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Original Article

Evaluating the Physiological Responses of Garut Sheep toward Sun Exposure and Physical Activity in Tropical Climate

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Abstract

Objective: This study investigates the effects of sun exposure, physical activity, measuring time and resting time on physiological parameters (heart rate, respiration rate, and rectal temperature) in Garut sheep.
Methods: Twenty Garut sheep were subjected to a factorial experimental design and assigned to four treatments over five days: Control (P0), Sunlight Exposure (P1), Physical Activity (P2), and Combined Treatment (P3). Physiological parameters were measured in the morning (10.00 am; T1) and afternoon (03.00 pm; T2), immediately after treatment (R1) and after a 15-minute resting period (R2).
Results: Significant differences were found in heart rate, respiratory rate (, and rectal temperature ($p<0.001$) across treatments, indicating heightened physiological stress under intensified conditions. Measuring time significantly affected rectal temperature ($p<0.001$), while both measuring time and resting time influenced respiration rate ($p<0.001$). Interactions between treatment, measuring time, and resting time revealed complex response patterns, with sheep subjected to physical activity, particularly in combination with sun exposure, exhibiting the greatest physiological alterations.
Conclusions: These findings stress the importance of considering both environmental and physical stressors in management of Garut sheep. Elevated physiological response were observed in treatment groups compared with controls, with heart rate not differing between measuring times, whereas respiration and rectal temperature were modulated by time and rest. A 15-minute resting period supported physiological recovery, indicating that rest management is crucial for maintaining optimal welfare and performance. Future research should explore long-term effects and interventions to mitigate stress impacts on Garut sheep well-being.

Keywords: Garut sheep; physiological responses; sun exposure; physical activity.

INTRODUCTION

Garut sheep, an indigenous breed native to Indonesia, play a significant role in the country's economy and culture. These sheep are highly valued for their meat, wool, and unique fighting abilities, which have made them a popular choice for traditional ram fighting contests [1]. However, the physiological challenges faced by Garut sheep, as other types of sheep, such as environmental stressors and physical demands, can have a profound impact on their health, welfare, and performance [2]. Additionally, stress in sheep can reduce meat quality by depleting muscle glycogen and limiting postmortem lactic acid formation, which leads to high-pH DFD meat with greater water-holding capacity but poorer colour and texture, lower carcass yields, and a shorter, less safe shelf-life due to increased oxidation and bacterial growth [10]. Stress can also indirectly affect wool quality, by reducing nutrient intake, it leads to lower wool production [10]. Understanding how these sheep respond to and cope with these challenges is crucial for developing effective management strategies and ensuring their well-being.

Pangandaran, as a coastal area, is a popular destination where the demand for meat consumption continues to rise. Coastal regions typically experience high temperatures and humidity, creating challenging conditions for animal life and productivity. Environmental stressors, particularly heat stress, pose significant threats to the physiological homeostasis of sheep. Exposure to high ambient temperatures can lead to increased heart rate, respiratory rate, and body temperature, as well as altered metabolic and hormonal responses [3]. Sheep have developed various adaptive mechanisms to cope with environmental challenges, including behavioral, physiological, and biochemical adjustments [4]. However, the extent to which these mechanisms are effective in mitigating the impact of heat stress on Garut sheep remains largely unexplored.

Sun exposure and physical activity are key environmental factors influencing the physiological responses and welfare of sheep. Sunlight regulates thermoregulation, vitamin D synthesis, and stress levels, and contributes to the maintenance of overall health [5,6,7]. Meanwhile, excessive heat or inadequate shelter can induce heat stress, which disrupts metabolic processes, impairs immune function, and reduces productivity, whereas appropriate sun exposure supports optimal bone health and general wellbeing [8,9,10,11,12]. Under direct sunlight, sheep and goats employ distinct thermoregulatory strategies, as Rahardja et al. [13] reported increased rectal temperatures in both species, with sheep primarily increasing respiration rate and goats relying more on sweating to dissipate excess heat.

Physiological and behavioral responses to sun exposure further highlight the importance of heat mitigation strategies. Elaref et al. [14] observed that direct sun exposure in Sohagi ewe lambs significantly increased rectal temperature, respiration rate, water intake, and haematological indicators of stress, while productivity and feed intake remained unaffected, indicating an adaptive capacity to heat stress under subtropical conditions.

