—Original Article—

Decrease in body surface temperature before parturition in ewes

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Abstract. This study investigated the correlation between the body surface temperature (BST) and core body temperature of ewes and changes in BST during the prepartum stage in pregnant ewes. Four non-pregnant adult ewes were used in the first experiment. The BST of the upper neck, vaginal temperature (VT), and ambient temperature (AT) were measured every 10 min for seven days and analyzed for correlations. The mean ($\pm$ SD) BST and VT of ewes during the study period were 35.4 $\pm$ 1.7°C and 39.1 $\pm$ 0.4°C, respectively, with a correlation of r = 0.62, P < 0.001. This finding suggested that the BST was associated with core body temperature in ewes. In the subsequent experiment, seven pregnant ewes in their third trimester were used to evaluate changes in BST measured at the upper neck 72 h before parturition. The mean BST at −24–0 h (0 h = time of parturition) was significantly lower than that at −72– −48 h and −48– −24 h (P < 0.05). The BST tended to decrease toward parturition; all BST measurements at −16– −3 h were significantly lower than those at −72 h (P < 0.05). A clear circadian rhythm in the BST was observed at two days and the day before parturition and an unclear circadian rhythm was observed on the day of parturition. Therefore, these findings indicate that the BST also decreases before parturition, as do vaginal and rectal temperatures.
Key words: Body surface temperature, Ewe, Parturition

The occurrence of dystocia is associated with an increased mortality of newborn offspring, and it negatively affects the reproductive performance of their dams [1, 2]. The incidence of dystocia was approximately 6.8–13.7% in dairy cattle [3–5], 8.6% in beef cattle [6], and 9.7–16.8% in ewes [7]. Recently, there has been an increasing interest in intensive husbandry systems in cattle and sheep. However, a reduction in labor and supervision at intrapartum is likely to cause an initial increase in offspring and dam mortality [2]. Therefore, predicting the onset of parturition would facilitate the ability to supervise parturition and potentially reduce losses of both offspring and dams as a result of dystocia [8, 9].

It has long been known that body temperature drops prior to parturition in cattle [10–14] and ewes [15]. Several studies have provided evidence that a decrease in body temperature occurs before the onset of parturition [12–14]. It is suggested that this decrease in body temperature before parturition is associated with the maternal plasma progesterone concentration [12].

The monitoring of the core body temperature is used in many physiological studies, including the study of disease and reproduction. Several methods exist for measuring the core body temperature, including the use of ruminal [16], rectal [17], and vaginal [18] temperature devices. However, many of the devices used to measure the core body temperature are invasive and not always practical in

a research setting.

The potential of a noninvasive technique to measure body surface temperature (BST) of dairy cattle using infrared thermography has been suggested for applications such as the study of various health disorders [19, 20] and the detection of estrus [21]. At present, however, the usefulness of infrared scanning for routine work under commercial conditions appears limited.

In this study, we also aimed to realize the utilization of cattle in the future; therefore, we evaluated the potential of BST measurements as a noninvasive measure to predict the time of parturition by examining 1) the correlation between the BST and the core body temperature of ewes, measured continuously with a temperature sensor and a data logger, and 2) prepartum change in the BST of pregnant ewes.

Materials and Methods

The animal experimentation protocol was approved by the president of Kitasato University with a judgment of the Institutional Animal Care and Use Committee of Kitasato University.

