during which these physiological parameters were assessed, they were found to demonstrate the normal diurnal and circadian rhythm under the influence of a circadian pacemaker located in the suprachiasmatic nucleus of the hypothalamus, although, may be modulated by environmental cycles of light and darkness, food availability, ambient temperature, and other factors (Van Esseveldt et al., 2000; Helfrich-Förster, 2004). Age, sex, nutritional and health status have also been reported to influence heart rate, pulse rate as well as blood pressure variability in men (Singh et al. 2003) and in horses (Piccione et al., 2008).

Most of these parameters are usually lower in the morning than in the afternoon in diurnal animals while higher values are observed in the night during the peak of activity of the nocturnal animals (Sanni et al., 2000).

Biochemical and haematological parameters such as the packed cell volume, haemoglobin concentration, red and white blood cell counts, blood glucose, plasma enzymes (ALT, AST, and GGT), ions (Na^+, K^+, Ca^{2+}, phosphate and lead), metabolites (urea and creatinine), cholesterol and triglycerides etc have been demonstrated to exhibit considerable diurnal variation in man and animals. According to Poccock et al. (1989) large epidemiological survey of the human population revealed a considerable diurnal variation in PCV, Hb, RBC and WBC values. Plasma enzymes - ALT, AST, and GGT, plasma electrolytes especially Na^+, K^+ and Ca^{2+} as well as cholesterol also showed significant diurnal variation, while glucose followed a pattern after food consumption.

These daily variations in physiological parameters have been attributed to variations in physical activities such as exercise (Kreeger et al., 1988) and feeding activities of the animals (Pan et al., 2004) and daily changes in light intensity monitored by the suprachiasmatic nucleus of the hypothalamus in the brain (Balakrishnan et al., 2008, Habbal and Al Jabal, 2009, Kim et al., 2020). Other factors include variations in environmental temperature, periodic changes in the day length and other climatic changes occasioned by the earth's rotation and revolution (Piccione et al., 2003).
Despite the extensive work that has been carried out on diurnal variation of various physiological, haematological and biochemical parameters in various animals, there is a paucity of information on the influence of age and sex as well as pregnancy status of the animal on diurnal changes of these parameters. The present study was therefore designed to investigate the diurnal variations in the heart rate, respiratory rate, rectal temperature and pulse rate as influenced by age, sex and pregnancy status using the West African dwarf goats.

Materials and Methods

Twenty healthy West African Dwarf (WAD) goats consisting of 5 adult male goats (with age range between 1-2 years), 5 adult non-gravid females (2-4 years old), 5 (2 years old) gravid females (based on records of servicing and palpation of the pelvic region), and 5 kids (less than 6 months old) were used in this study. The animals were kept under a semi-intensive system of management and fed with a concentrate ration consisting of dried brewer's grain and water *ad libitum.* Data were collected at 08:00hr, 10:00hr, 12:00hr, 14:00hr, 16:00hr, 18:00hr and 20:00hr on the sampling day. Rectal temperature was measured using a digital clinical thermometer (DT 203, OST Inc. China), and respiratory rate by counting the number of respiratory flank movements per minute. Heart rate was measured with the use of a stethoscope placed between the third and fourth intercostal spaces (at the point of the elbow joint) on the left side of the animal, the number of rhythmic movements of the heart was counted per minute in each animal while the pulse rate was determined by placing two fingers on the femoral artery at the medial aspect of the thigh with slight pressure for the pulsation to be counted per minute for each animal. All readings were taken without agitating, exciting or introducing any form of discomfort to the animals.

Data analysis

The mean and standard deviation of each parameter at each period of the day were calculated and compared. One-way ANOVA with Tukey's post hoc test was performed using GraphPad Prism version 9.00 for Mac, GraphPad Software, San Diego California USA, www.graphpad.com. A p-value less than 0.05 was considered to be statistically significant.

