Relationship of activity and temperature of dairy calves as measured by indwelling rumen boluses

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Abstract.

Circadian rhythm of body temperature is naturally occurring in animals with a lower temperature at dawn and higher at dusk. In the past, this work was manually completed by a person using rectal temperature with temperature recorded every 2 or 3 hours. Rumen indwelling boluses allow for continuous temperature monitoring without human intervention. Human intervention can increase animal stress which can elevate temperature. Current literature indicates that the animal's body temperature also fluctuates about 0.55°C if the animal is standing versus lying down. When animals are handled for rectal temperature monitoring, they often stand up which lowers their body temperature at that time, compared to if they had stayed lying down. These natural fluctuations in body temperature from circadian rhythm and activity affect management decisions producers make.

This study uses the Farmfit® temperature and activity monitoring system to evaluate the circadian rhythm of calves from 3 weeks of age to 12 weeks of age by week. In the

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Farmfit® system, a fever is triggered when a calf has 4 consecutive hours of temperature that are 1.11°C above that calf's average daily temperature. The natural circadian rhythm would cause the daily average temperature used to set the baseline to trigger a fever to require an even greater rise in temperature during the dawn than the dusk time of day. The study also used the activity data from this bolus to evaluate how increased movement decreased calf temperature compared to resting.

The objective of this study was to determine the circadian rhythm of dairy calves from 3 weeks of age through 12 weeks of age by week. We also defined the change in ruminal temperature when calves were active versus resting. Results indicated that in pre-weaned calves when activity increases around feeding time, ruminal temperature decreases. This knowledge is important when assessing pyrexia since calves are often assessed around the same time as feeding. Season stressors were found to have a significant effect on the periodicity power and on the significant periods throughout a calves day. The understanding of the circadian rhythm helps calf managers' assessment of calves with pyrexia explain why the same temperature in the morning may not affect calves the same way as in the evening. The understanding of circadian rhythms and how they change as calves develop will allow for more advanced equation development for the detection of pyrexia.

Keywords.
Circadian rhythm, rumen bolus, activity, temperature

Introduction

Circadian rhythms are a critical part of an animal's life, demonstrating sleep and wake cycles, feeding cycles, and day and night through activity and temperature rhythms. Rhythms change as animals grow and develop but regular rhythms can be an indicator of healthy animals while irregularities can indicate poor animal welfare (Rhodes, 2022). Calf body temperature normally varies in a distinct, pattern with the lowest temperature around 08:00 and the highest temperature between 17:00 and 22:00 depending on season (Hill, 2016). New precision livestock farming technologies such as indwelling rumen boluses provide continuous monitoring of an animal's temperature and activity status. Current calf research into circadian temperature had been done using manual rectal temperature collection that would interfere with a calf's normal activity. Lowe, 2018 found that changes in a calf's temperature and activity can be used as an early detection tool for neonatal calf diarrhea and bovine respiratory disease in calves being feed with an automated calf feeding system.

While circadian rhythm activity research has been done using collars this is the first project collecting both from the same sensor location. Our project used the Farmfit® Indwelling Temperature monitor bolus and data collection system. In a circulating water bath system these boluses are found to consistently read within 0.04°C of the actual water temperature (Bault, 2023). The bolus recorded temperature is weakly correlated to rectal temperature with a Lin's Correlation Coefficient of 0.36 and a Bias Correlation of 0.988, however, the average difference between rectal and bolus measured temperature was only 0.001°C (Hartschuh, 2023)

In our study, we calculated periodicity and power for select weeks of the calves' life during multiple seasons to assess how consistent circadian rhythms are as young calves on milk develop and change through early weaning. This assessment investigates the natural changes in calves as they develop that are not related to changes in the potential welfare conditions of individual calves. It also investigated the effect that season stressors such as heat stress and cold stress may have on the calf's circadian rhythm power.