BST was measured as follows: a temperature sensor with a data logger (Kestrel DROP D1; Kestrel Meters, Sylvan Lake, MI, USA) was placed in close contact with the skin on the upper neck of each test ewe, fixed by tying it with the ewe's fur, and covered with fur so that the sensor was not exposed to ambient air (Fig. 1). BST was recorded every 10 min. After completion of the measurement, the data were retrieved and used for analysis. Hoffmann *et al.* [22] showed that this method has potential as a monitoring system for BST in cattle by infrared thermography temperature collection at different body locations (i.e., the eye, back of the ear, shoulder, and vulva). However, when the temperature sensor was used to measure BST, it was necessary to attach the sensor on the outside of the ewe's body in
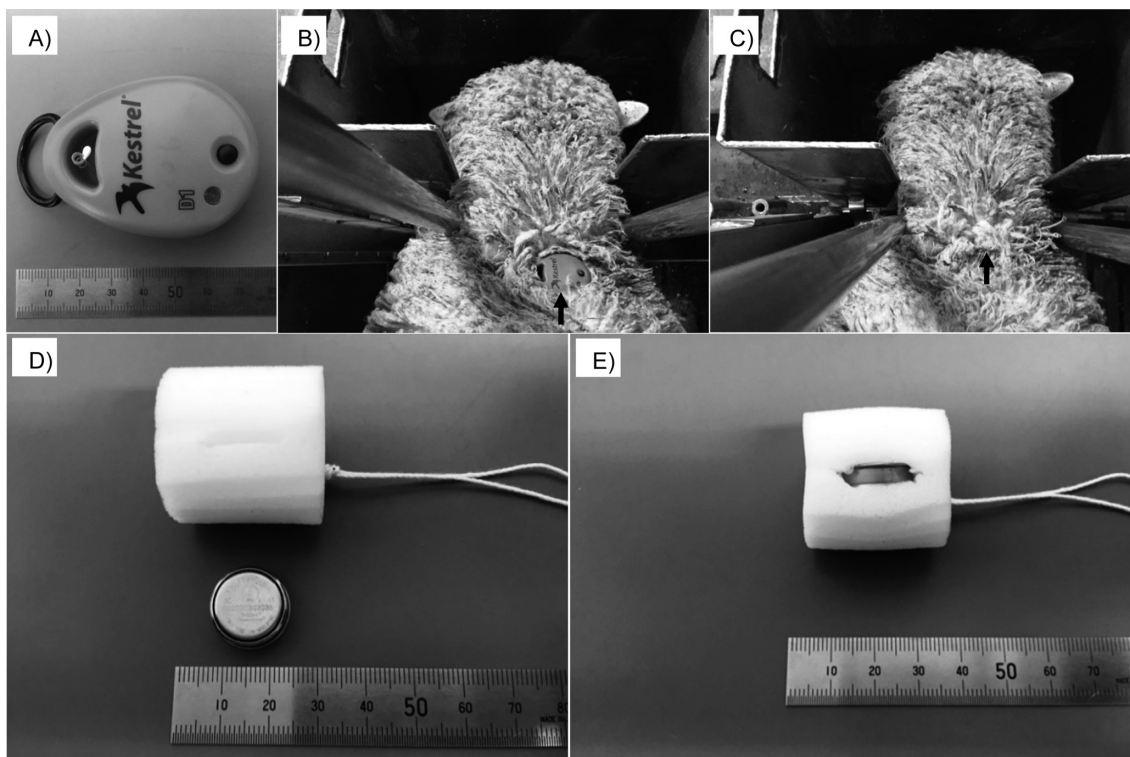
Fig. 1. The body surface temperature sensor (A) was placed in close contact with the skin on the upper neck of the ewe (B), fixed by tying it with the ewe's fur, and covered with fur so that the sensor was not exposed to the ambient air (C). The arrow indicates the temperature sensor's attachment area. A small temperature sensor with a data logger for the measurement of vaginal temperature was embedded in a sponge (D, E).

a place from which an ewe could not remove the sensor. Therefore, the skin on the upper neck was used in this study.

Vaginal temperature (VT) was used to assess the core body temperature. A small temperature sensor with a data logger (Thermocron SL, KN Laboratories, Osaka, Japan) was embedded in a sponge, placed in the vagina of each test ewe, and set to record VT every 10 min. After the completion of the measurement, the sponge was removed from the vagina and the measurement data was retrieved in the same way as for BST.