Results

Rectal Temperature

As shown in Fig 1.0, the rectal temperature of the adult male WAD goats shows considerable diurnal variation throughout the day. The lowest temperature was recorded at 8:00 am being significantly lower ($P<0.001$) than the rectal temperature recorded at all the other periods of the day. The temperature thereafter increased steadily before it peaked in the night at 8:00 pm. The temperature of the male WAD at 10:00 am was similar to the value obtained at noon (12:00 hr) but was significantly lower ($P<0.001$) than the values obtained at the remaining periods of the day (2:00 pm, 4:00 pm, 6:00 pm and 8:00 pm). The rectal temperature of the adult male WAD at noon was not significantly different from the temperature at 2:00 pm, but it was lower than the temperature at 4:00 pm ($P<0.01$), 6:00 pm and 8:00 pm ($P<0.001$). Similarly, the value at 4:00 pm was lower ($P<0.05$) than that of 8:00 pm while no significant difference was observed between the temperatures at 4:00 pm and 6:00 pm neither was there any difference between the rectal temperature of the adult male WAD at 6:00 pm and 8:00 pm.

Although the lowest temperature was obtained at 8:00 am in the adult non-pregnant females, the slope of the curve is less steep compared to that of the males. A sharp and significant rise in temperature was only noticed at 4:00 pm unlike in the males in which the curve was steeper. The rectal temperature of the adult female at 8:00 am was significantly lower than the temperature at 4:00 pm ($P<0.01$), 6:00 pm ($P<0.001$) and 8:00 pm ($P<0.001$).

