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Original Article

Evaluation of automated monitoring calving prediction in dairy buffaloes a new tool for calving management

Avaliação do monitoramento automatizado da previsão de parto em búfalos leiteiros: uma nova ferramenta para o gerenciamento de parto

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Abstract

Buffalo is one of the leading milk-producing dairy animals. Its production and reproduction are affected due to some factors including inadequate monitoring around parturition, which cause economic losses like delayed birth process, increased risk of stillbirth, etc. The appropriate calving monitoring is essential for dairy herd management. Therefore, we designed a study its aim was, to predict the calving based on automated machine measured prepartum behaviors in buffaloes. The data were collected from n=40 pregnant buffaloes of 2nd to 5th parity, which was synchronized. The NEDAP neck and leg logger tag was attached to each buffalo at 30 days before calving and automatically collected feeding, rumination, lying, standing, no. of steps, no. of switches from standing to lying (lying bouts) and total motion activity. All behavioral data were reduced to -10 days before the calving date for statistical analysis to use mixed model procedure and ANOVA. Results showed that feeding and rumination time significantly (P<0.05) decreased from -10 to -1 days before calving indicating calving prediction. Moreover, Rumination time was at lowest (P<0.001) value at 2h before the calving such behavioral changes may be useful to predict calving in buffaloes. Similarly, lying bouts and standing time abruptly decreased (P<0.05) from -3 to -1 days before calving, while lying time abruptly increased (P<0.01) from -3 to -1 days before calving (531.57±23.65 to 665.62±18.14, respectively). No. of steps taken and total motion significantly (P<0.05) increased from -10 to -1 days before calving. Feeding time was significantly (P<0.02) lowered in 3rd parity buffaloes compared with 2nd, 4th and 5th parity buffaloes, while standing time of 5th parity buffaloes were lowered (P<0.05) as compared to 2nd to 4th parity buffalos at -1 day of prepartum. However, rumination, lying, no. of steps taken and total motion activity at -1 day of prepartum was independent (P>0.05) of parity in buffaloes. Neural network analysis for combined variables from NEDAP technology at the daily level yielded 100.0% sensitivity and 98% specificity. In conclusion NEDAP technology can be used to measured behavioral changes -10 day before calving as it can serve as a useful guide in the prediction calving date in the buffaloes.

Keywords: calving predication, buffaloes, NEDAP logger technology, automated monitored prepartum behaviors.

Resumo

O búfalo é um dos principais animais produtores de leite. Sua produção e sua reprodução são afetadas por causa de alguns fatores, incluindo o monitoramento inadequado ao redor do parto, que causam perdas econômicas, como atraso no processo de parto, aumento do risco de natimorto, etc. O monitoramento adequado do parto é essencial para o manejo do rebanho leiteiro. Portanto, projetamos um estudo cujo objetivo foi prever o parto com base em comportamentos pré-parto medidos por máquina automatizada em búfalas. Os dados foram coletados de 40 búfalas prenhes de 2ª a 5ª paridade, que foi sincronizada. A etiqueta NEDAP de pescoço e perna foi fixada em cada búfala 30 dias antes do parto e coletava dados, automaticamente, durante a alimentação e a ruminação, em posição deitada e em pé, além do número de passos, número de mudanças de pé para deitado (período deitado) e atividade de movimento total. Todos os dados comportamentais foram reduzidos para -10 dias antes da data do parto para análise estatística usando o procedimento de modelo misto e ANOVA. Os resultados mostraram que o tempo de alimentação e de ruminação diminuiu significativamente (P < 0,05) de -10 dias para -1 dia antes do parto, indicando a previsão de parto. Além disso, o tempo de ruminação apresentou seu menor valor (P < 0,001) 2 horas antes do parto, e tais mudanças comportamentais podem ser úteis para predizer o parto em búfalas. Da mesma forma, o período deitado e o tempo em pé diminuíram abruptamente (P < 0,05) de -3 dias para -1 dia antes do parto, enquanto o tempo deitado aumentou abruptamente (P < 0,01) de -3 dias para -1 dia antes do parto (531,57 ± 23,65 para 665,62± 18,14, respectivamente). O número de passos dados e o movimento total aumentaram significativamente (P < 0,05) de -10 para -1 dias antes do parto. O tempo de alimentação foi significativamente (P < 0,02) reduzido em búfalas de 3ª paridade em comparação com búfalas de 2ª, 4ª e 5ª paridade, enquanto o tempo de

