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Calving time identified by the automatic detection of tail movements and rumination time, and observation of cow behavioural changes

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A B S T R A C T

The use of electronic devices to improve animal health, welfare and farm efficiency in precision livestock farming is a developing area of great scientific and commercial interest. In particular, the use of on-site dairy farm instruments to detect calving is a tool in reproduction livestock farming. The primary aim of this study was to validate the ability of the Moocall device (**MD**) to detect calving cows. In addition, behavioural changes in parturient dairy cows were evaluated using video-based observations. The MD was applied approximately 9 days before cow delivery. Observational sessions were conducted three times a day for each cow from the day before MD application to calving time. The sensitivity (**Se**) and specificity (**Sp**) at 3 and 24 h before calving were measured to test the effectiveness of the MD. In addition, behavioural changes were investigated before and after the MD application as well as before and during calving time. The 3 h Se and the 3 h Sp obtained were 95.2 and 71.4%, respectively. No false negatives were observed in the 24 h before delivery (24 h Se = 100%) while the 3 h Se was 95.2%. The MD was well tolerated by the dairy cows since no change in behaviours was observed in this study among the cows with or without the MD, except for an increase in eating behaviour in the animals with the MD. As regards, the behavioural pattern during calving time (8 h before calving) in comparison with the previous phases, a significant increase in tail contraction frequency and raised tail position, and a decrease in eating behaviour and rumination time were observed. The first principal component (**PC**) was primarily explained by these variables, and calving cows best contributed to this PC. According to the results of the present study, the use of the MD can be a useful tool in detecting the moment of calving.

Implications

The use of electronic tools to improve farm efficiency in precision livestock farming is a developing area with scientific and commercial interest. The results of the present work tested the effectiveness of an external electronic device in identifying cow delivery and assessed any disturbance of this device in the animals. In addition, the prodromal behavioural delivery pattern of cows was identified. The implementation of a new device, associated with visual and automatic monitoring of cow behavioural changes, may be an important approach in detecting imminent calving and in improving neonatal and maternal survival by means of the improvement of monitoring.

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Introduction

The use of electronic tools to improve animal health, welfare and farm efficiency in precision livestock farming is a developing area with great scientific and commercial interest (Schirmann et al., 2009; Soriani et al., 2012; Clark et al., 2015; Saint-Dizier and Chastant-Maillard, 2015; Caja et al., 2016; Borchers et al., 2017; Fadul et al., 2017; Marchesini et al., 2018; Abeni et al., 2019). For example, the individual monitoring of cows around calving time is becoming important in helping farmers to identify calving difficulties as soon as possible (Saint-Dizier and Chastant-Maillard, 2015). The use of on-site dairy farm instruments to detect calving is a tool in reproduction livestock farming; these devices give farmers the possibility of monitoring the animals and preventing fatal outcomes with early interventions; consequently, they are useful in improving the fertility and welfare of dairy herds (Miedema et al., 2011a). Four types of precision dairy technologies, based on behavioural signs changing during the last 48 h before parturition, are currently available on the market (Miedema et al., 2011a; Caja et al., 2016; Ricci et al., 2018): 1) inclinometers and

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accelerometers (e.g., detection of tail raising and rumination time (**RT**)); 2) abdominal belts (monitoring uterine contractions); 3) intravaginal thermometers (detection of body temperature changes and the expulsion of the allantochorion and 4) devices fixed on the vulvar lips (detection of calf expulsion). This study involved the use of a type 1 device (**MD**, Moocall©, Moocall Ltd., Dublin, Ireland), capable of identifying birth by monitoring the activity of the pregnant cow's tail.

In recent decades, several studies regarding animal welfare have been carried out to study the behavioural changes of cows which occur before calving. These studies first aimed at controlling parturient cows, and at preventing dystocia and metritis. For this reason, maintenance behaviours, such as locomotor and postural behaviour (standing, lying down and walking) and self-grooming and ingestive behaviour (eating, drinking and ruminating) have been monitored (Huzzey et al., 2005; Proudfoot et al., 2009a and 2009b; Miedema et al., 2011b; Jensen, 2012). Rumination and activity parameters measured by neck collars (HR-Tag, SCR Engineers Ltd., Netanya, Israel) have been used on both dairy and beef cattle to identify calving and to evaluate animal health status (Schirmann et al., 2013; Gentry et al., 2016; Marchesini et al., 2018; Giaretta et al., 2019). This study had three main goals: 1) testing the effectiveness of an external electronic device placed around the tail in identifying cow calving time; 2) assessing any possible disturbance of this electronic device by evaluating changes in animal behaviour and 3) identifying imminent cow calving by combining automatic and visual behavioural assessments.