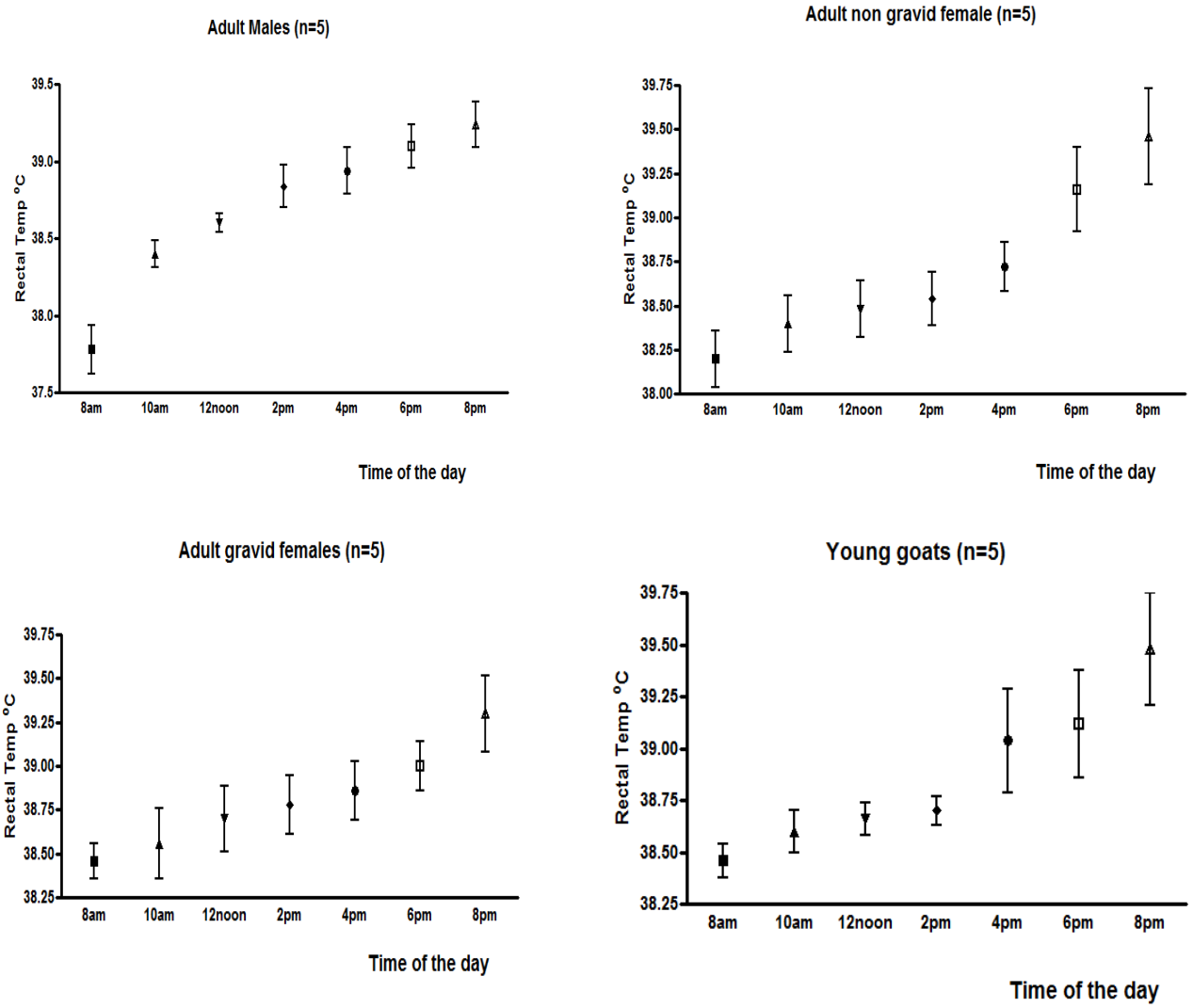

Fig 1.0: Diurnal variation in rectal temperature of adult male, non-gravid female, gravid female and young West African Dwarf goats.

The temperatures at 10:00 am, 12:00 noon and 2:00 pm were only significantly lower ($P<0.001$) than the values at 6:00 pm and 8:00 pm. Similarly, the temperature at 4:00 pm was lower than that of either 6:00 pm ($P<0.05$) or 8:00 pm ($P<0.001$).

The temperature of the gravid female WAD goats also varied at different times of the day. The pattern was however similar to that of the non-gravid female (Fig 1.0). The lowest temperature, as usual, was recorded at 8:00 am, a significant difference was however not noticed until 4:00 pm when the temperature at 8:00 am was lower ($P<0.05$) than that recorded at 4:00 pm. The temperature thereafter increased considerably until it peaked at 8:00 pm. The temperature at 8:00 am was lower ($P<0.001$) than that of either 6:00 pm or 8:00 pm. No significant difference was observed between 8:00 am and 2:00 pm. But

the temperature at 10:00 am was lower than that of either 6:00 pm (P<0.01) or 8:00 pm (0.001) while that of 8:00 pm was higher than the value noon (P<0.001), and 2:00 pm or 4:00 pm (P<0.01).

The rectal temperature also increased steadily in the young goats with significant difference noticed at 4:00 pm. The temperature at 8:00 am was lower (P<0.001) than the values at 4:00 pm, 6:00 pm or 8:00 pm. The temperature was also lower at 10:00 am than at 4:00 pm (P<0.05), 6:00 pm (P<0.01) and 8:00 pm (P<0.001). Similarly, the temperature recorded at noon was lower than the value at 6:00 pm (P<0.01) and 8:00 pm (P<0.001), while that of 2:00 pm was lower than either the value at 6:00 pm (P<0.05) or 8:00 pm (P<0.01). The temperature of the young goat at 8:00 pm was higher (P<0.05) than that of 4:00 pm but there was no significant difference between the values at 6:00 pm and 8:00 pm.