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espera de búfalas de 5ª paridade foi reduzido (P < 0,05) em comparação com búfalas de 2ª a 4ª paridade em -1 dia antes do parto. No entanto, ruminação, posição deitada, número de passos dados e atividade de movimento total em -1 dia antes do parto foram independentes (P > 0,05) da paridade em búfalas. A análise de rede neural para variáveis combinadas da tecnologia NEDAP no nível diário produziu 100% de sensibilidade e 98% de especificidade. Em conclusão, a tecnologia NEDAP pode ser usada para medir mudanças comportamentais -10 dias antes do parto, pois pode servir como um guia útil para prever a data do parto em búfalas.

Palavras-chave: previsão do parto, búfalos, tecnologia de registrador NEDAP, comportamentos pré-parto monitorados automatizados.

1. Introduction

Buffalo is one of the major dairy animal's worldwide and in Pakistan, it is known as the black gold of Pakistan. According to Food and Agricultural Organization (FAO, 2000) report, 95% of world's buffalo population is present in Asian countries, like Pakistan, India, Nepal, Bangladesh, etc. Buffaloes are raised for many purposes in Pakistan i.e. milk, meat, hide and byproducts. There are more than 30 million buffaloes in Pakistan and producing 2400-2600 ltr milk per lactation (Abdelrahman et al., 2010; Mansour et al., 2016). However, these animals exhibit a somewhat sluggish frequency of reproduction due to low fertility (Gupta et al., 2015), inactive ovaries, and long calving interval (Heringstad et al., 2006; Mansour et al., 2017). Many other reasons for economic losses in production and reproduction of buffaloes, i.e. inadequate monitoring around the parturition time in dairy animals may unnecessarily delay the birth process, increasing the risk of stillbirth (Vasseur et al., 2010). Calving complications directly related to longer calving-to-conception intervals (Dematawena and Berger, 1997). Therefore, the ability to identify imminent calving is essential for dairy herd management.

Parturition is the expulsion of the calf. Pelvic ligament relaxation, udder edema, and other behavioral changes are the signs of the onset of calving in dairy animals (Miedema et al., 2011a; Streyl et al., 2011). Providing appropriate calving assistance decreases the risk of dystocia (Mainau and Manteca, 2011) and improves milk production in subsequent lactation (Bellows et al., 1988). Farmers estimated calving time through breeding records and visual indications (behavioral and physiological changes) (Ouellet et al., 2016), which is not accurately predict calving due to the limitation of experienced persons (Palombi et al., 2013).

Accurate monitoring technologies for observation and assessment of calving behaviors provide a precise approach for predicting calving time. Various protocols have been used to predict the exact time of calving. Ultrasound examination (Wright et al., 1988) and maternal body temperature monitoring (Lammoglia et al., 1997; Burfeind et al., 2011) are primarily applied for the prediction of calving time. Monitors inserted in the vagina (Palombi et al., 2013), estimation of blood levels of estradiol and progesterone (Matsas et al., 1992) to predict the calving time, but these techniques have not been validated. Changes in behaviors associated with calving have been reported in recent years and maybe monitored automatically on the farm (Schirmann et al., 2016). Changes in feeding, rumination, and lying behaviors had observed during calving time in dairy animals (Miedema et al., 2011b; Jensen, 2012; Schirmann et al., 2013; Pahl et al., 2014). Clark et al. (2015) used the SCR HR Tag to monitor rumination behavior for prediction of calving events and achieving 70% sensitivity and specificity in the estimation of calving time. Similarly, Ouellet et al. (2016) monitored rumination time, vaginal temperature, and lying behaviors to predict the day of calving and found 77% sensitivity, 77% specificity.

These technologies are very useful in calving prediction, but research is needed to improve the sensitivity and specificity of monitoring devices. Cow-specific reports on dairy monitoring technologies used for the prediction of calving are commonly available. However, the data on behavioral changes to identify the onset of calving in buffalo is lacking. Therefore, we hypothesized that monitoring of activity, rumination, and lying behaviors would predict the calving time and value addition in the buffalo industry to reduce the risk of dystocia. The objectives of this study were: (1) to quantify activity, rumination, and lying behaviors 10 days before calving and 24 hours before calving by using 2 commercially available technologies, (2) by these quantifications determine the calving time and determine the efficacy of these technologies.