Ambient temperature (AT) in the barn was also measured throughout the study period using a temperature sensor with a data logger (Kestrel DROP D1; Kestrel Meters). AT was recorded every 10 min and the atmospheric temperature of the height was the same as that of the ewes in the barn. The barn was naturally ventilated and lights were on from 0830 to 1730 h JST. To enable filming with light-sensitive cameras during the dark period, small lights were left on (Experiment 2). The animals did not receive direct sunlight.

Experimental design

Experiment 1: The measurement of BST and core body temperature. Four non-pregnant adult Corriedale ewes (25.2 ± 20.7 months old, 45.9 ± 1.5 kg BW) were used in this experiment in spring. The animals were housed individually in stainless steel cages 86 cm wide × 136 cm long with a raised wooden slatted floor (height: 30 cm) in the barn. The animals could lie down or stand up and move freely in the cage. This experiment was conducted over seven days. The animals were fed the necessary amount of roughage and concentrated feeds calculated on the basis of each test ewe's body weight according to the Japanese Feeding Standard for Sheep [23]. The feed was divided into two doses: one in the morning (0830 h) and one in the late afternoon (1630 h). The animals had access to water and rock salt *ad libitum*. After seven days, the BST of the upper neck, VT, and AT were collected and analyzed.

Experiment 2: Prepartum changes in the BST of pregnant ewes. Seven pregnant Corriedale ewes (38.9 ± 0.3 months old, 52.0 ± 7.7 kg BW) in their third trimester were used in this experiment and housed individually in cages (86 cm wide × 136 cm long). Animals were fed according to the same protocol described above. The test ewes were continuously monitored by a web camera to accurately determine the time of parturition. BST was recorded every 10 min, starting three days before the expected date of parturition and continuing until the end of parturition, using the aforementioned procedure. At the end of the study, the measurement data were retrieved and analyzed to calculate the hourly averages of BST during the 72 h before parturition. None of the tested ewes had dystocia and all had a single birth.

Statistical analysis

Pearson's correlation coefficient was used to calculate BST, VT, and AT correlations. BST measurements several days before

parturition were compared using Tukey-Kramer's multiple comparison test. Using Dunnett's test, prepartum hourly BST measurements were compared with measurements between 72 h and 69 h before parturition as the control. All statistical analyses were performed using JMP 8.0.1 software (JMP Version 8.01; SAS Institute, Cary, NC, USA). Differences were considered to be significant at P < 0.05.

Results

Experiment 1

The mean (± SD) AT during the study period was 16.5 ± 3.9°C (ranging from 9.0 to 26.4°C). The mean ewe's BST and VT during the study period were 35.4 ± 1.7°C and 39.1 ± 0.4°C, respectively, with a correlation between BST and VT of $r = 0.62$ (P < 0.001; Fig. 2). The correlations between AT and BST and between AT and VT were $r = 0.26$ (P < 0.001) and $r = 0.28$ (P < 0.001), respectively.

Experiment 2

Table 1 shows the comparison of the mean BST measurements at −72– −48 h, −48– −24 h, and −24– 0 h (0 h = time of parturition). The mean BST at −24– 0 h was significantly lower than that at −48– −24 h (0.5°C) and −72– −48 h (0.7°C) (P < 0.05).

Figure 3 shows the change in BST measurements during the 72 h before parturition compared with the measurements at −72 h. The BST tended to decrease with measurements that were taken closer to parturition; a continuous decrease in BST was observed in −27– −3 h. In addition, measurements at −16– −3 h were significantly lower than those at −72 h (P < 0.05). The mean BST measurements at −16– −3 h was 1.1°C (ranging from −0.93 to −1.27°C) lower than those at −72 h. In contrast, the BST increased at −2– 0 h.

Figure 4 shows the difference between the BST at a particular time of the day and at the same time on the preceding day. A decrease in BST of 0.2 to 0.7°C between a particular time of day and the same time of the preceding day was observed at −33– −3 h.