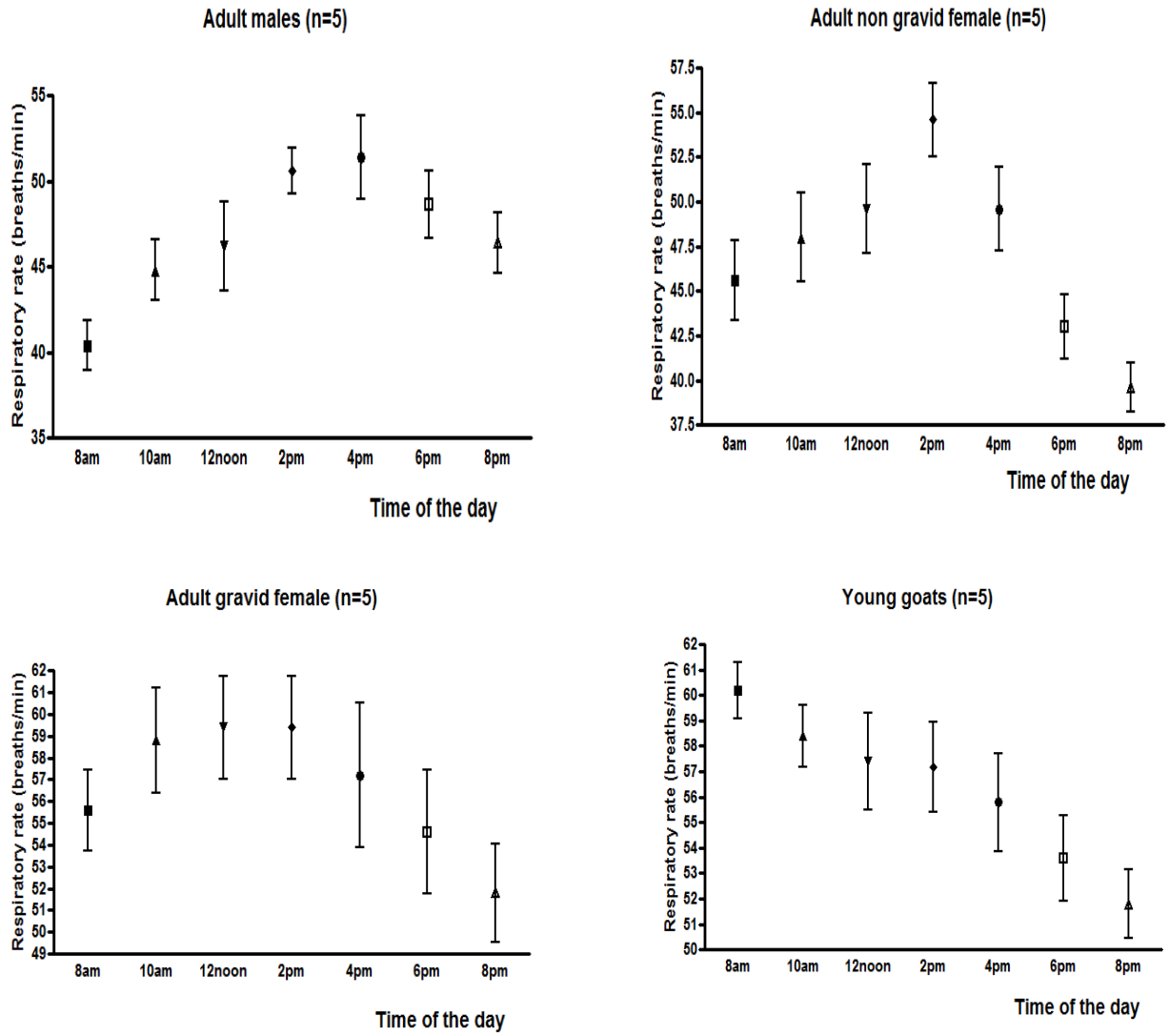

Fig 2.0: Diurnal variation in the Respiratory rate of adult males, non-gravid females, gravid females and young West African Dwarf goats.