2. Materials and Methods

This study was conducted at Dairy Animals Training and Research Center, B Block, Ravi Campus, UVAS, Pattoki located in Punjab, Pakistan. Data were collected from n = 40 pregnant buffaloes of the 2nd- 5th parity. The ovsynch synchronization protocol was routinely applied in the farm for synchronized AI and calving. The buffaloes were enrolled 30 days before calving having good health and body condition score (BCS). The buffalos were divided into four groups on the basis of parity (n = 10 buffaloes in each groups having 2nd, 3rd, 4th and 5th pairy). NEDAP system was fitted to each buffalos 30 days before predicted calving time. After calving, data were reduced to 10 days before calving from each buffaloes (from -10 days to onset of calving "0 days"). The NEDAP system data loggers were attached to the left side of the neck and left front leg of each buffalo. The NEDAP logger of neck tag collected feeding and rumination behaviors continuously from 10 days before calving till onset of calving. The NEDAP logger of leg tag automatically collected lying, standing, the number of steps, time spent in standing and total motion variable from 10 days period before calving to onset of calving in each buffalo.

The selected animals were separated in prepartum pens, which was well ventilated and straw bedding

(20 ± 4 buffaloes). The buffaloes had free access to fresh drinking water and fed TMR once daily. Buffaloes were monitored for signs of calving every 2 h interval. Individual buffaloes were watched every 15 min after the appearance of calving signs. When the calving of buffaloes started, this buffalo was separated and recorded calving beginning time, total duration of calving from start to end when calf full outside the dam, parity and date of calving. Video cameras (Panasonic WV BP120, Panasonic, Bracknell, UK) were installed to observe the time of calving and calving ease. Each calving event was videotaped for the correct recording of calving time. The experimental design and methodology of this study was approved by ethical committee of University of Veterinary and Animal Sciences, Lahore, Pakistan.

2.1. Statistical analysis

The data of changes in behavior before calving, NEDAP loggers neck activity (feeding and rumination) and NEDAP loggers of leg activity (lying and standing behaviors, numbers of steps, total motion) were divided into 2 data sets: per day comparison of calving behaviors and per hour comparison of calving behaviors. The average of data was taken in per days comparison and specific hours were taken in per hours comparison to put all buffalos in the same time line regardless of time of the day. Mixed linear model procedure of SAS version 21 was generated with parity groups (2^{nd}, 3^{rd}, 4^{th} and 5^{th}) and day before calving (-1, -3, -6 and -10d) as fixed effects. Repeated measure ANOVA were used to tested the days comparison and significance level was (P<0.05). tukey's test was used to identifying significant difference between days before calving.

All 24-h periods were labeled "0-2, 2-6, 6-12 and 12-24 h before calving" for each behavior changes in buffaloes. The least squares means were calculated from all activity with parity and per hour period before calving as fixed effects. Repeated measure ANOVA were used to tested the hour comparison. Data of number of steps and total motion, as well as bihourly neck activity were transformed to normal distribution though natural logarithm transformation to full fill normality assumptions for mixed linear models.

2.2. Development of model for prediction of calving

Three machine learning techniques were used to predict the day of calving in buffaloes. The machine learning techniques were random forest, linear discriminant and neural network analysis. For calving prediction the variables for machine learning techniques were the day before calving (-10 to -1 day of prepartum). Data of days were arranged in the form of 24h format, (from 0h to 240 h). The day of calving was not included in the data. Data were presented to machine-learning techniques in 3 separate ways. Analysis of the data were performed individually and combined. Variables of neck tag: feeding and rumination behaviors, leg tag: lying, standing, no. of step taken and total motion behaviors and combination model: all variables from both NEDAP neck and leg tag.

3. Results

3.1. Changes in automated monitoring Feeding and Rumination behaviors in relation with calving

The results of daily feeding time was first increased (P>0.05) from -10 to -6 then decreased (P<0.05) from -6 days of prepartum till onsent of calving as shown in Table 1. The feeding time was lowest on 1 day before calving in buffaloes (162.47±9.85 min) as compared to 3-10 days before calving. The feeding time at 24 h before calving is shown in Figure 1a. The feeding time was increasing from 24 to 6 h before calving then decreased at 2 h before the onset of calving. The rumination time was non-significant between -10 to -3 days of prepartum, however rumination time was lowest at 1 day before calving (443.99±13.49 min; P<0.01), as shown in Table 1. We observed an increased in rumination time at the beginning on the day of calving then decreased at 6 h (P<0.01) and 2 h (P<0.001) before calving, as shown in Figure 1b. These observations predicated that feeding and rumination time decreases as calving approaches in buffaloes.