Material and methods

Subjects and study area

The experimental trial was carried out at the Experimental Educational Dairy Farm of the Department of Veterinary Medical Sciences (DIMEVET) located in Ozzano Emilia (BO, Italy). The subjects were 12 randomly chosen pluriparous Holstein Friesian dairy cows approaching their expected delivery date; artificial insemination of the subjects allowed estimating the delivery date for each animal. The experimental period (autumn-winter) was chosen to avoid the possible interference of flies.

Approximately 15 days before the expected delivery day, the subjects were moved from the dry cow area to a separate straw-bedded section dedicated to parturient animals (8×10 m) with access to an external paddock (6×8 m). Each animal had a space allowance of a minimum of 12 m^2. The feeding program was quite similar to that used in the Parmigiano–Reggiano production area (Mordenti et al., 2017). Specifically, the animals were fed once a day and had *ad libitum* access to water; the total mixed ration (**TMR**) was administered every morning using a horizontal mixer waggon equipped with a weighing scale. The close-up TMR (last week of the dry period) for each cow included: grass hay (4 kg), straw (5 kg), concentrate (2.5 kg) and magnesium chloride (0.7 kg).

Experimental design

In this study, the effectiveness of the MD, an external device (Moocall©, Moocall Ltd., Dublin, Ireland) consisting of a bracelet (weight 354 g) which wraps around the proximal part of the tail was tested for the first time. The device consists of an inclinometer and an accelerometer which are able to evaluate and record each single tail movement. The type, number and intensity of the macro and micro tail movements were analysed using an algorithm which was developed by Moocall Ltd. to differentiate normal tail movements from the specific tail behaviour during parturition. At 1-h intervals, the tail movements were compared to the baseline which was calculated using Moocall Ltd. software, which continuously developed the algorithm with the new data coming from all over the world. If significant differences were detected, a Global System for Mobile (**GSM**) Communications unit communicated to the server which sent an alarm to the customer via text message, e-mail or mobile app notification.

The experiment was divided into two periods (Table 1): 1) pretreatment control (**CTR**) in which animals did not wear the MD (approximately 10 days before the expected delivery) and

2) treatment period (**TRT**) in which the MD was placed on the animal's tail (approximately 9 days before the expected delivery) and immediately removed after cow parturition. Data were collected from November to January over 14 weeks for a total of 12 cow delivery events. The behavioural and rumination data were assessed during both the CTR and the TRT periods by video recording and HR-Tag neck collars, respectively. At first, the behavioural sampling included an *ad libitum* approach (Altmann, 1974) used during the first week to develop an ethogram and standardise the data collection. Focal animal sampling was then used (Altmann, 1974), having an observation time of 15 min for each focal individual (*minimum* 1 to *maximum* 3 cows were observed during the same session). The sessions were conducted three times a day, each scheduled during one of the three 8 h phases selected (A: 0600–1400 h; B: 1400–2200 h and C: 2200–0600 h). For each daily phase 15 min of visual observations were recorded; thus, a total of 45 min/day were analysed for each cow. The behaviours assessed in this study are explained in Table 2. The majority of them are described as frequency and duration.

In addition, the subjects had previously been fitted (approximately 60 days before the experimental period) with an automatic neck collar system HR-Tag, used to collect individual RT and activity time (**AT**). The animals were monitored every day to verify the correct position of the MD and the neck collar.

Data collection and analysis

The duration and frequency of the MD alarms were registered for each parturient cow to study the sensitivity (**Se**) and specificity (**Sp**) of the MD.

The behavioural observations were video recorded using a Sony HDR – CX240E digital camera. Data were collected inside the pen to allow the observer to obtain a full view of the body and tail posture of the subject. All video registrations were carried out by a single observer. Prior to each registration, the observer entered the enclosure and waited 10 min without recording the animal's behaviour, thus allowing the subjects to get used to the presence of the observer. When the animal was fully or partially not visible, and the tail movements could not be recorded due to proximity with other animals, the counts were considered to be ‘out of view’ and were thus removed from the dataset. Rumination and ATs were recorded by the software as daily means (rumination minutes or activity bits during a day) and as 2 h intervals to study daily patterns. The behaviours of interest were determined according to the study ethogram (Table 2). Video recordings of the observations were analysed using Behavioural Observation Research Interactive Software (BORIS) v.4.1.11 (Friard and Gamba, 2016). The data conversion from BORIS software to Excel files was carried out by time slot, considering three times of 15 min each.