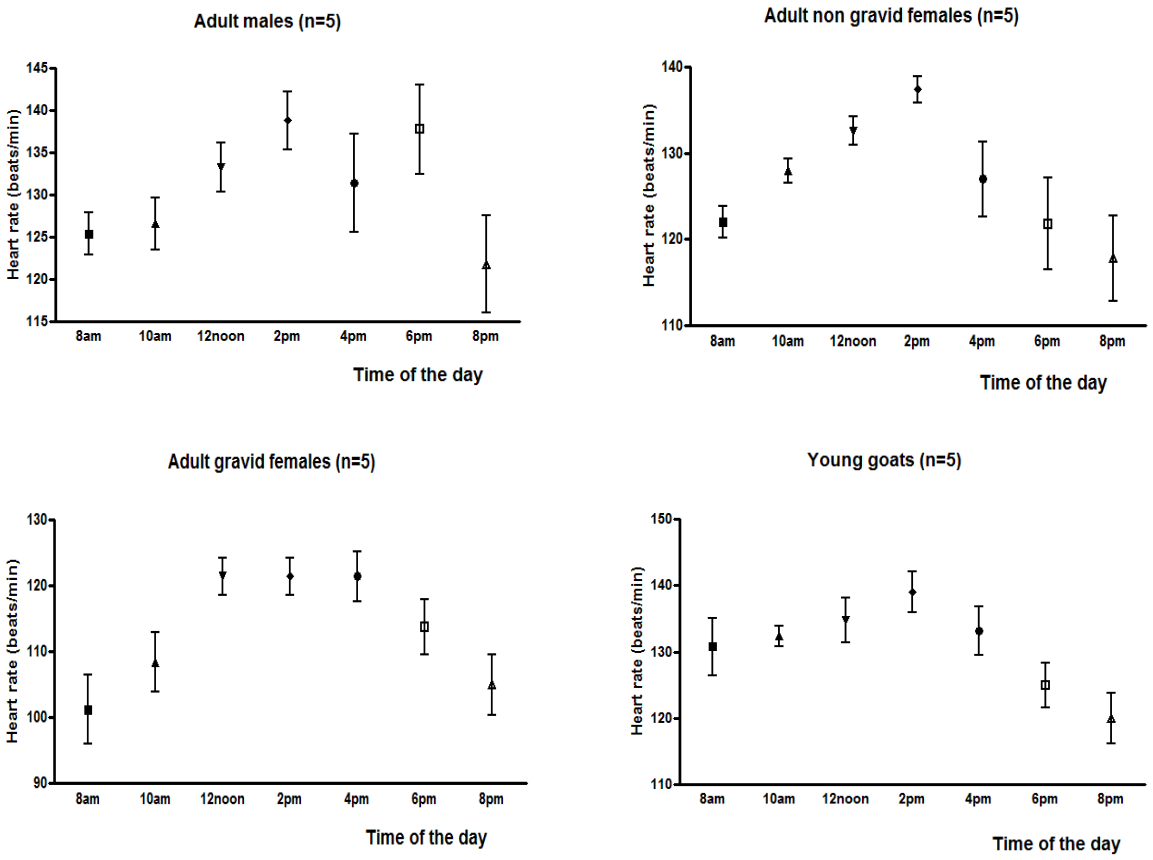

Fig 3.0: Diurnal variation in the heart rate of adult males, non-gravid females, gravid females and young West African Dwarf goats.

Respiratory rate

Fig 2.0 shows the diurnal variation in the respiratory rate of the WAD goats. The respiratory rate increased steadily until it reached the peak at 4 pm before declining, in the adult male goats. The lowest respiratory rate was observed at 8 am. It was lower than the values observed at 10 am ($P<0.05$), noon ($P<0.01$), 2, 4, 6 and 8 pm ($P<0.001$). The value at 10 am was significantly lower than those at 2 pm ($P<0.01$) and 4 pm ($P<0.001$) while that observed at noon was lower than the respiratory rate recorded at 2 pm ($P<0.05$) and 4 pm ($P<0.01$). The respiratory rate observed in the male at 8 pm was however lower than those observed at 2 pm ($P<0.05$) and 4 pm ($P<0.01$).

The respiratory rate in the female WAD also increased steadily from 10 am but peaked at 2 pm unlike in the males where it peaked at 4 pm. A sharp decline was observed afterwards until its lowest value was reached at 8 pm in the night. The values obtained at 8 am and 10 am were significantly lower ($P<0.001$) than that at 2 pm. The respiratory rate at noon and 4 pm was also lower ($P<0.05$) than that at 2 pm. The value obtained at 6 pm was lower than any of the ones at 10 am ($P<0.05$), noon, 2 pm or 4 pm at $P<0.001$. The lowest respiratory rate in the adult non-gravid female was observed at 8 pm. It was significantly lower than that at 8 am ($P<0.01$), 10 am, noon, 2 and 4 pm ($P<0.001$).

The respiratory rate of the gravid female was similar to that of the non-gravid, the lowest value being obtained at 8 pm in the night while the highest occurred between noon and 2 pm. The respiratory rate at 8 pm was significantly lower than the value recorded at 10 am ($P<0.01$), noon and 2 pm ($P<0.001$). It was also lower than the value at 4 pm ($P<0.05$).

Contrary to the observations in the adult WAD goats, the respiratory rate of the young immature goats was highest at 8 am (Fig 4.0), the value then decreased progressively until it reached the minimum value at 8 pm in the night. The respiratory rate was higher at 8 am than at 4 pm ($P<0.01$). It was also higher ($P<0.001$) than those recorded at 6 and 8 pm. Similarly, the value at 10 am was higher ($P<0.001$) than those at 6 and 8 pm while the respiratory rate at noon and 2 pm were higher than the value at 6 pm ($P<0.05$) and 8 pm ($P<0.001$). The respiratory rate at 8 pm was also lower than that obtained at 4 pm ($P<0.01$).