3.2. Changes in Lying behaviours during prepartum period

The lying time was increased at -1 day before calving (665.62±18.14 min/day), indicating that buffaloes return to its normal behaviors, as shown in Table 1. The lying time throughout 24h period before calving were variable, but lying time was decreased to its lowest level (P<0.001) at 6h before calving than increased till calving, which indicate normal behaviors, as shown in Figure 1d. We observed that lying bouts significantly (P<0.05) decreased from -10 to -1 day of prepartum period (10.07±0.24 to 8.97±0.23 bouts/day, respectively), as shown in the Table 1. However, lying bouts were significantly increased on the day of calving and highest (P<0.001) lying bouts was observed at -2 h before calving, as shown in Figure 1c. The increasing of lying behaviors indicating that the onset of calving approaching in buffaloes.

3.3. Association of Number of steps and total motion with calving

We observed that number of steps taken throughout the -10 days of prepartum period significantly increased in buffaloes, as shown in Table 1. The highest steps taken per day was at -1 day (2314.1±3.2 steps/d; P<0.001) before calving as compared to -10, -6 and -3 days of prepartum period (1672.3±2.3, 1776.4±3.1 and 1984.7±2.8 steps/d, respectively). Similarly, the number of steps taken in 24 h before calving was continuously increased to its highest (P<0.001) value at 2h before calving, as shown in Figure 1e. Moreover, total motion was increased from -10 to -1 day before calving, as shown in Table 1. We observed that total motion was continuously increased to its highest (P<0.001) value at 2h before calving (Figure 1f, which indicated calving approaches in buffaloes.

3.4. Effect of parity on behaviours at one day before calving

We found significantly lower (P<0.01) feeding time in buffaloes having 3^{rd} parity as compared to 2^{nd}, 4^{th} and

Table 1. Adjusted (mean± SE) from daily mixed models accounting for 10 days of prepartum behavioral data in buffaloes.

Behaviors	Days before calving			
	-10	-6	-3	-1
Feeding time (min/day)	220.71±16.07[a]	246.90±12.52[a]	181.07±11.60[b]	162.47±9.85[b]
No. of feeding bout	5.17±0.37[b]	5.75±0.64[ab]	7±0.64[ab]	7.6±0.77[a]
Average feeding bout length	35.95±2.9[b]	39.48±3.32[ab]	46.04±3.96[a]	35.53±3.41[b]
Rumination time (min/day)	559.69±24.99[a]	603.37±15.23[a]	568.10±22.09[a]	443.99±13.49[b]
No. of rumination bout	19.25±0.63[c]	22.27±1.07[b]	25.42±1.02[a]	23.19±1.09[ab]
Average rumination bout length	23.85±0.96[ab]	26.74±1.29[a]	24.75±0.89[ab]	23.19±1.09[b]
Lying bouts (bouts/day)	10.07±0.24[a]	9.85±0.285[ab]	9.17±0.22[cb]	8.97±0.23[c]
Lying time (min/day)	557.40±18.41[b]	566.20±13.95[b]	531.57±23.65[b]	665.62±18.14[a]
Average lying bout length	75.36±2.5[a]	59.15±2.94[b]	59.55±2.323[b]	56.09±2.04[b]
Standing time (min/day)	515.88±29.66[ab]	515.15±31.28[ab]	586.06±37.16[a]	453.6±18.19[b]
No. of standing bout	17.35±0.46	17.77±0.50	17.82±0.78	17±0.74
Average standing bout length	26.71±1.21[b]	34.02±2.44[a]	29.13±1.36[ab]	33.44±3.29[a]
No. of steps (steps/day)	1672.3±2.3[c]	1776.4±3.1[c]	1984.7±2.8[b]	2314.1±3.2[a]
Total motion (units/day)	241561.4±3.4[c]	278391.3±3.6[c]	763281.9±3.4[b]	1123781.1±3.4[a]

Means with different superscripts within column showed significant difference ($P < 0.05$) of means ± SE within a column.10, 6, 3 and 1 denoted days before calving, Nedap neck activities (feeding and rumination behaviors); NEDAP leg activities (lying, standing, No. of steps and total motion behaviors).

