INTRODUCTION

Assistants should be accompanied to mares during foaling for several reasons. A high rate of dystocia with a high risk of death of foals an mares was recorded during foaling (Morley and Townsend, 1997). In recent days, several studies have tried to understand mare’s reproductive physiology with respect to their reproductive hor-
mone, seasonal effect to reproductive organ, device for controlling seasonal effect and biotechnology for embryo transfer (Park et al., 2017; Yu et al., 2017; Lee et al., 2020; Seong et al., 2020). Especially, the foaling is considered as one of main topics among several fields of reproductive physiology of mares. Typically, foal mortalit

## MATERIALS AND METHODS

### Animals

All procedures for this study were approved by the Animal Experimentation Ethics Committee of Kyungpook National University (approval number: 2020-0140). The present study was performed at a Thoroughbred breeding farm located in Sangju city, Republic of Korea (geographical coordinates: 36°19′52.7412″ N, 127°56′05.5392″ E). Five Thoroughbred mares (9-20 yrs) were randomly selected from the breeding farm.
selected for observation of the foaling behaviors in a sawdust bedded stall. Horses were grazed during the daytime (9:00 to 18:00) and stayed in the 3.5 × 3.5 m stall at night (18:00 to 09:00). In the stall, horses were fed with 0.8% body weight (dry matter) of concentrate, twice a day. Timothy hay and water were provided ad libitum. The mean atmosphere temperature during the observation period was approximately 4.2℃ in the region.

Behavioral data
To analyze the pre-foaling behaviors, a video recorder (DS-7204HQHI-K1, HIKVISION, China) was used to record the behavior patterns during foaling. Discharge of amniotic fluid was considered as a sign the onset of foaling and the behaviors for pre-foaling were divided into 3 different period categories as follows: 1) from -90 min to -60 min, 2) from -60 min to -30 min, and 3) from 30 min to the time for the discharge of the amniotic fluid, respectively (Table 1). Ethogram was described to organize the features of specific behavior patterns of the mare following to pre-foaling period (Table 2). In the number of behavior patterns, the data between 2 days before foaling (day -2) and foaling (foaling day, not after foaling) was analyzed to compare the differences and the data based on 2 days before beginning discharge of the amniotic fluid was used as a control group (Table 3 and 4).

Statistical analysis
Analysis of variance (ANOVA) was performed using the general linear models procedure of SAS software (SAS Institute, NC, USA). Significant differences in the behavior data were detected using the least squares method with Bonferroni correction for multiple comparisons. The mean value and standard error of the mean (SEM) were calculated after recording the specific number of horse behavior. p-values < 0.05 were considered statistically significant.

### Table 1. Description of categorized periods

| Period category | Description                                      |
|-----------------|--------------------------------------------------|
| Period 1        | From -90 min to -60 min                          |
| Period 2        | From -60 min to -30 min                          |
| Period 3        | From -30 min to the time for the discharge of the amniotic fluid |

### Table 2. Ethogram for pre-foaling behaviors in the mares

| Behavioral category       | Behavior                  | Description                                                                                   |
|---------------------------|---------------------------|-----------------------------------------------------------------------------------------------|
| State behavior            | Lateral recumbency        | Horses lying sideways with the flank attached to the ground                                    |
|                           | Sternal recumbency        | Horses lying with the lower abdomen on the ground and head in the air                          |
|                           | Standing                  | Horses four legs on the ground, except for eating                                             |
|                           | Walking                   | Horses moving more than a step                                                                |
|                           | Eating                    | Horses drinking water and eating hay, concentrate feed, or bedding material without moving    |
| Frequent behavior         | Sitting down and standing up | Horses sitting and standing up                                                                |
|                           | Defecation                | Horses discharging feces                                                                    |
|                           | Urination                 | Horses discharging urine                                                                     |
|                           | Pawing                    | Horses scratching the floor with their front legs                                             |
|                           | Weaving                   | Horses shaking their head from side to side                                                   |
|                           | Lowering the head         | Horses lowering their head without eating                                                    |
|                           | Looking at the belly       | Horses turning their head and looking at the abdomen                                          |