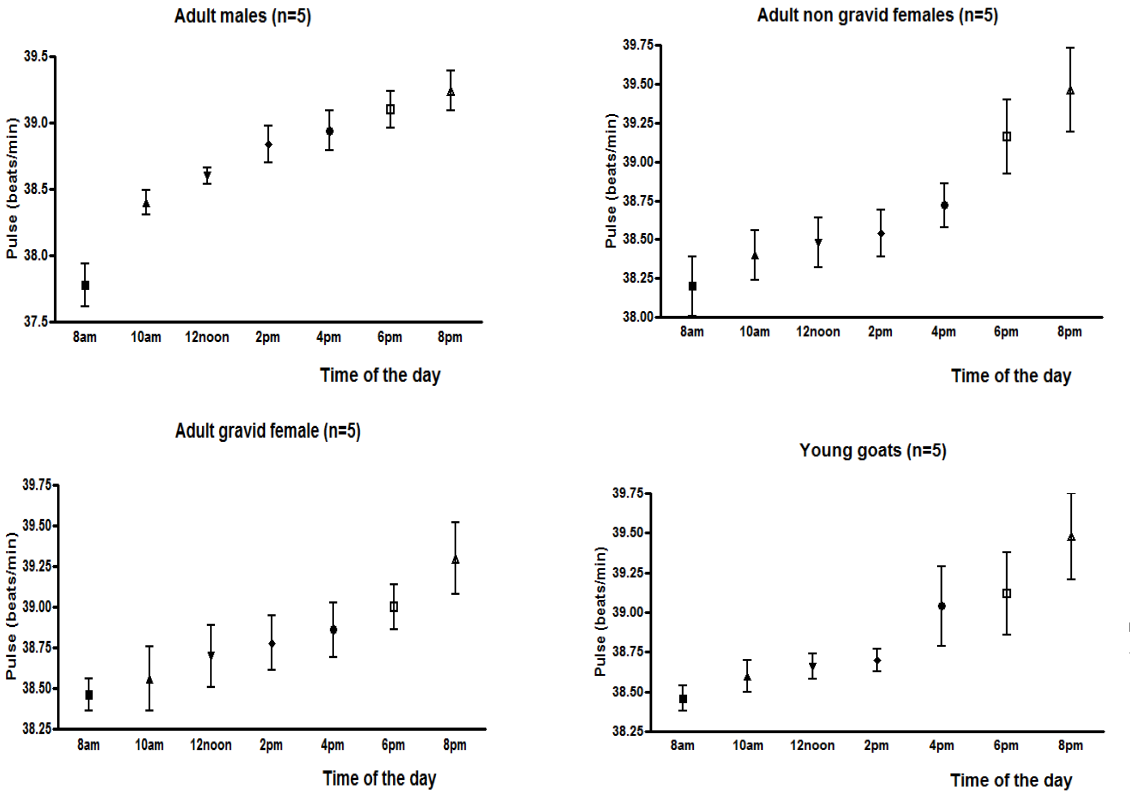

Fig 4.0: Diurnal variation in the Pulse rate of adult male, non-gravid female, gravid female and young West African Dwarf goats.

Heart rate

The influence of sex, age and pregnancy status on the heart rate in the WAD goats is shown in Table 3.0. The heart rate of the adult male WAD goats was steady between 8 and 10 am; it increased significantly ($P<0.001$) at 2 pm before declining at 4 pm and later rose at 6 pm before its final decline at 8 pm. The heart rate at 8 am was significantly lower than the values at 2 pm

(P<0.001) and 6 pm (P<0.01). The value at 10 am was also lower (P<0.01) than those observed at 2 and 6 pm. But the heart rate at 8 pm in the night was significantly lower than the values recorded at noon (P<0.01), 2 pm (P<0.001), 4 pm (P<0.05) and 6 pm (P<0.001).

Unlike in the males, the heart rate increased steadily in the adult non-gravid females from 10 am until it peaked at 2 pm before descending to the minimal level at 8 pm in the night (Fig 3.0). The heart rate of these female WAD goats at 8 pm was significantly lower (P<0.001) than the values observed at noon and 2 pm. The value at 10 am was also lower (P<0.05) than the heart rate at 2 pm. Sequel to the decline in the heart rate; the value recorded at 4 pm was lower (P<0.001) than that of 2 pm while that of 6 pm was significantly lower (P<0.001) than that of either noon or 2 pm. Like in the males, the lowest heart rate in the female WAD goat was also observed to occur at 8 pm. It was lower than the values obtained at 10 am (P<0.01), noon (P<0.001), 2 pm (P<0.001) and 4 pm (P<0.01).