De et al. [15] showed that providing tree shade improved comfort and welfare in rams by increasing feeding time and reducing panting and prolonged standing, which emphasizes the role of shade as an effective strategy to enhance thermal comfort and welfare in sheep during hot periods.

Physical activity, such as exercise and fighting, also imposes significant physiological demands on sheep. During physical exertion, the cardiovascular and respiratory systems must work harder to meet the increased oxygen and energy requirements of the active muscles [16]. This can lead to elevated heart rate, respiratory rate, and body temperature, as well as altered blood flow distribution and metabolic responses [17]. In Garut sheep, the physiological responses to physical activity may be further complicated by the additional stress of fighting and the cultural practices associated with their management.

While the individual effects of environmental stress and physical activity on sheep physiology have been studied, there is limited research on the combined effects of these stressors, particularly in Garut sheep. Studies on other livestock species, such as cattle [18] and goats [19], have demonstrated that the combination of environmental stress and physical activity can have a more pronounced impact on physiological parameters compared to either stressor alone. However, the specific responses of Garut sheep to these combined challenges remain unknown.

This study aimed to investigate the physiological responses of Garut sheep to sun exposure and physical exercise, to evaluate the influence of measuring and resting times on these responses, and to assess the interaction between treatment, measuring time, and resting time on the physiological parameters observed. We hypothesized that combination of sun exposure and physical exercise would increase heart rate, respiratory rate, and rectal temperature in Garut sheep, and that the response would vary depending on the measuring time and resting time. We also expected that the interaction between treatment, measuring time and resting time would influence the physiological responses of sheep and their ability to recover, although the extent of recovery might vary depending on the parameter and treatment.

Table 1. Ambient temperature and humidity during the experiment (Cijulang, Pangandaran)

Day	Morning 10.00 AM		Afternoon 03.00 PM	
	Temperature	Humidity	Temperature	Humidity
1	33°C	50%	28°C	70%
2	31°C	65%	29°C	70%
3	33°C	65%	29°C	70%
4	33°C	60%	29°C	75%
5	32°C	75%	29°C	75%

MATERIALS AND METHODS

Animal and Prior Experimental

A total of 20 Garut sheep, free from any known health issues and with similar age (3 ± 0.5-yrs-old) and weight profiles (32 ± 1 kg), were selected for the experiment. The sheep were acclimatized to the experimental conditions for a week prior to the commencement of the study (Fig 1). The study was conducted straight a week without rain. During the experiment, the temperature and humidity index were measured twice daily to monitor environmental conditions, as outlined in Table 1. All sheep were housed under similar environmental conditions with access to water and feed.

Experimental design

Twenty Garut sheep were used in a factorial experimental design to evaluate the effects of sun exposure, physical activity, measuring time, and resting time on physiological responses. Animals were randomly divided into four treatment groups, each consisting of five sheep (replicates). The treatment group, to undergo different treatments related to sun exposure and physical activity, which consisted of: Control (P0), no additional sun exposure or physical activity beyond their normal routine; Sun Exposure (P1), exposed to direct sunlight for an additional 1 hour in the morning and 1 hour in the afternoon; Physical Activity (P2), subjected to moderate physical exercise (guided walking or running) for 1 hour twice a day (morning and afternoon) without additional sun exposure; Combined Treatment (P3), exposed to both additional sun exposure for 1 hour and moderate physical activity for 1 hour twice a day, in the morning and in the afternoon. All groups were measured at two different time, T1: in the morning starting at 10.00 am and T2: in the afternoon starting at 03.00 pm. In addition, there will be grouping again according to resting time, consist of R1: control (without resting time) and R2: rest for 15 minutes in the shade after treatment. Hence, in a day each sheep has grouping by treatment, time measurement and resting time (Fig.1). This design enabled evaluation of the main effects of treatment (P), measuring time (T), and resting time (R), as well as their interactions, on the physiological status of Garut sheep.

Physiological parameters, including heart rate (HR), respiration rate (RR) and rectal temperature (RT) were measured. Each measurement was held for a minute and 3 times repetition directly after the treatment was applied to detect the impact of treatment. Heart rate (HR) was measured using a portable veterinary heart rate monitor, ensuring minimal stress to the animals. Respiration rate (RR) was measured by putting the hand in front of the sheep nose or in the stomach area. Rectal temperature (RT) was recorded using a digital veterinary thermometer in the rectal to monitor for signs of heat stress or hypothermia, particularly in the groups exposed to additional sun or exercise. Throughout the data collection process, strict ethical guidelines were adhered to, ensuring the welfare of the sheep was prioritized. Any signs of adverse reactions or distress led to immediate evaluation by the veterinary team, with the option to adjust or withdraw the affected sheep from the study.