### Table 3. The number of mares in pre-foaling state behavior observed every 5 min in each period

|                   | Period 1 (~90 to ~60 mins) | Period 2 (~60 to ~30 mins) | Period 3 (~30 to ~0 mins) |
|-------------------|----------------------------|-----------------------------|---------------------------|
|                   | Day -2                     | Foaling                     | Day -2                     | Foaling                     | Day -2                     | Foaling                     |
| Lateral recumbency| 0                          | 0                           | 0                          | 0                           | 0.17 ± 0.18                |
| Sternal recumbency| 0                          | 0                           | 0                          | 0                           | 0.17 ± 0.18                |
| Standing          | 2.50 ± 0.47                | 1.67 ± 0.23                 | 1.83 ± 0.34                | 2.67 ± 0.46                 | 1.67 ± 0.46a               | 3.17 ± 0.18a               |
| Walking           | 0                          | 0.33 ± 0.23                 | 0.17 ± 0.18                | 0.33 ± 0.23                 | 0                          | 0.33 ± 0.23                 |
| Eating            | 2.17 ± 0.59                | 2.50 ± 0.47                 | 3.00 ± 0.28                | 2.00 ± 0.56                 | 3.33 ± 0.46a               | 1.17 ± 0.34a               |

Different superscripts indicate a significant difference (p < 0.05).
RESULTS

Pre-foaling state behaviors

The state behaviors of the mares were monitored and analyzed every 5 min based on a description of the categorized period of the foaling (Table 1) and each specific state behavior (Table 3), respectively. In period 3 (-30 to -0 min), the only 2 behaviors (standing and eating) of the described various behaviors were significantly (p < 0.05) different between day -2 and foaling groups, respectively. In standing behavior, the number of mares in standing in the foaling group (3.17 ± 0.18) at period 3 was significantly (p < 0.05) higher than the day -2 group (1.67 ± 0.46). In contrast, the number of mares in eating of the foaling group (1.17 ± 0.34) at period 3 was significantly (p < 0.05) lower than the day -2 group (3.33 ± 0.46). The other behaviors such as lateral and sternal recumbency, and walking were not significantly different in all periods.

Pre-foaling frequent behaviors

The frequent behaviors of the mares were monitored between intervals of 5 min for the purposed period time (Table 4). The 7 different behavior patterns were categorized as sitting down and standing up, defecation, urination, pawing, weaving, lowering the head, and looking at the belly. In period 1, weaving of foaling group was significantly (p < 0.05) higher than day -2 group (1.17 ± 0.34) at period 3 was significantly (p < 0.05) higher than the day -2 group (1.67 ± 0.46). In contrast, the number of mares in eating of the foaling group (1.17 ± 0.34) at period 3 was significantly (p < 0.05) lower than the day -2 group (3.33 ± 0.46). The other behaviors such as sitting down and standing up, pawing, weaving, and lowering the head in the foaling group were significantly (p < 0.05) higher than the day -2 group (p < 0.05).

DISCUSSION

In the present study, the pregnant mares were monitored to classify the behavioral indications that can predict the pre-foaling period using a video information transmitter and the categorized behavior patterns were compared with normal behaviors (control, day -2). The number of sitting down and standing up behaviors was significantly higher in period 3 compared with that of a normal day, which indicates that this behavior is a pre-foaling sign. Sitting down and standing up behaviors are often exhibited by horses who are suffering from diseases such as colic (Pritchett et al., 2003). An altitude sensor such as BMP280 that can perceive changes in the height of the sensor target may be used to detect the behavior of sitting down and standing up. An accelerometer sensor such as MPU6050, which senses the three-axis movement of an object, can also be used to detect sitting down and standing up behavior. Because horses seldom show sitting down and standing up behaviors, additional typical pre-foaling behaviors should be added to the new system.