The heart rate of the gravid female WAD goats was generally lower than those of the non-gravid female at all periods of the day. It also showed a significant increase from 10 am, peaked at noon and maintained a plateau or a steady state between noon and 4 pm before declining at 6 and 8 pm. The heart rate in the pregnant females at 8 am was significantly lower (P<0.001) than those obtained at noon, 2, 4 and 6 pm. The value at 10 am was also lower (P<0.001) than those obtained at noon, 2 pm and 6 pm while the value at 8 pm in the night was lower (P<0.001) than those recorded at noon, 2 and 4 pm.

The young goats had the highest heart rate values at most of the periods of the day. It also increased steadily from 10 am and peaked at 2 pm before declining to the lowest value at 8 pm in the night. The value at 8 am was only significantly lower (P<0.05) than that at 2 pm. But the heart rate at 10 am was higher than that of 6 pm in the young goats. Similarly, the values at noon and 2 pm were significantly higher than those of 6 pm at P<0.01 and P<0.001 respectively. Similar to the observation in the other groups of WAD used in this study, the heart rate at 8 pm the night was the lowest. It was lower (P<0.001) than the values observed at 8 and 10 am, noon as well as 2 and 4 pm.

Pulse rate

As shown in Fig 4.0, the pulse rate varied throughout the day in all four groups of WAD goats. The lowest pulse rate was observed at 8:00 am in the adult male WAD goat. It was significantly lower (P<0.001) than the value obtained at any of the other periods of the day. The pulse rate was also lower (P<0.001) at 10:00 am than at 2:00 pm, 4:00 pm, 6:00 pm and 8:00 pm while that of noon was lower than the value at 4:00 pm (P<0.01), 6:00 pm (P<0.001) and 8:00 pm (P<0.001). The pulse rate at 8:00 pm was also higher than that obtained at 2:00 pm and 4:00 pm (at P<0.001 and P<0.05, respectively).

In the adult non-gravid female goats sampled, the pulse rate did not show any sharp or significant difference until 4:00 pm. Thus the pulse rate at 8:00 am was not significantly different from the values at 10:00 am or noon. It was however significantly lower than the value at 4:00 pm (P<0.01), 6:00 pm (P<0.001) and 8:00 pm (P<0.001). The pulse rate at 10:00 am was lower (P<0.001) than the value at 6:00 pm and 8:00 pm. Similarly, the pulse rate at 12:00 pm and 2:00 pm

were lower (P<0.001) than the value at either 6:00 pm or 8:00 pm. The pulse rate at 4:00 pm was also lower than that value observed at 8:00 pm.

Like that of the non-gravid female, the pulse rate of the gravid female WAD goats at 8 am was only lower than those recorded at 4 pm (P<0.05), 6 pm (P<0.001) and 8 pm (P<0.001), while the pulse at 10 am was lower than those at 6 pm (P<0.01) and 8 pm (P<0.001). The pulse at 8 pm was also significantly higher than those at noon (P<0.001), 2 pm (0.01) and 4 pm (P<0.01).

The lowest pulse rate was also observed at 8 am in the young immature goats. It was significantly lower (P<0.001) than the pulse rate at 4, 6 or 8 pm (Fig 4.0). Similarly, the pulse rate of the young goats at 10 am and 12 noon were lower than those at 4 pm (P<0.05), 6 pm (P<0.01) and 8 pm (P<0.001) while the pulse at 2 pm was lower than those at 6 pm (P<0.05) and 8 pm (P<0.001). The value at 4 pm was also lower (P<0.05) than that of 8 pm.

Discussion

The rectal temperature increased steadily (in all the groups of the WAD goats used in the present study) throughout the day, with the highest values obtained at 8 pm. This is in agreement with previous observations in cattle, also in the humid region by Kabuga (1992) and Olayemi and Adeola (2008). They observed that the rectal temperature of the Holstein and Nigerian Zebu cows increased with the increasing ambient temperature in the hot humid tropical environment. Similarly, Zakari et al. (2021) reported a considerable diurnal variation in the rectal temperature of large white piglets that was in direct correlation with the surface temperature of those animals. Kreeger et al. (1989) also reported that the rectal temperature of captive-bred red foxes varied throughout the day, the highest value being obtained at night. Similar observations in man by Reilly and Garrett, (1998) showed that the rectal temperature was lower in the morning than in the afternoon. This variation must have been driven by the metabolic activities of the animals, which, according to Kreeger et al., (1989) have been observed to influence the temperature, heart and pulse rates. PCV, haemoglobin concentration and RBC count according to Piccione et al., (2005) also showed nocturnal acrophases in the horse, which was believed to be due to the influence of the light and dark cycle rhythm.