Statistical analysis

Data were analyzed using a general linear model (GLM) using IBM SPSS 27 (SPSS Inc, USA) to determine the effects of treatment, measuring time and resting time on the physiological parameters of the Garut sheep. Post hoc tests were conducted using Bonferroni tests to identify significant differences between treatment groups. A p-value of less than 0.05 was considered statistically significant. Interaction effect between treatment, measuring time and resting time on the physiological status of Garut sheep was also measured.

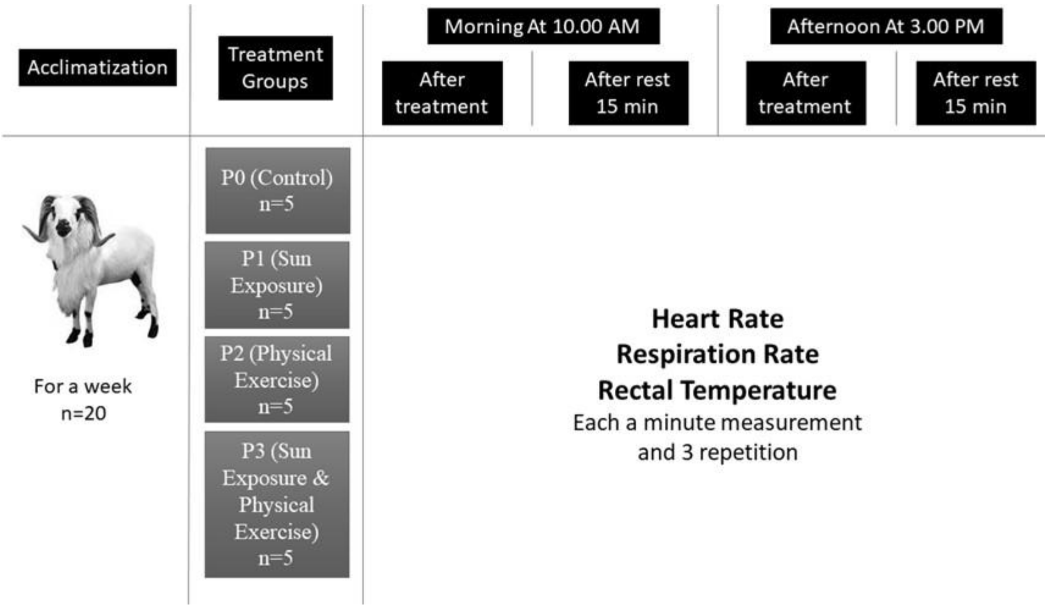

Figure 1. Experimental design model for assessing physiological responses of Garut sheep to sun exposure and physical exercise. After a 7-day acclimatization period, 20 sheep were randomly assigned to four treatment groups (P0–P3; n = 5/group): P0 (control), P1 (sun exposure), P2 (physical exercise), and P3 (combined treatment). Heart rate, respiration rate, and rectal temperature were recorded for 1 minute (three repetitions) at 10:00 (morning) and 15:00 (afternoon) for five days consecutive, immediately after treatment and after a 15-minute rest period.

RESULTS

This study investigated the physiological responses of Garut sheep to different treatments, measuring time and resting times. The result of physiological response categorized by treatments were showed in Table 2. While, the results of measuring time and resting time group were showed in Table 3.

Effect of Treatment

Physiological responses, HR, RR and RT of all sheep was significantly different (pp<0.001) across four group treatments (Table 2). The control group (P0) exhibited a baseline HR of 74.39 ± 0.18 beats per minute, which progressively increased with treatment intensity, peaking at 76.13 ± 0.18 beats per minute in the P3 group. This increase indicates heightened cardiac activity due to combined stressors. Respiratory rate differed significantly among four treatment groups, starting at 30.47 ± 0.10 breaths per minute in the control group, it escalated to 32.04 ± 0.10 breaths per minute in the P3 group (Table 2). Increasing RR was suggested reflecting increased respiratory demand. Rectal temperature showed significant increases with treatment intensity (p<0.001), from 38.46 ± 0.03 °C in the P0 group to 39.81 ± 0.03 °C in the P3 group. This trend demonstrates the thermal effect of physical exertion and environmental factors.