Figure 5 shows the diurnal variation in BST between 0000 and 2300 h on day −2, day −1, and day 0 (day 0 = day of parturition). On day −2 and day −1, a clear circadian rhythm in BST was observed whereby the temperature was low in the morning and high in the late afternoon and during the night, and increased after feeding (0830, 1630 h), with a smaller magnitude of variation on day −1. On day 0, a clearly different pattern of diurnal variation than those observed during the two preceding days was observed, showing an unclear circadian rhythm.

Discussion

Studies using Holstein cattle have shown a good correlation between vaginal and rectal temperatures [24, 25]. While it is difficult to place a short-term internal temperature-measuring device in the rectum, intravaginal placement is relatively easy. The usefulness of VT measurements has been demonstrated for continuous monitoring of the core body temperature [26, 27]. In this study, although the mean BST measured at the upper neck of ewes was lower than the mean VT by 3.7°C, a significant correlation was observed between the two parameters, suggesting that BST is associated with core body temperature. Berry et al. [28] also observed a significant positive
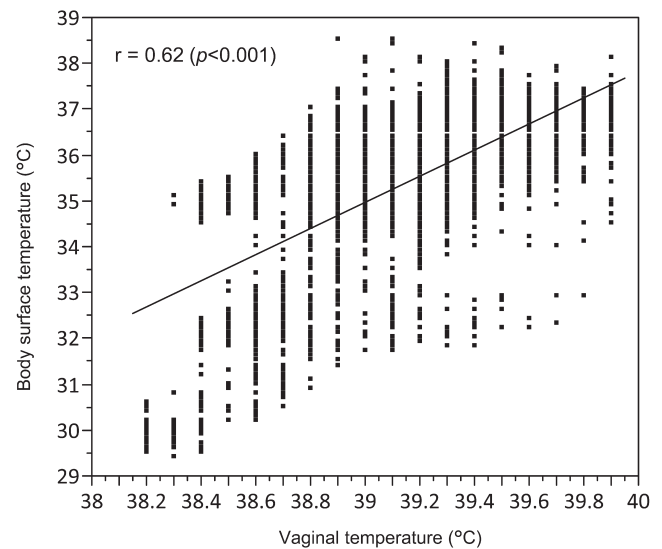

Fig. 2. The relationship between vaginal and body surface temperatures in ewes (n = 4).

Table 1. Body surface temperature (mean ± SD) of ewes (n = 7) 72 h before lambing

Time before lambing (h)	Body surface temperature (°C)
−72– −48	35.4 ± 1.5 [a]
−48– −24	35.2 ± 1.4 [a]
−24– 0	34.7 ± 1.3 [b]

[a,b] Denotes significantly different means (P < 0.05).

correlation between udder surface temperature measured by infrared thermography and rectal temperature. Although BST is considered to be affected by changes in AT [29], the correlation between BST and AT was comparable to that of VT and AT in this study. This may be because the temperature sensor was closely attached to the body surface at the upper neck of ewes and covered by the ewes' fur. This observation demonstrates the validity of the method for measuring BST at the upper neck. However, the present study was performed in mild weather conditions (AT ranged from 9.0 to 26.4°C). Hence, in severe hot or cold conditions, it is possible that the results would be different from those of this study. Thus, further studies will be needed under severe weather conditions.