Materials and methods

One hundred twenty-five female Holstein calves were enrolled in this trial born between November 2022 and October of 2023. The calves were housed on a commercial dairy farm in North Central Ohio. From birth through eight weeks of age calves were housed in individual pens measuring 122 cm by 203 cm in a barn. When environmental temperatures were over 22.7°C calves were provided with supplemental fan cooling. When daytime temperatures were consistently below 10°C calf jackets were put on all pre-weaned calves through six weeks of age. In all season's calves were provided with deep bedded straw in their pens. Pre-weaned calves on this farm are fed three liters of pasteurized whole milk twice per day at 8:00 and 18:00 hours. From birth, all calves are offered free choice water and calf starter grain all day long. After eight weeks of age calves were moved into group pens where they were feed grain at around 9:00 and 19:00 hours and had free choice hay and water all day. All care and management of these calves was done by the farm. Calves were bloused with Farmfit® rumen boluses during their second week of life. The farm normally boluses calves at two weeks of age. These boluses contained sensors for temperature and activity. Farm personnel were responsible for determining if a calf was sick and providing it with treatment. This trial had no calf death loss but for various reasons, not all boluses were still reading by three months of age. The Farmfit® user online interface was used to store all data from the calf bolus on activity, temperature, and treatment records.

Three different time points in the calves' life were analyzed for the circadian rhythm of a calves' temperature and activity. The farm assisted with identifying the time points that they believed were changes in the calves' eating routine. The first time point was three weeks old which was the first full week of data collection from the bolus. The next time point started when the calf was six weeks old, at this age most calves were consuming grain and water each day. The final week was when the calf was twelve weeks old, at this time calves had been weaned and in group housing for approximately four weeks and were now eating free-choice hay.

In addition, to assess if seasonal stress affected the calves' circadian temperature or activity rhythm an analysis was conducted by season based on possible environmental temperature stressors. The non-stress season was during the spring and fall using the months of March, April, May, September, October, and November as the average daily temperature during these six months in Northern Ohio is within a calf's thermal neutral zone. Winter cold stress was possible during December, January, and February when the average temperatures are below a newborn calf's lower critical temperature of 10°C. Heat stress often occurs in June, July, and August when daytime temperatures are often over 25°C a calf upper critical temperature.

Calves were removed from the analysis if they were treated during the age week being analyzed based on the farm's treatment records or if the Farmfit® system flagged a calf as having a fever during that week. Twenty-one calves were removed for treatment during one of the periods but only for the period during which they were marked as ill or possibly ill. They were also removed if there was more than 24 hours of consecutive missing data from the week being analyzed. Issues with bolus battery life during this project led to only 74% of the calves still being in the data set by twelve weeks of age. Once potentially ill calves were removed the age range by season was analyzed as a group creating an average hourly temperature and activity value for that group.

Data was analyzed to determine the group's rhythmic temperature and activity behavior using R Studio version 4.2.2 with the packages digiRhythm (Nasser, 2024) and lomb (Ruf, 1999). We did a Lomb-Scargle analysis to determine the period, harmonic power, and degree of functional coupling. The Lomb-Scargle analysis was chosen since it is stronger at detecting periodicity and power in unevenly sampled time series (Vanderplas, 2017). During each time and season series combination, the peaks in temperature and activity were compared to determine the effects on temperature that activity might have.

Results

The Farmfit® Rumen bolus is a system that can be used to collect both activity and temperature data on the same calf without human intervention that may affect the data. Table 1 summarizes the data from each analysis by season and by age in weeks. At all times both temperature and activity maintained a 24-hour periodicity, but the power of the periodicity was significantly affected by season and age. Activity was less affected by season but was significantly affected by age. Even though the group of calves were all fed at once keeping a similar power 24-hour period across all age groups the significant 8 and 12-hour periods weakened in power or were no longer significant by 12 weeks of age. The 12-week-old calves had greater between grain feeding activity with a portion of the calves being observed eating hay throughout most of the day.

Table 1. Analyses of rhythmic behavior and temperature of calves during 3 seasons and 3 age groups. The significant periods using a Lomb-Scargle periodogram analyses are listed and there power.

	3 week summer		6 week summer		12 week summer		3 week winter		6 week winter		12week winter		3 week spring/fall		6 week spring/fall		12 week spring/fall	
Temperature																		
		Power		Power		Power		Power		Power		Power		Power		Power		Power
Period	24	0.27	24	0.59	24	0.28	24	0.64	24	0.51	24	0.32	24	0.57	24	0.78	24	0.37
	12	0.61							12	0.21	12	0.13					12	0.20
											8	0.17					8	0.16
Function																		
Coupling	1.00		1.00		1.00		1.00		1.00		1.00		1.00		1.00		1.00	
Harmonic	0.53		0.65		0.52		0.64		0.81		0.82		0.69		0.81		0.82	
Activity																		
Period	24	0.14	24	0.31	24	0.18	24	0.32	24	0.26	24	0.15	24	0.23	24	0.22	24	0.29
	12	0.39	12	0.40			12	0.12	12	0.25			12	0.40	12	0.40	12	0.21
	8	0.10					8	0.19	8	0.19	8	0.20	8	0.14	8	0.13	8	0.18
DFC	1.00		1.00		0.58		1.00		1.00		1.00		1.00		1.00		1.00	
HP	0.70		0.78		0.31		0.87		0.93		0.51		0.89		0.93		0.81	