Table 2. Effects of Treatment sun exposure and physical exercise on the physiological response of Garut sheep

Parameter (n=20)	Treatment				SEM	Sig.[1]
	P0	P1	P2	P3		
Heart Rate	74.39[a]	75.26[b]	75.35[b]	76.13[c]	0.18	< 0.001**
Respiration Rate	30.47[a]	30.39[a]	31.16[b]	32.04[c]	0.10	< 0.001**
Rectal Temperature	38.46[a]	38.47[a]	39.58[b]	39.81[c]	0.03	< 0.001**

P0, control; P1, Sun Exposure; P2, Physical Activity; P3, Combined Treatment.
1) Comparisons between the Con and Trt groups based on a multivariate generalized linear model (GLM).
**) showed significantly different between treatment.
a,b,c) Comparisons between the Con and Trt groups based on a Bonferroni post-hoc test

Effect of Measuring Time

Measuring time significantly influenced RR and RT ($p<0.001$), but not HR. Sheep measured at T1 had higher HR, RR and RT compared to sheep in T2 (Table 3). These results indicate that ambient temperature and humidity at different measuring times may lead to increased RR and RT (Table 1, 3).

Effect of Resting Time

Heart rate and respiration rate of sheep in R1 and R2 groups showed significant changes ($p=0.008$; $p=<0.001$), for HR and RR respectively (Table 3). Sheep in R2 group had significantly lower HR and RR compared to sheep in R1 group. These results indicating treatments group influenced the initial increase in respiratory rate, while a 15-minute rest period allowed for recovery (Table 3). Sheep in R2 did not show a significant elevation in RT ($p=0.71$; Table 3), meaning that RT did not change differently after 15 minutes resting. These results suggest a sustained physiological response of sheep post-treatment.

Interaction effect of treatment, measuring time and resting time

Table 4 presents the interaction effects between treatment, measuring time, and resting time on the physiological parameters. Significant interactions were observed in RR ($p<0.001$) for interaction treatment with both measuring time and resting time. Interaction between treatment and resting time was also significant for RT ($p=0.019$). No interaction effect on HR. These interactions suggest that the effects of treatment on RR and RT may vary depending on the time of measurement and the resting period, respectively.

DISCUSSION

The significant increase in HR of sheep within the combined sunlight and physical activity group (P3) aligns with findings by Smith et al. [6], who reported similar cardiovascular responses in livestock exposed combined environmental and physical stressors. Elevated HR under high activity and heat load may be attributed to heightened sympathetic nervous system activity as an adaptive mechanism to stress, as discussed by Jones et al. [20]. Jones et al. [20] further noted that coordinated activation of the sympathetic nervous system and hypothalamic–pituitary–adrenal axis is adaptive during acute stress but, when prolonged or dysregulated, contributes to cardiovascular strain and cumulative allostatic load. In our study, HR increased in all with treatment groups compared with the control group, however no significant differences were observed between measuring times. Moreover, HR decreased following theresting time, consistent with Bulitta et al. [21], who observed more rapid normalization of heart rates during rest and recovery. This decline is associated with reduced stress hormone activity and increased parasympathetic stimulation, which together contribute to lowering heart rate [30].

The elevation in RR under more intense treatments reflects an increased metabolic and thermoregulatory demand, consistent with Joy et al. [22] and Sevi & Caroprese [23]. Joy et al. [22] reported that heat-stressed small ruminants typically exhibit elevated respiration rate as a primary adaptive response to dissipate excess heat, and identified RR, together with RT and HR, as a sensitive indicator of thermotolerance in hot environments. While, Sevi and Caropprese [23] highlighted that in sheep, enhanced respiratory frequency is a major route of heat dissipation under high ambient temperature, particularly when sweating is limited by the wool coat and temperature–humidity index exceeds the thermoneutral range. Respiratory rate is the first response to increase under high ambient temperature as part of the thermoregulation mechanism to help maintain body temperature [24], andunder hot conditions, some animals may experience panting as an intensified evaporative cooling response. The significant decrease in respiratory rate after a 15-minute rest period aligns with the reviews of Bernabucci et al. [25], suggesting effective physiological recovery mechanisms in these sheep.