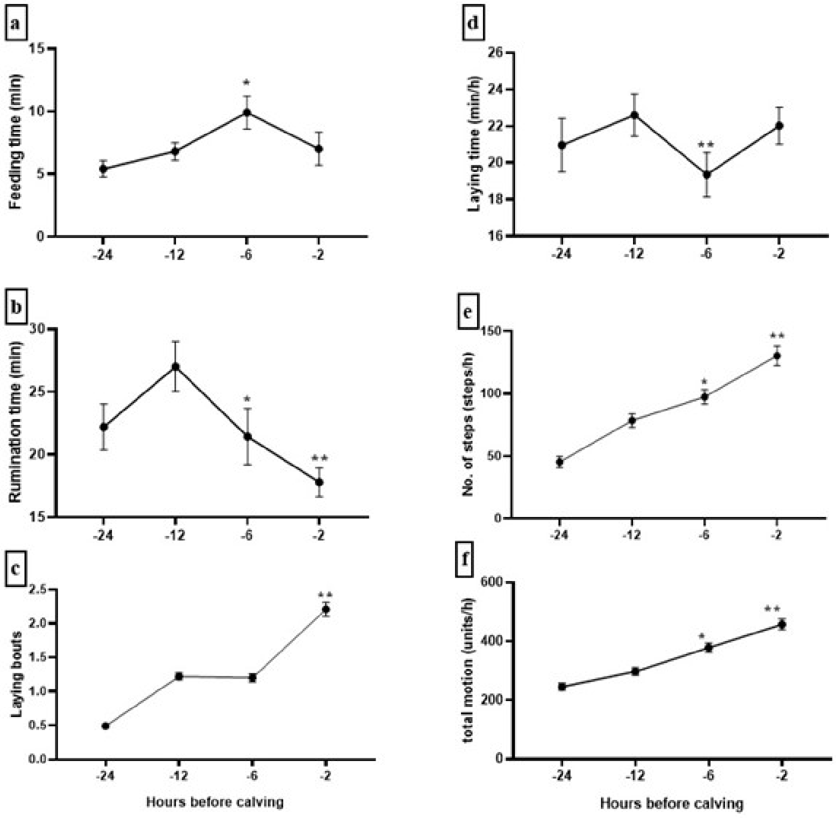

Figure 1. Behavioral differences expressed as mean ± SE in 24-h periods before calving for (a) Feeding time (measured by the Nedap neck Tag); (b) rumination time (measured by the Nedap neck Tag); (c) Laying bouts (measured by the Nedap leg tag); (d) Laying time (measured by the Nedap leg tag); (e) Number of steps (measured by the Nedap leg tag); and (f) Total motion (measured by the Nedap leg tag). Differences were calculated as each buffaloes -24, -12, -6 and -2 days before calving. *$P < 0.01$ and **$P < 0.001$.

5th parity buffaloes on -1 day before calving, as shown in Table 2. The lying time was significantly higher (P<0.02) in 4th parity (615.07±24.55 min/d) buffalos as compared to 2nd parity, however no significant difference between 3rd, 4th, and 5th parity buffaloes (Table 2). We found that there was significantly lowered standing time in 5th parity buffaloes at -1 day before calving compared with 2nd to 4th parity buffaloes (Table 2). The rumination time, lying bouts, no. of steps and total motion was non-significant among parities at -1 day before calving in buffaloes (Table 2). Similarly, there was no significant difference in no. of steps, total motion, and standing time between parity at -2h before calving in buffaloes (Table 3).

3.5. Machine learning analysis

The machine learning analysis was shown in Table 4. We found that the ability to predict the day of calving was best when measuring of behavioral variables of both NEDAP neck and leg tags. The best daily calving prediction results were obtained in combination of neural network analysis with 100% sensitivity and 98% specificity. Similarly, the highest sensitivity and specificity was obtained in the combination variables random forest and linear discriminate analysis.