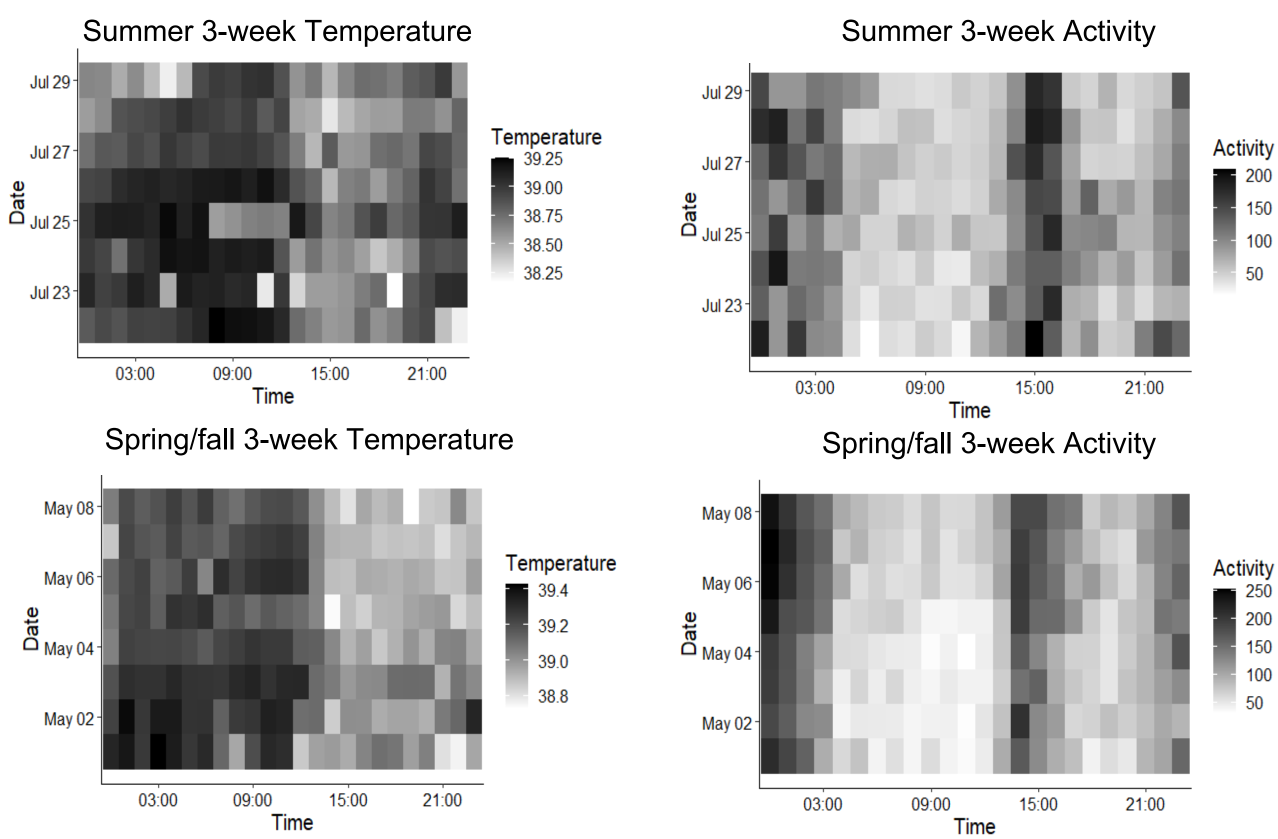

Figure 1. Actograms for summer compared to spring/fall Temperature and activity for 3-week-old pre-weaned calves.