Table 1
Experimental design for every single cow.

Day	−10	From −9 to −1	Delivery day
Period	CTR	TRT	TRT
Presence of the Moocall device	No	Yes	Yes
Presence of the neck collar (HR-Tag device)	Yes	Yes	Yes
Behavioural observation	Yes	Yes	Yes

Table 2
Cow behaviours recorded by visual observations. Behaviours are expressed as frequency (n/15 min) and duration (sec/15 min).

BEHAVIOUR state/event	Description
Relaxed tail (sec/15 min)	The tail is relaxed.
Relaxed tail (n/15 min)	The tail returns to a relaxed position.
Raised tail (sec/15 min)	The tail rises, remains raised and contracts rhythmically at each contraction.
Raised tail (n/15 min)	The tail rises.
Tail left (n/15 min)	The tail moves to the left.
Tail right (n/15 min)	The tail moves to the right.
Tail contraction (n/15 min)	Tail up, kept away from the body; each raising/contraction of the tail is followed by a return to the starting position adherent to the body of the cow.
Walking (sec/15 min)	Animal in the quadrupedal standing position and moving in one direction
Walking (n/15 min)	The number of walking events (from a lying or a standing position)
Eating (sec/15 min)	The period when the animal feeds
Eating (n/15 min)	The number of feeding events
Lying down (sec/15 min)	Animal lying on the ground
Lying down (n/15 min)	The number of lying bouts (postural transition from a standing or a walking position)
Standing (sec/15 min)	Animal in quadrupedal standing does not move forward or backward
Standing (n/15 min)	The number of standing bouts (postural transition from a lying or a standing position)

Statistical analysis

The data were analysed using R version 3.4.0 (2017-04-21) (The R Foundation for Statistical Computing, Vienna, Austria). The Se and Sp tests were carried out to evaluate the effectiveness of the MD device. The Se (Se 3 h and Se 24 h) and Sp (Sp 3 h and Sp 24 h) were calculated according to the following equations: Se = True positive/(True positive + False negative); Sp = True negative/(True negative + False Positive). The true positive cases were calculated on the MD alerts in the 3 h or the 24 h before delivery. The false-positive cases were calculated on the MD alarms preceding the 3 or 24 h before delivery.

To evaluate the tolerance of the MD, the cows' behaviours were assessed by video recording during the CTR day (absence of the MD) and the first day of the TRT (with the MD). The various behaviours were analysed using linear mixed models. The treatment was considered as a fixed effect while animal by time phase was included in the model as a random effect. For each model, the residues were checked for variance homogeneity and normal distribution.

To compare calving time with the previous phases the dataset was built using the behaviours automatically registered and visually observed during the 4 days before parturition. To evaluate the behaviours before and during calving, binomial logistic regression, using the general linear model (**GLM**) function, was utilised. The binomial variable considered the 15 min data recorded within the last 8 h before parturition as 'calving time'. The 15 min data collected in the 8 h periods before delivery were considered as 'no calving time'. Animal by time phase was included in the model as a random effect. For each model, the residues were checked for variance homogeneity and normal distribution. The behavioural data were also analysed using linear mixed models to evaluate the differences regarding the days before cow parturition.

A principal component analysis (**PCA**) was carried out using the R commander plugin FactoMineR to reduce the variable numbers and to identify any latent structures in the data. Briefly, animal behaviours described as frequency and duration were used as independent variables in the PCA. Prior to carrying out the PCA, the Kaiser-Mayer-Olkin measurement of sample adequacy and the Bartlett test of sphericity were carried out. The variables were standardised using Z-scores and sorted into PCA components. As a result, regression scores for each of the PCA components were calculated, and a new variable for the first two PCA components was created.

The data are expressed as median and interquartile range. The significance level was set at $P < 0.05$ in accordance with the two-tailed hypothesis.