4. Discussion

Calving is an important event in the life of cattle and buffaloes, in which expulsion of calf after the completion of gestation period (Miedema et al., 2011a; Barrier et al., 2012). Prediction of calving in animals may be helpful to reduce economic losses in the farm which is present due to dystocia, stillbirth, cow death (Burfeind et al., 2011). Additional benefits of calving prediction are, to provide assistance to the animals at calving for helping them from hypocalcemia (Oetzel and Miller, 2012) or to reduce the labor pain by giving medicine (non-steroidal anti-inflammatory drugs) to the animals during calving (Newby et al., 2013). The calving prediction machine is also useful to identifying whether normal calving or dystocia (Ouellet et al., 2016; Rutten et al., 2017). Proudfoot et al. (2009) observed that cows with dystocia were more restless in 24 h prepartum period as compared to normal calving (eutocia). Therefore date of calving prediction has necessary in modern dairy farming.

The feeding time in the current study reduced from -6d till onset of calving. The other scientists observed similar findings that feeding time was decreased during 10 days of prepartum in dairy animals (Newby et al., 2013; Ouellet et al., 2016; Rutten et al., 2017). Braun et al. (2014) found that feeding time was reduced to 114 min on the day of calving, which was lowered than our finding (162 min). The difference in feeding time between current findings with previous findings might be due to species difference or feedstuff or environmental condition. These findings showed that pregnant dairy animals reduced their feeding behavior as compared to nonpregnant, reduction in feeding time might be due to pregnancy stress or labor pain (Braun et al., 2014; Büchel and Sundrum, 2014).

Rumination behaviors in the current study decreased from -6 days to -1 days before calving. The rumination time were significantly decreased in last -12 to onset of calving. The rumination time was declined to 23.19±1.09 min at 1 before the calving date. Different researcher observed rumination behaviors before calving through different

Table 2. Interaction between parity and 1 day prepartum behavioral data in buffaloes.

Behaviors	Parity			
	2nd	3rd	4th	5th
Feeding time (min/day)	226.83±10.57^{a}	170.56±15.06^{b}	193.25±13.0^{ab}	222.16±12.11^{a}
No. of feeding bout	6.62±0.78^{a}	6.20±0.55^{a}	6.32±0.70^{a}	6.38±0.53^{a}
Average feeding bout length	46.68±3.6^{a}	32.45±3.1^{b}	36.82±3.74^{ab}	41.46±3.14^{ab}
Rumination time (min/day)	530.38±21.41^{a}	533.22±18.78^{a}	539.95±31.06^{a}	569.95±18.90^{a}
No. of rumination bout	21.67±0.87^{a}	23.70±1.01^{a}	23.60±1.63^{a}	22.59±0.67^{a}
Average rumination bout length	25.05±0.89^{a}	23.79±1.17^{a}	23.58±1.39^{a}	25.83±0.89^{a}
Lying bouts (bouts/day)	9.3±24^{a}	9.37±0.20^{a}	9.67±0.26^{a}	9.77±0.29^{a}
Lying time (min/day)	556.35±18.13^{b}	564.83±20.41^{ab}	615.07±24.55^{a}	596.45±18.45^{ab}
Average lying bout length	60.75±2.2^{a}	61.78±2.75^{a}	64.90±3.11^{a}	63.50±2.73^{a}
Standing time (min/day)	527.52±26.71^{ab}	560.58±30.18^{a}	517.35±36.95^{ab}	462.11±28.08^{b}
No. of standing bout	16.75±0.63^{b}	18.72±0.58^{a}	16.96±0.82^{ab}	17.13±0.53^{ab}
Average standing bout length	33.62±2.83^{a}	30.37±1.57^{a}	31.79±2.70^{a}	28.16±2.13^{a}
No. of steps (steps/day)	1672.3±2.3^{a}	1676.4±3.1^{a}	1614.7±2.8^{a}	1714.1±3.2^{a}
Total motion (units/day)	241561.4±3.4^{a}	251391.3±3.6^{a}	243281.9±3.4^{a}	254378.1±3.4^{a}

Means with different superscripts within column showed significant difference (P < 0.05) of means ± SE within a column. 2nd (second parity), 3rd (third parity), 4th (forth parity) and 5th (fifth parity), Nedap neck activities (feeding and rumination behaviors); NEDAP leg activities (lying, standing, No. of steps and total motion behaviors)

Table 3. Interaction between parity and 2 hours prepartum behavioral data in buffaloes.