A higher number of mares in pawing behavior was observed in period 3 compared with that of a normal day. During pawing, the mares drag one of their front legs on the ground. Horses frequently show this type of behavior when they feel frustration, pain, or/and stress (Houpt and McDonnell, 1993; Minero et al., 2006). According to a previous study, the average heart rate (HR) of horses showing pawing behavior increases (Minero et al., 2006). Also, electromyographic (EMG) data was strictly corre-
lated with HR in another study (Giovagnoli et al., 2002). Thus, this pre-foaling sign can be detected by monitoring changes in the mares using HR and EMG sensors.

The number of mares in lowering the head behavior was significantly higher from periods 2-3 in comparison with that of a normal day, which indicates that this behavior may be regarded as pre-foaling behavior. This behavior is often associated with unrelenting pain (Ashley et al., 2005). To exactly detect this type of behavior, altitude and accelerometer sensors should be attached to the halter. Lowering the head behavior was also often observed during the post-foaling periods. During this time, mares lower their head to smell and lick their infants.

In the present study, a higher number of mares in lateral and sternal recumbency was observed after the amniotic sac ruptured compared with that of a normal day. This behavior can be easily detected with altitude and accelerometer sensors. An emergent foaling assistant should be applied when the foal does not come out within 30 min after amniotic sac rupture. Thus, the foaling alarm system should be developed to trigger a signal before amniotic sac discharge, which means that sensors that only detect the data module for lateral and sternal recumbency are not suitable. The foaling alarm system should be operated to detect other pre-foaling behaviors as well.

The placement of sensors is an important factor in detecting a specific pre-foaling behavior. In the present study, the mares in weaving behavior, which is categorized as abnormal locomotion, were higher during periods 1 to 3 in comparison with that of a normal day (Ashley et al., 2005). This result indicates that weaving behavior is one of the specific pre-foaling behaviors that can be detected as early as 90 min before amniotic sac discharge. Therefore, weaving behavior should be monitored to detect pre-foaling signs. The weaving behavior can be monitored by halter-attached altitude and accelerometer sensors.

The number of mares in scanned standing behavior significantly increased in period 3. The mares in eating behavior have also reduced from period 3 in comparison with that of a normal day. Based on the observation results, standing behavior was affected by a reduction of eating behavior in period 3. The behaviors such as walking, defecation, and urination were not considered to be specific signs of pre-foaling because these behaviors are considered to be routinely exhibited horse behaviors even when they are stable. Looking at the belly (flank watching) behavior is known as a sign of pain and is regarded as a major pre-foaling sign (Sanchez and Robertson, 2014). However, in the present study, the number of mares in looking at the belly compared with that of a normal day was not significant.

There are several types of foaling alarm systems that detect various pre-foaling signs. Haluska and Wilkins (1989) and Cross et al. (1992) reported that rectal temperature decreased before foaling (especially 3-4 hours before) and increased after foaling until 24-48 hours. Recently, Auclair-Ronzaud et al. (2020) compared the temperature of mares during the pregnancy period and foaling days by using a neckline implanted microchip. Similar to the rectal temperature measurement, body temperature decreased before foaling, and the correlation between the temperature and behavior of pre-foaling was analyzed. Nagel et al. (2012) revealed that the HR was comparatively constant for 15 days before foaling but significantly decreased during the foaling period. According to previous studies, changes in body temperature and HR can be also used as a pre-foaling sign. Based on the result of the previous study, a pre-foaling detection device should be equipped with a thermometer and HR or EMG sensors.

CONCLUSION

In conclusion, an optimal foaling alarm system should be equipped with altitude and accelerometer sensors as well as HR and EMG sensors. In addition, the system should be equipped with a thermometer sensor to detect the changes in the temperature of pre-foaling mares.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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