The mean BST measurements at −24– 0 h was significantly lower than those at −72– −48 h and −48– −24 h. Similar results were reported in previous studies that measured VT in prepartum beef cattle [14] or VT and rectal temperature in Holstein cattle [24]. In the assessment of hourly incremental changes in BST over 72 h before parturition, a continuous decrease in BST was observed at −27– −3 h. In addition, a decrease in BST of 0.2 to 0.7°C between a particular time of day and the same time of the preceding day was observed at −33– −3 h. Aoki et al. [14] continuously measured VT of prepartum beef cattle and observed a consistent decrease in VT of ≥ 0.5°C with respect to the temperature at the same time on the
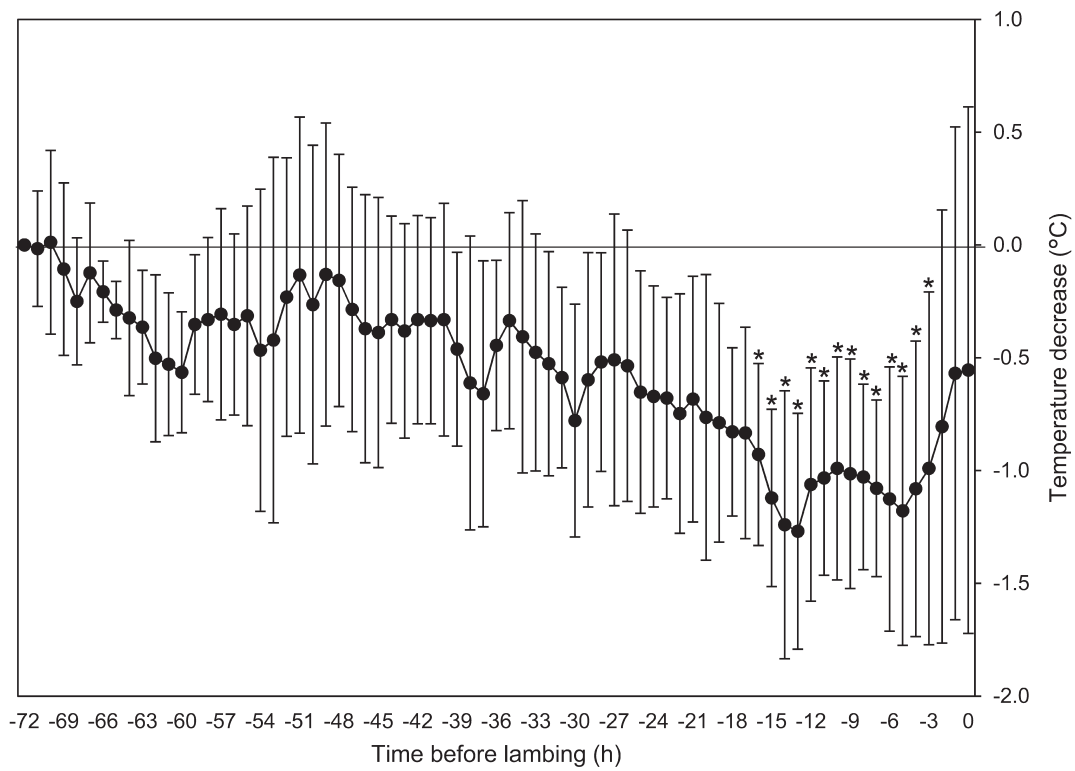
Fig. 3.   Changes in body surface temperature (mean ± SD) in ewes (n = 7) during 72 h before parturition. Relative changes in body surface temperature when the temperature was –72 h (0 h = time of parturition) is set at 0. * indicates a significant difference compared to the value at –72 h (P < 0.05).
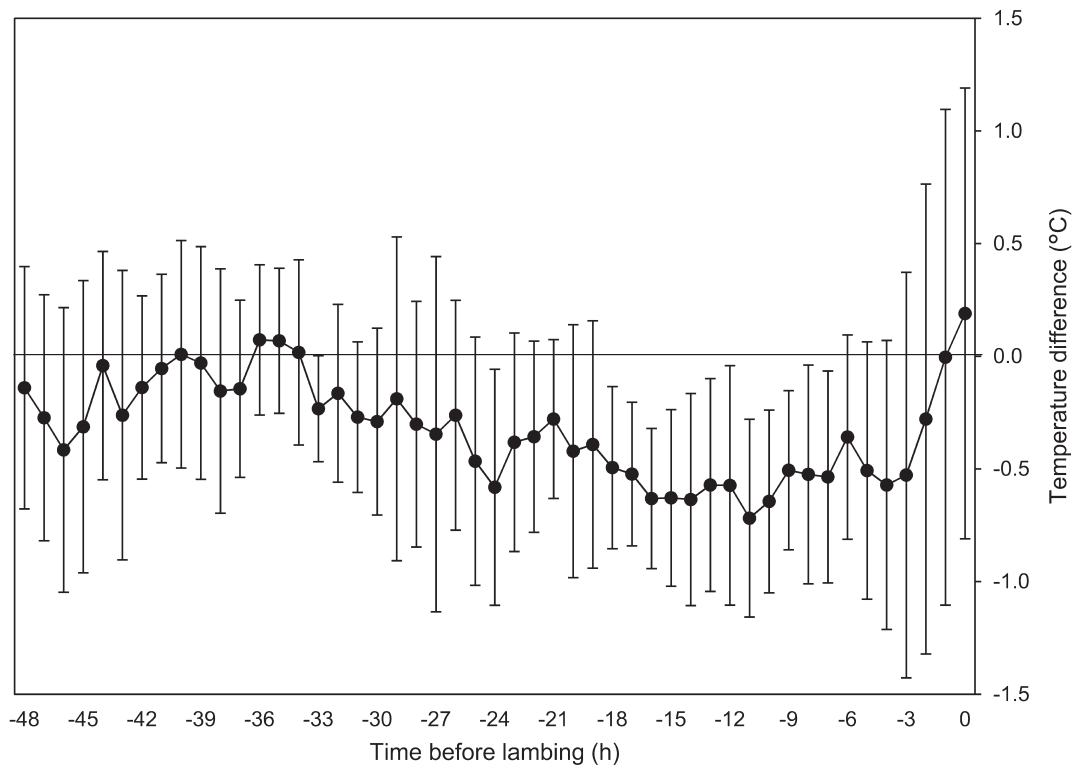