Results

The effectiveness of the Moocall device in identifying cow delivery

The MD alarm rang once in five parturient cows, twice in six cows and more than three times in only one case. The MD rang in the 24 h before calving time for all the parturient cows (24 h Se = 1). Moreover, for all the cows (except one), the MD detected imminent parturition in the 3 h period before parturition (3 h Se = 0.94). Regarding the Sp, the MD rang in the 24 h period before delivery in all the cows, except in one cow when it rang before the 24 h period (24 h Sp = 0.95); the Sp for the identification of the onset of calving in the next 3 h period was 0.77. There was a case of dystocia during a twin birth for which the MD rang four times 24 h before delivery.

Tolerance of the Moocall device

As regards the effect of the application of the MD on the cow's tail, a significant increase was observed in the frequency and the duration of eating behaviour ($P = 0.0159$ and $P = 0.0326$, respectively) in the first 24 h following the MD placement as compared with the previous day (Fig. 1). No other behaviours assessed in this study were influenced by the application of the MD.

The behavioural pattern before delivery

Significant differences regarding tail movements (Table 3 and Fig. 2a–c) emerged between calving time and the periods before calving time. In fact, in the last phase, called 'calving time', which consisted of a 15 min period recorded in the 8 h before calving, the animals contracted their tails more frequently ($P = 0.0000$) than in the previous phases. On the other hand, during calving time, the tail was maintained relaxed for a significantly shorter time ($P = 0.0000$). Furthermore, during calving time, the frequency and duration of the raised tail behaviour were higher ($P = 0.0000$ and $P = 0.0000$, respectively) than in the previous hours. During calving, a significant increase in the duration of lying down was also observed ($P = 0.0451$). Table 3 and Fig. 2d and e also show that eating behaviour (frequency and duration) was significantly reduced ($P = 0.0327$ and $P = 0.0380$, respectively) during the 8 h before calving when compared to the preview phases. Rumination time measured using an HR-Tag device significantly decreased around calving (Figs. 2f and 3b). No differences in AT were observed between calving and the previous hours (Fig. 3a). For each variable analysed no significant differences were observed among the phases before calving time.

The first five principal components (**PC**) described by the PCA explained 81% of the total variance and presented eigenvalues greater than 1. Fig. 4 presents the first three PCs. As shown in Fig. 4a the first PC explained 18.22% of the total variance and was primarily composed of lying down behaviour (frequency and duration), tail contraction and a raised tail (frequency and duration). The second PC explained 15.40% of the total variance and was primarily described by standing behaviour (frequency and duration), walking (frequency and duration), raised and relaxed tail frequencies, and defecation. As shown in Fig. 4b, the third PC explained 12.18% of the total variance and was principally composed of rumination behaviour (frequency and duration) and a

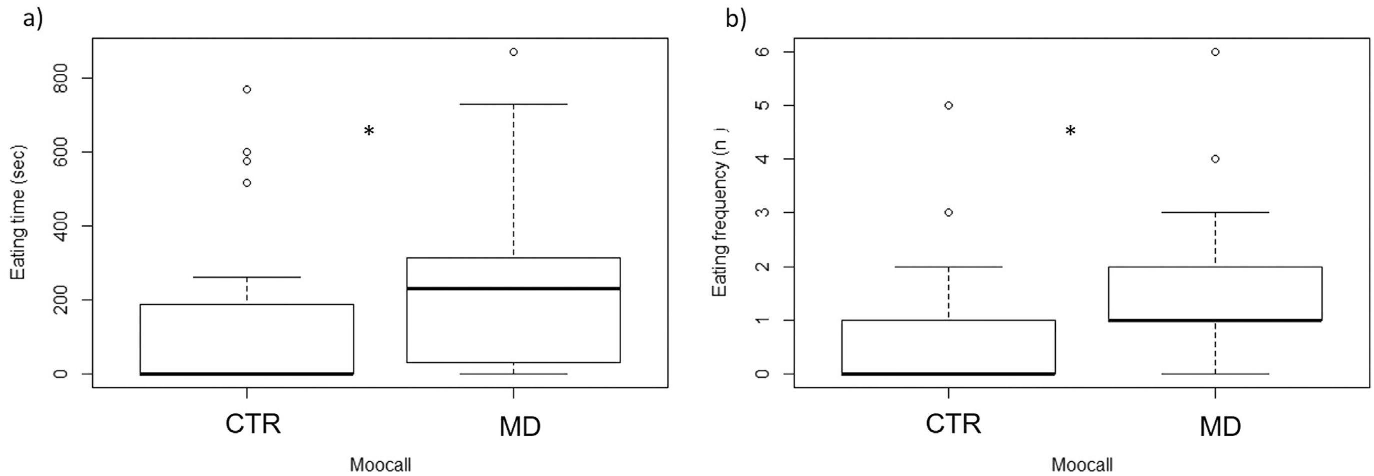

Fig. 1. Boxplots representing eating behaviours (a: duration and b: frequency) among control (CTR) cows (without the Moocall device-MD) and cows with the MD in the first 24 h following the MD placement as compared with the previous day. Asterisks indicate significant ($P < 0.05$) differences between the groups.