The three week old calves across seasons show many similarities as demonstrated in Figure 1 above. Calf activity between seasons was similar with both seasons containing significant periodicity cycles of 8, 12, and 24 hours, the time of the activity peaks was not affected by season. The 12-hour cycle was the strongest followed by the daily 24-hour cycle. Figure 2 shows clear peaks in activity at the time calves were fed every day. Feeding activities and other calf care such as bedding were done around each peak in activity. The actogram in Figure 1 demonstrates that during summer when calves are under heat stress conditions there is less activity intensity but the rhythm of activity in the summer is the same as in the spring and fall.

Summer also adds a strong 12-hour temperature period with a power of 0.61 instead of the 24-hour rhythm that was the only period during spring and fall. The summer 24-hour period only has a power of 0.27 while the winter power is 0.64 and spring/fall is 0.57. During the non-stressed spring and fall calves have a very defined temperature pattern increasing in temperature in the late afternoon and through the evening with the lowest temperatures in the morning. Figure 2 shows that the temperature high peak in the spring/fall occurred each day after the evening feeding activity spike. The temperature would stay high through the night but fell at about the same time as the morning feeding. This has major implications for calf managers using continuous monitoring temperature sensors. The daytime between the activity peaks is also the time when calf managers would most likely to be taking manual calf temperatures. A constant monitoring system may find a low-grade fever at night which is in the normal range during the day.

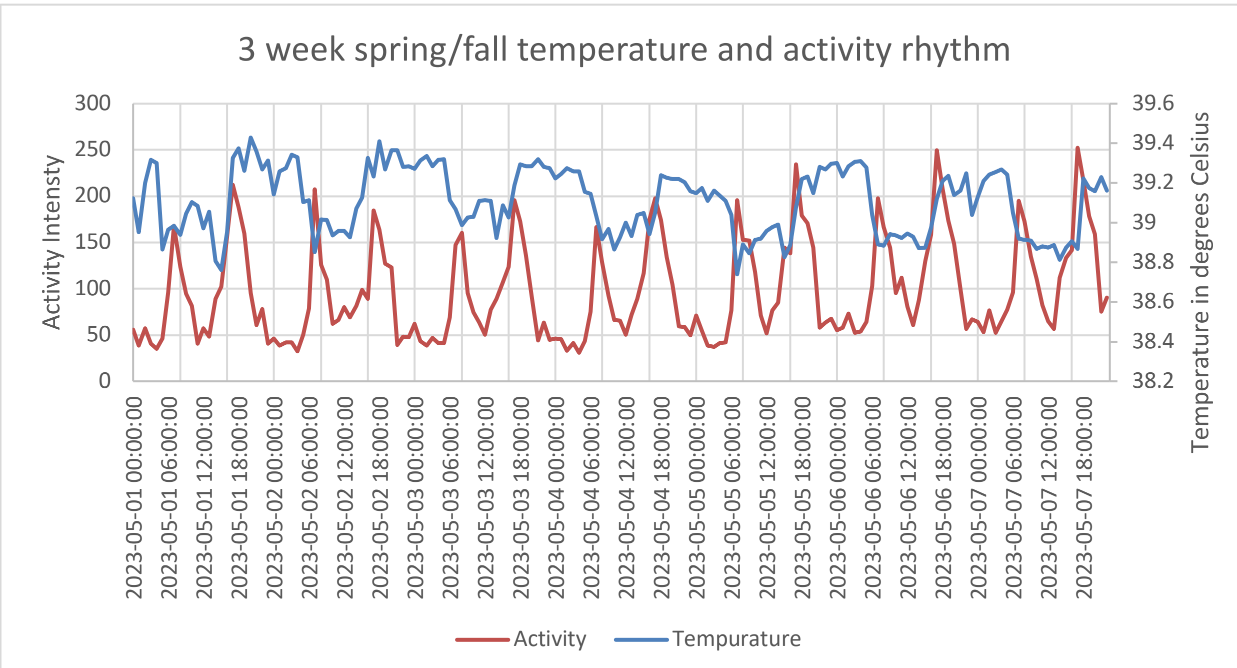

Figure 2. Temperature and Activity week-long rhythm for 3-week-old calves in the spring and fall when the group should not have been experiencing heat or cold stress.