Behaviors	Parity			
	2nd	3rd	4th	5th
Feeding time (min/day)	9.54±1.87[a]	4.95±0.97[b]	7.13±1.87[ab]	7.86±1.10[ab]
No. of feeding bout	0.71±0.09[a]	0.65±0.06[b]	0.84±0.13[a]	0.91±0.06[a]
Average feeding bout length	4.90±1.29[a]	2.02±0.45[b]	2.83±1.12[b]	2.78±0.55[b]
Rumination time (min/day)	17.27±1.25[b]	22.79±1.67 [a]	23.17±2.28 [a]	25.08±1.59 [a]
No. of rumination bout	1.94±0.01[a]	2.01±0.11 [a]	1.98±0.19 [a]	1.96±0.11 [a]
Average rumination bout length	3.62±0.59 [a]	5.02±1.04 [a]	5.77±1.57 [a]	5.54±0.90 [a]
Lying bouts (bouts/day)	1.15±0.09 [a]	1.26±0.09 [a]	1.33±0.13 [a]	9.77±0.29[a]
Lying time (min/day)	18.46±0.97[b]	21.69±1.17[a]	23.19±1.76[a]	22.18±1.31[a]
Average lying bout length	6.25±0.94 [a]	6.98±0.96 [a]	7.36±1.38 [a]	63.50±2.73[a]
Standing time (min/day)	34.97±1.28[a]	30.27±1.34 [a]	29.79±1.93 [a]	28.40±1.35 [a]
No. of standing bout	1.75±0.11 [a]	1.62±0.09 [a]	1.74±0.14 [a]	1.62±0.09 [a]
Average standing bout length	10.41±1.87 [a]	8.44±1.32[b]	7.62±1.51 [b]	8.08±1.31 [b]
No. of steps (steps/day)	272.3±2.3[a]	316.4±2.1[a]	314.7±2.4[a]	334.1±2.7[a]
Total motion (units/day)	2461.4±3.4[a]	2391.3±3.6[a]	2431.9±3.4[a]	2438.1±3.4[a]

Means with different superscripts within column showed significant difference (P < 0.05) of means ± SE within a column. 2nd (second parity), 3rd (third parity), 4th (forth parity) and 5th (fifth parity), Nedap neck activities (feeding and rumination behaviors); NEDAP leg activities (lying, standing, no. of steps and total motion behaviors)

Table 4. Prediction of the day before calving using automated recorded daily behavior data for 10 days before calving.

Analysis	Technology	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)
Random forest	**Nedap neck tag**	47	96	52	72
	Nedap leg tag	68	89.3	71.1	83
	Combination	81	90.2	61.2	77
Linear discriminate analysis	**Nedap neck tag**	49.2	93.4	44.9	86.5
	Nedap leg tag	74.1	87.4	87	91.1
	Combination	70.2	83.9	67.0	95.0
Neural network	**Nedap neck tag**	21.1	99.3	24.0	91.0
	Nedap leg tag	67.0	97.4	67.3	85.0
	Combination	100	98.9	76.7	89.9

The day of calving was included from daily machine-learning analyses. Sensitivity = TP/(TP + FN) × 100; specificity = TN/(TN + FP) × 100; positive predictive value =TP/(TP + FP) × 100; negative predictive value = TN/(TN + FN) ×100; where TP = true positive, TN = true negative, FP = false positive, and FN = false negative.

techniques (Braun et al., 2014; Büchel and Sundrum, 2014; Ouellet et al., 2016; Rutten et al., 2017). Most of the scientists found that rumination behaviors declined before calving date, Soriani et al. (2012) and Braun et al. (2014) found similar results to our results that rumination behaviors began to decline in last 6 day of prepartum. In the current study we found that rumination time was less than 20 min/6 h in last 2 h before calving. This finding was in agreement with previous results that rumination time was decreased to 25.6 min/6h in the last final 6 h before the onset of calving (Büchel and Sundrum, 2014; Pahl et al., 2014). Clark et al. (2015) found that 33% of rumination time was declined at 2 days before calving. One scientist Borchers et al. (2017) reported that no significant decrease in rumination behaviors during prepartum period. The difference in the magnitude of decreased in rumination behaviors in present study and previous reports may be due to breed difference, environment and feedstuffs (sugar beet pulp in previous study). The decreased in rumination behaviors may be good predictor of calving in buffaloes.