relaxed tail (vector not shown in the graph). As shown on the individual graphs in Fig. 4c, the first PC roughly corresponded with the calving cows (the red dots on the right side of the graph), which implied that this component could summarise calving behaviours. In contrast, the parturient cows showed negative scores regarding the third PC (Fig. 4d).

Discussion

Currently, the use of technology to detect calving is a tool in reproduction livestock farming. The physiological variability of the day of delivery makes it difficult to foresee parturition, resulting in the threat of unassisted dystocia. For this reason, different ways of evaluating the moment of parturition have been studied for years and include the development of various technologies (Saint-Dizier and Chastant-Maillard, 2015).

The Se and Sp results demonstrated that the MD is a valid support for identifying calving and can be used in routine livestock management. In addition, it could be useful for pasture-based systems in which animals are not contained and the calving time is more difficult to identify. In all the cases taken into account, except one, the MD rang within 3 h before delivery; thus, it could be a valid support for imminent calving detection. Only in one case, for the twin birth, did the MD ring more than twice (four times in the 24 h before calving). These many alerts could be related to pain episodes of the parturient cow related to dystocia. Additional research is necessary to study the connection between calving problems and MD warning.

Considering all the behaviours measured in this study, the increase in eating behaviour (frequency and duration) on the first day of the MD application was the only difference observed in comparison with the CTR day (without the MD). Thus, it can be stated that the application of the MD did not generally alter the ethologic pattern analysed in this study. In other studies, it has been demonstrated that cows reestablish their feeding patterns almost immediately after acute stressor events, such as regrouping (von Keyserlingk et al., 2008). In addition, the temporary increase in eating behaviour in the first hours after the application of the MD could be a response to the stress event. Overeating in response to stress and negative emotions has been well documented in humans as well as in animals in experimental settings and has been shown to function by alleviating the unpleasant emotional experience (Torres et al., 2007; McMillan, 2013). Therefore, considering that no other behavioural changes occurred other than those recorded, it can be stated that the MD was well tolerated by the dairy cows.

Calving is a critical time for dairy cows due to regrouping, diet change and the moment of parturition itself. The greatest changes in behaviour around calving occurred in the 24 h before and after parturition. In the present study, changes in cow behaviour were observed between calving time (8 h before and during parturition) and the previous hours (Table 3). During calving time, the tail was raised, contracted more frequently and was kept raised for a longer time than in the previous hours. These data are in accordance with Miedema et al. (2011b) who monitored 15 cows grouped in a large straw-bedded barn and who noted significant differences in tail movement during the last 6 h before calving. In the study of Miedema et al. (2011b), an increase in lying frequency was also observed during calving time. In addition, other studies have demonstrated that lying time decreases around calving hours with an increase in lying bouts (Huzzey et al., 2005; Jensen, 2012; Barraclough et al., 2019). Alteration in lying behaviour may indicate an increase in the restlessness and discomfort associated with calving. The improvement in cow comfort, by providing an environment which avoids stress and allows the expression of maternal behaviour (Newby et al., 2013), may be particularly important during the time around calving, modifying lying and standing behaviour, which may be used as a welfare indicator in the parturient cows (Huzzey et al., 2005; Rice et al., 2017). According to the present study, a significant increase in lying duration during calving time as compared with the

Table 3
Behaviours of the dairy cows before and during calving time. Data are expressed as median and interquartile range (IQR).