The summer weeklong temperature and activity are displayed in Figure 3. The additional 12-hour period with the power of 0.61 corresponds to a midday temperature increase that happens during the summer, which occurs during the daytime rest period coupled with a temperature drop in the early evening after the increased activity caused by feeding. These activities are creating an additional rhythm that is 12 hours long. The 24-hour rhythm that can be observed in the spring/fall season still occurs in the summer but with additional temperature period cycles during lower and higher temperatures of a normal rhythm. Under nonstresses conditions calves reach maximum coolness around the morning activity increases and maximum temperature during the evening rest time.

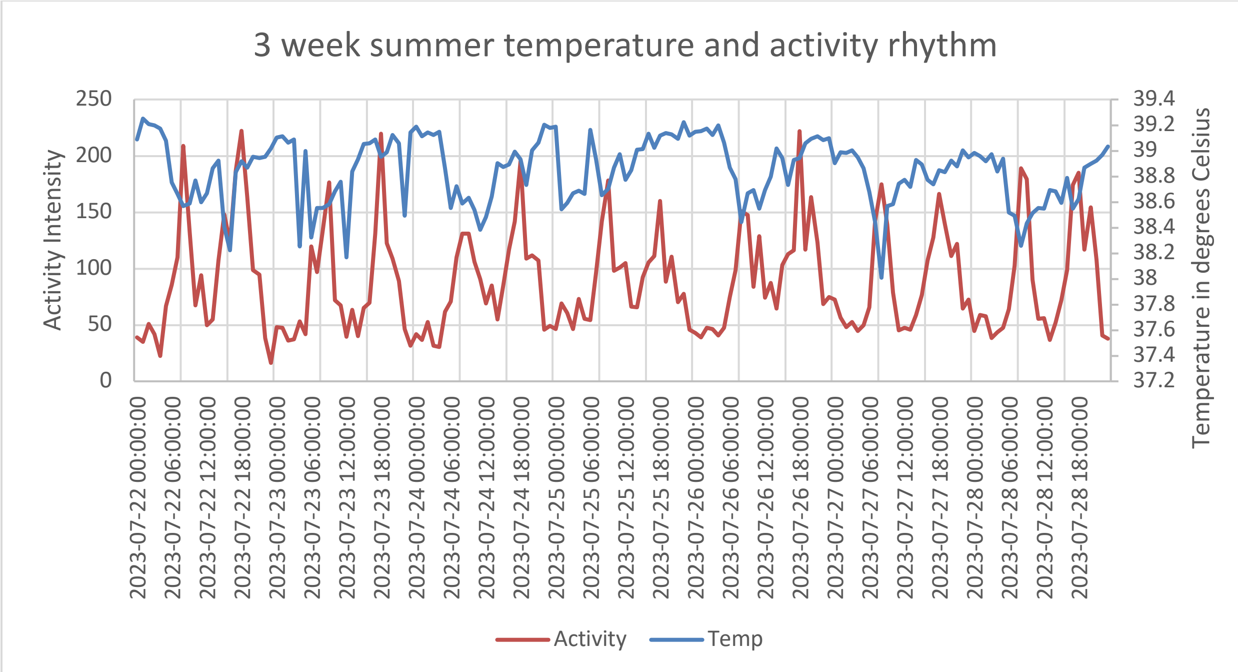

Figure 3. Temperature and Activity week-long rhythm for 3-week-old calves in the summer when the group was experience temperatures that may have created heat stress conditions.

Conclusion

Understanding the temperature and activity relationship of calves is critical for improving disease detection and management of calf health. By using the Farm Fit® bolus we can identify this relationship in healthy calves with one sensor in the same position in the calf. Further research is needed to identify if changes in this rhythm combination can be used as an additional tool to detect disease. The change in the rhythm between seasons supports the findings by (Rhodes, 2022) that circadian rhythm periodicity intensity can be used as indicator of herd welfare. While their work was using activity rhythm ours shows that temperature may be even more sensitive to seasonal changes that may cause stress than activity. However, for disease detection changes in periodicity intensity will need to be a dynamic system that accounts for the season variation. These rhythms may also be different between each farm. A farm that feeds 3 times per day or a farm that utilizes automated feeding systems will most likely have a very different activity rhythm since the peak activity points in this study match the farm's feeding schedule. The relationship between peak activity and temperature maybe different on other farms also since spike in activity lead to better heat dissipation and lower temperatures around those activity times a farm that feeds three times per day may see more temperature variation.

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