Fig. 4.   The difference between the body surface temperature (mean ± SD) in ewes (n = 7) at a particular time of the day and at the same time on the preceding day.
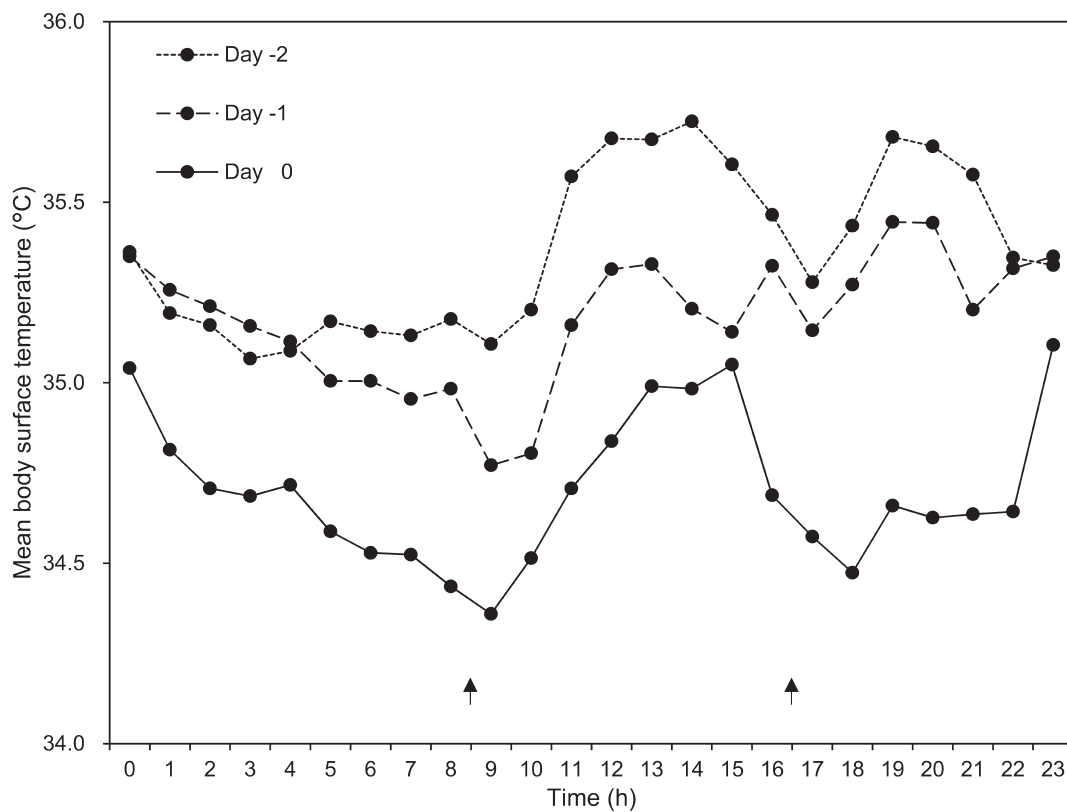
Fig. 5. A comparison of the diurnal rhythm of the body surface temperature in ewes (n = 7) for day –2, day –1, and day 0 (day 0 = day of parturition). The arrows indicate the time of feeding. Data for day –2, day –1 and day 0 body surface temperature are presented as the mean ± SD. SD ± 1.25, 1.29, and 1.40 for day –2, day –1, and day 0, respectively.