State	Hours before delivery	Delivery time	*P*-value
	Median (IQR)	Median (IQR)	
Relaxed tail (sec/15 min)	891 (856–899)	427 (191–599)	0.0000[a,b]
Relaxed tail (n/15 min)	3 (3–4)	3 (1–6)	0.8548
Raised tail (sec/15 min)	0 (0–23)	390 (308–551)	0.0000[a,b]
Raised tail (n/15 min)	0 (0–1)	3 (1–5)	0.0000[a,b]
Tail left (n/15 min)	20 (7–32)	10 (6–26)	0.2555
Tail right (n/15 min)	14 (6–30)	4 (1–29)	0.6604
Tail contraction (n/15 min)	0 (0)	103 (64–131)	0.0000[a,b]
Walking (sec/15 min)	18 (0–60)	7 (0–18)	0.9770
Walking (n/15 min)	2 (0–4)	1(0–1)	0.1583
Eating (sec/15 min)	92 (0–304)	0 (0)	0.0380[a,b]
Eating (n/15 min)	1 (0–2)	0 (0)	0.0327[a,b]
Visual rumination (sec/15 min)	0 (0–124)	0 (0)	0.1069
Visual rumination (n/15 min)	0 (0–1)	0 (0)	0.1015
Lying down (sec/15 min)	290 (168–562)	331 (300–560)	0.0451[a,b]
Lying down (n/15 min)	1 (0–2)	2 (1–2)	0.0610
Standing (sec/15 min)	299 (168–562)	256 (131–386)	0.5101
Standing (n/15 min)	3 (2–6)	2 (1–3)	0.0860

[a,b]Indicates significant ($P < 0.05$) differences between the groups.