Table 3. Effect of measuring and resting time on the physiological status of Garut sheep

Parameter (n=20)	Measuring Time		SEM	Sig.1	Resting time		SEM	Sig. 1
	T1	T2			R1	R2		
Heart Rate	75.345	75.222	0.13	0.501	75.53	75.04	0.13	0.008*
Respiration Rate	31.826	30.203	0.73	< 0.001**	31.23	30.80	0.07	< 0.001**
Rectal Temperature	39.143	39.014	0.21	< 0.001**	39.05	39.11	0.02	0.71

Measuring time T1, morning at 10.00 AM; T2, afternoon at 03.00 AM; Resting Time R1, no resting time; R2, 15 minutes resting time;

1) Comparisons between the Con and Trt groups based on a multivariate generalized linear model (GLM).

*$p < 0.05$, **$p < 0.01$.

Table 4. Interaction effect between treatment, measuring time and resting time on the physiological status of Garut sheep

Parameter (n=20)	Interaction Significance1			
	P x T	P x R	T x R	P x T X R
Heart Rate	0.959	0.134	0.537	0.511
Respiratory Rate	< 0.001**	< 0.001**	0.109	0.507
Rectal Temperature	0.062	0.019*	0.376	0.569

P, Treatment; T, Measuring time; R, Resting Time;

1) Comparisons between the Con and Trt groups based on a multivariate generalized linear model (GLM).

*$p < 0.05$, **$p < 0.01$.

The increase in RT under stress corroborates the study of Patel et al. [26], highlighting thermoregulatory challenges in livestock subjected to physical exertion and environmental heat. This finding aligns with Sejian et al. [27], who observed that RT and RR of Sohagi ewe lambs increased under high ambient temperature as an effort to dissipate body heat. However, the lack of significant temperature change post-resting differs from Arfuso et al. [28], who reported a more rapid return to baseline temperatures. This discrepancy might be attributable to breed-specific thermoregulatory characteristics [29].

This study found that both measuring time and resting time for sheep in the control group (P0) and the group only exposed to the sun (P1) showed no significant difference in RR (Fig. 1). However, an increase in RR was observed in the P2 and P3 groups, indicating the effect of additional physical activity on those groups may affect sheep thermoregulation. A similar trend was noticeable in the rectal temperature of sheep in the P0 and P1 groups, where sheep without physical activity had lower rectal temperatures.

The findings of this study are consistent with previous research on the physiological responses of livestock to environmental and physical stressors. Sejian et al. [3] reported increased heart rate, respiratory rate, and rectal temperature in sheep exposed to heat stress, similar to the responses observed in the P1 and P3 groups in the current study. Similarly, the combined effects of physical activity and environmental stress on physiological parameters have been documented in other livestock species, such as cattle [18] and goats [19].

However, some aspects of the current study's findings differ from previous research. For instance, the lack of significant changes in heart rate during the resting period contrasts with the findings of Abdelatif et al. [16], who reported a rapid decrease in heart rate in sheep following the cessation of exercise. This discrepancy may be due to differences in the intensity and duration of the physical activity, as well as the specific breed of sheep studied.

Furthermore, the interaction effects observed between treatment, measurement time, and resting time on physiological parameters have not been extensively explored in previous studies on Garut sheep. These findings highlight the importance of considering the complex interplay between environmental factors, physical activity, and recovery periods when assessing the physiological responses of these animals.

Understanding these physiological responses is essential for the welfare and management of Garut fighter sheep, particularly in contexts of physical training and environmental management. The resilience shown by these sheep under combined stressors, as observed in this study, is a critical factor for their management in sports or farming activities. Implementing appropriate rest periods and monitoring environmental conditions can help mitigate the effects of stressors and promote optimal health and performance.

CONCLUSION

Garut sheep subjected to combined sun exposure and physical activity exhibited greatest physiological response, as reflected by significantly elevated heart rate, respiration rate, and rectal temperature compared with other treatments. Limiting simultaneous exposure to direct sunlight and exercise, particularly at critical measuring times in the morning, is therefore recommended to maintain physiological stability. The provision of a short resting period in the shade improved recovery of physiological parameters, indicating its value as a practical management strategy to reduce acute stress. The findings highlight the importance of considering the interaction between physical activity and environmental factors in managing Garut sheep, and suggest that minimizing combined stressors should be prioritized to support their welfare and performance. Future studies should investigate the long-term effects of repeated exposure to these conditions and evaluate targeted interventions, such as optimized shading, exercise scheduling and cooling strategies, to further mitigate stress and enhance their well-being.

CONFLICT OF INTEREST

The authors declare no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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