preceding day (29.7 h before parturition), which is consistent with our data. Pregnancy-related fluctuations in body temperature, such as increased body temperature during pregnancy [30] and a prepartum decrease in body temperature [31], have been associated with a change in the plasma concentration of progesterone secreted from the corpus luteum during pregnancy [32, 33]. The progesterone concentration decreases as the corpus luteum regresses [34]. Thus, the prepartum decrease in BST observed in this study was also likely to reflect corpus luteum regression and a subsequent decrease in progesterone concentration. In addition, the mean BST measurements at –16– –3 h were lower (1.1°C) than those at –72 h. It is possible to predict the time of parturition by detecting this decrease.

Simultaneously, a rise in BST was observed immediately before parturition. Such an elevation in body temperature immediately before parturition has been previously reported [13, 14, 25]. Although the precise cause of this phenomenon is unknown, it is likely associated with increased activity, such as frequent changes between standing and lying during the first stage of labor [35].

A circadian rhythm in body temperature, whereby temperature is low in the morning, high in the late afternoon until the night, and declines until the following morning, has been observed in cattle [30] and ewes [36]. In addition, Piccione *et al.* [37] confirmed that BST was lower than core body temperature, but exhibited significant daily rhythmicity in sheep. In this study, a clear circadian rhythm

in the BST was observed on day –2 and day –1, although the magnitude of the diurnal variation was lesser on day –1. Moreover, a different pattern than those observed during the two preceding days was observed on day 0, showing an unclear circadian rhythm. The circadian rhythm of body temperature is affected by physiological status [38]. Lammoglia *et al.* [13] reported that the circadian rhythm of body temperature disappeared at 48 h before parturition in beef cattle. These observations support the results of this study.

In conclusion, this study showed that BST was continuously measured at the upper neck of ewes using a temperature sensor with a data logger was significantly correlated with VT, suggesting that BST is associated with core body temperature. We also observed a marked decrease in BST at the upper neck in the prepartum period. A number of previous studies have shown prepartum decreases in vaginal and rectal temperatures in cattle [13, 14, 25] and in ewes [15], measured using invasive techniques. To the best of our knowledge, there have been no previous reports on the prepartum decrease in BST. However, unshorn sheep have much more natural body insulation than cattle. Further studies will be needed to clarify whether the prepartum decrease in BST varies in a species-specific manner.

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