Unlike in the female and young goats where the temperature was relatively stable until 4 pm, the rectal temperature of the adult male goats started showing a significant increase at 10 am. This might not be unconnected with the anabolic effects of testosterone in the matured male goats or higher activities (Kreeger et al., 1989) at the early hours of the day, which may also be due to the effects of the male androgen hormone.

The respiratory rates also showed significant diurnal variation in the WAD goats, the highest values being recorded at 2 pm. This variation in the respiratory rate was probably in response to the high ambient temperature in the hot tropical afternoon. Similar diurnal changes were observed in the White Fulani and Sokoto Gudali cows under the influence of the environmental temperature (Olayemi and Adeola, 2008). These authors also observed that the respiratory rate of the Nigerian Zebu cattle was at its peak in the afternoon when the ambient temperature was

highest. However, the young WAD goats had the highest respiratory rate at 8 am from where it fell to its minimum value at 8 pm in the night. The diurnal changes in the present study followed the observed changes in the environmental temperature because the highest values were obtained in the afternoon when the ambient temperature of the hot humid tropics is at its peak. This might be influenced by adrenaline released during high ambient temperatures leading to increased respiratory rates for increased evaporative heat loss by the animals as directed by the hypothalamus in the brain (Deitweiler, 1993). The respiratory rate was higher in the young goats than in the adults in this study. This is in agreement with previous observations of Melbin and Detweiler, (1993) that smaller animals have higher heart rate and respiratory rates because respiratory and cardiovascular functions are related to the body mass.

The heart and pulse rate also showed diurnal variation (Fig 3 and 4), the highest value being obtained at 8 pm. This variation must have been driven by the metabolic activities of the animals which, according to Kreeger et al., (1989) has been observed to influence the temperature, heart and pulse rates in red foxes. PCV, haemoglobin concentration and RBC count according to Piccione et al., (2005) also showed nocturnal acrophases in the horse under the influence of exogenous factors especially, the light and dark cycle. The pulse rate in the male WAD goats began its significant, steady increase at 10 am, unlike in the female and young goats where significant changes were not noticed until 4 pm.

The heart and pulse rates also showed significant diurnal variation in the female WAD goats, the highest values being recorded at 2 pm. However, the young WAD goats had the highest respiratory rate at 8 am from where it fell to its minimum value at 8 pm in the night. A similarity was observed between the diurnal changes in the heart rate and that of the pulse rate, probably because the pulse rate is a function of the systolic pressure of the heart. The diurnal changes in the heart rate of the goats in the present study followed the observed changes in the environmental temperature because the highest values were obtained in the afternoon when the ambient temperature of the hot humid tropics is at its peak. Piccione et al. (2009) also observed similar significant increases in the body temperature, heart rate, and systolic and diastolic pressure of horses increased in the afternoon, irrespective of whether the horses were exercised or at rest. This might be influenced by adrenaline released during high ambient temperatures leading to increased respiratory and heart rates for increased evaporative heat loss by the animals as directed by the hypothalamus in the brain (Detweiler, 1993). However, the pulse rate observed in the goats did not appear to follow the changes in the ambient temperature because the highest values occurred at 8 pm at night. This is an indication that the pulse rate followed some endogenous rhythm as suggested by Ayo et al. (2009). They observed that the heart rate, rectal temperature and respiratory rate in the donkey did not positively correlate with changes in the ambient temperature and relative humidity, but followed an endogenous biological rhythm.

The heart and pulse rates were higher in the young goats than in the adults in this study. This is in agreement with previous observations of Melbin and Detweiler (1993) that smaller animals have higher heart rates and respiratory rates because respiratory and cardiovascular functions are related to body mass. Smaller

animals have been known to have higher metabolic rates (Donsova and Zotin, 2019), which may be responsible for the higher heart and pulse rate in the younger goats than in the adults as observed in this study. Kovac et al (2018) also reported that the Heart rate, cardiac vagal tone, respiratory rate, and rectal temperature in dairy calves are generally higher than those observed in adults.

Conclusion

It was demonstrated in this study that, although diurnal variation occurs in the rectal temperature and respiratory, heart and pulse rates of the WAD goats. It may be influenced by the sex and age of the animal involved. Therefore, these factors should be considered whenever physiologic parameters are being evaluated, especially during disease diagnosis or fitness tests in these animals.

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