The lying behaviors were changed during calving time, therefore finding of these behaviors could predict the calving date before its onset (Miedema et al., 2011b; Jensen, 2012). In the present study we found that the daily lying bouts significantly decreased from -10 days to -1 day before calving date (10.07±0.24 vs 8.97±0.23 bouts/day). Our results were in contrast to previous study in Holstein that lying bouts were increased at -10 to -1 day before calving (9.3-13.6 bouts/day) (Borchers et al., 2017). However others (Miedema et al., 2011b; Jensen, 2012) reported that lying bouts were 16.2-24.4 bouts/day at 1 day before calving, which was much higher than our finding. In the present study, the lying bouts were significantly increased from 0.5 to 2.1 at the last 24h of prepartum period. Similarly, Jensen (2012)and Borchers et al. (2017) found 0.83-2.79 lying bouts at last 12h of perpartum period. The variation in the increase of lying bouts between our finding and other studies might be due to difference in the housing system, bedding materials (as in our study the bedding material was straw while in other study the bedding material was bed mattress) and may be Holstein cattle have more restless than buffaloes. In the current study, the lying time was significantly increased from 9.5 to 10.6 h/d at last 10 days of prepartum period and 18.5-25 min at last 24h before calving time. Jensen (2012) observed similar decreasing pattern in lying time at last 4-2 day of prepartum but reported higher lying time at daily and hourly basis than our finding (16.6 vs 10.6 h/d and 42.8 vs 25 min). However some (Huzzey et al., 2005; Borchers et al., 2017) researchers found decreasing in lying time (11-9.2 h/d) at last 10 days before calving which was in contrast to our finding. These decreasing changes in lying time and bouts indicated that animals become restless due to labor pain (Albright, 1993; Schirmann et al., 2012).

In the current study, the no. of steps taken and total motion was increased at last 10 days of prepartum period and also significantly increased at last 2h before calving time. These finding suggested that animals become restless in response of pain during perpartum period (Hogeveen et al., 2010; Rutten et al., 2013). Similar observation was reported by Jensen (2012) and Borchers et al. (2017) in Holstein cattle. In this study the parity did not affect the rumination behaviors, lying bouts, no. of steps taken and total motion at last 1 day before calving time, However lying time was lowered in 2nd pairty buffaloes as compared to 3rd – 5th pairty bauffaloes, might be due to age factor or body condition score (2nd pairty buffaloes lighter than other pairty buffaloes). Similar results were found in previous reports that showed higher lying time in multiparous than primiparous (Borchers et al., 2017). Combination of automatically collected behavioral changes in daily steps count, lying behaviors and rumination has used to predict the calving (Albright, 1993; Schirmann et al., 2012).

Sensitivity and specificity of technologies are the two important and necessary factors to evaluate the validity of technology for predication of calving in animals (Burfeind et al., 2011). Previously many automatically technologies were used to predict the calving date i.e. Maltz and Antler (2007) reported calving predication methods which measured daily steps count, lying bouts, lying time and feeding time over a period of 7 days before calving with 83.3% sensitivity and 95.2% specificity. Ouellet et al. (2016) also observed combinations of variables (rumination and lying behaviors and vaginal temperature) for predication of calving in holstein cattle and achieved 77% sensitivity, and 77% specificity. The lowered sensitivity and specificity in this study might be due to intra vaginal device, which may be disturbed the animal. In the current study we found 100% sensitivity and 98.9 specificity for combination of variable to predict the calving date in buffaloes, which is high than previous study, may be due to buffalo was not aggressive nature, therefore, data was collected easily. Borchers et al. (2017) observed similar results to the preset study that combinations of variables were most useful in calving prediction.

5. Conclusion

IN this study, rumination, lying, feeding and standing behaviors showed clear changes within last 10 day before the onset of calving in buffaloes. No. of steps taken and total motion clearly increased in last 2h of prepartum period. Application of NEDAP neck and leg data logger tags were able to measure these changes in buffaloes and effective in calving prediction. Combining activity of variables in neural network machine-learning methods generated 100% sensitive and 98.9 specificity at daily level.

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Erratum

ERRATUM: Evaluation of automated monitoring calving prediction in dairy buffaloes a new tool for calving management

Due to a desktop publishing honest mistake the article "Evaluation of automated monitoring calving prediction in dairy buffaloes a new tool for calving management" (DOI https://doi.org/10.1590/1519-6984.257884), published in Brazilian Journal of Biology, vol. 82, 2022, e257884, was published with an error.

On pages 1-9, where the text reads:

Brazilian Journal of Biology, 2024, vol. 84, e257884

It should read:

Brazilian Journal of Biology, 2022, vol. 82, e257884

The publisher apologizes for the errors.