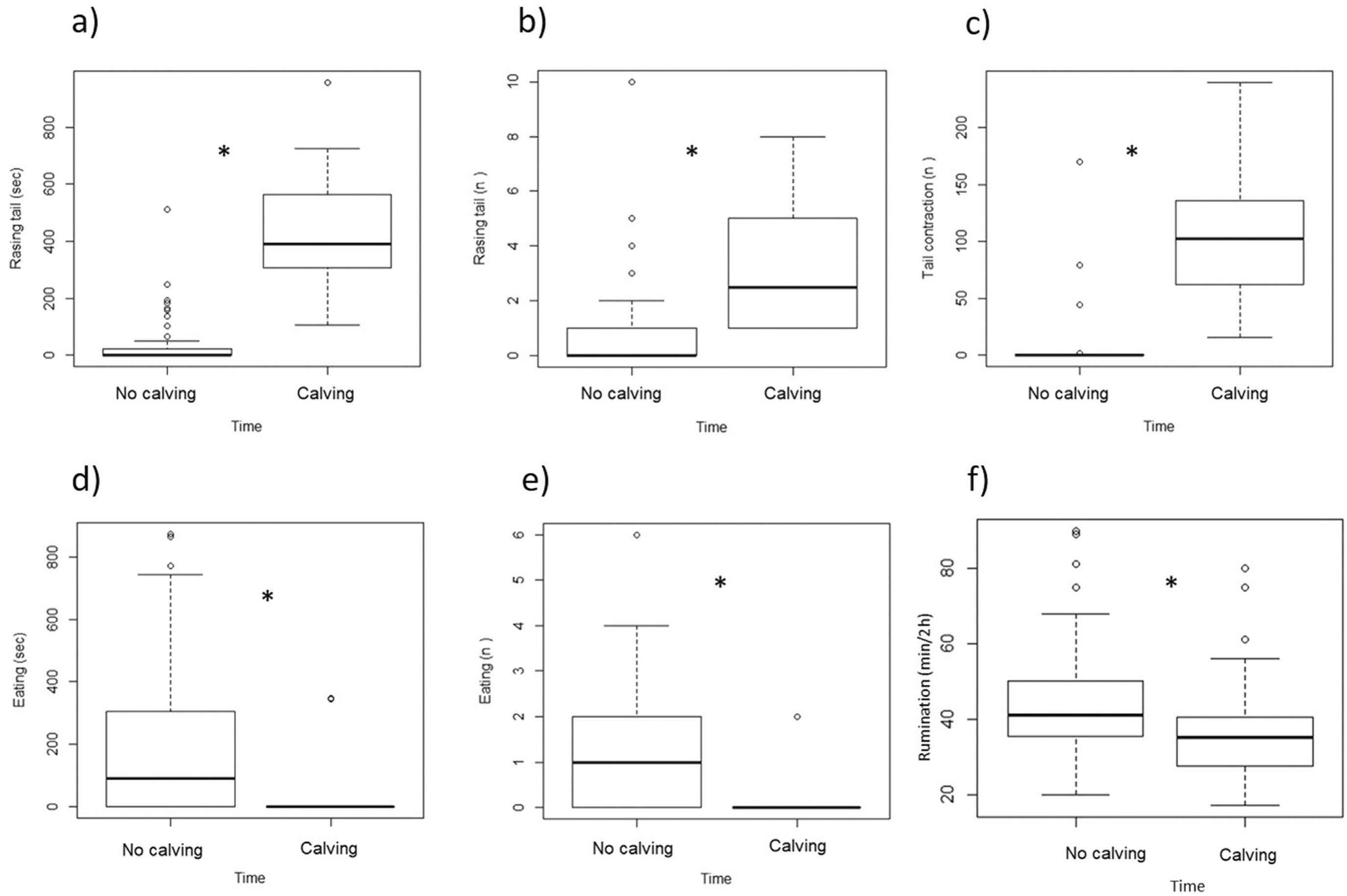

Fig. 2. Boxplots representing cow behaviours recorded during the 4 days before calving (no calving time) and during calving time. The raised tail position (duration and frequency), tail contraction and eating behaviour (duration and frequency) were assessed by video-based observations while the rumination time (min/2 h) was automatically detected by the neck collars. Asterisks indicate significant ($P < 0.05$) differences between the groups.

previous phases was observed. In addition, the lying variables (frequency and duration) were significantly correlated with the first PC (R = 0.80 and 0.82, respectively) which showed strong correspondence with parturient cows.

According to the present results, a significant reduction in eating behaviour was observed during calving time as has been widely observed in other studies (Miedema et al., 2011a and 2011b). One of the major challenges faced by the cow at this time is obtaining sufficient energy to support the onset of lactation, especially given that feed intake tends to be suppressed around the time of calving (Drackley, 1999). Changes in feeding duration and frequency have already been objectively determined in other studies to correctly detect the variations in feed and water intake which occur during the transition period (Huzzey et al., 2005).

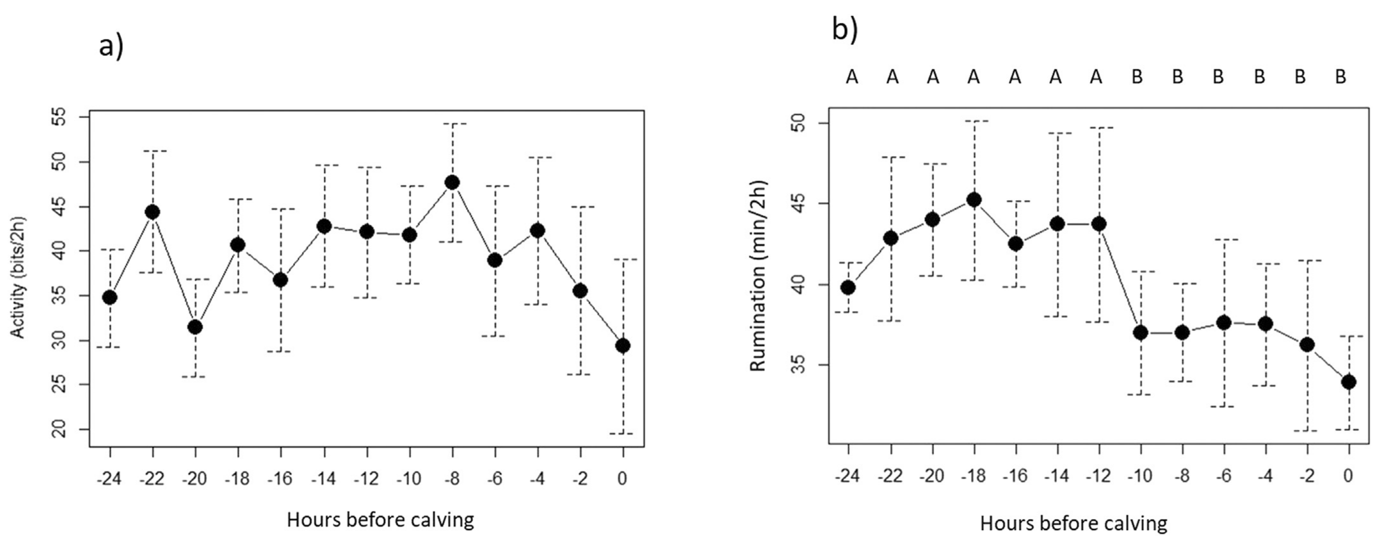

Fig. 3. Graph representation of activity time and rumination time (AT and RT) of dairy cows in the 24 h before calving. Values are reported as mean (points) and SEM (bars). The letters above the graphs indicate the significant differences between the hours.

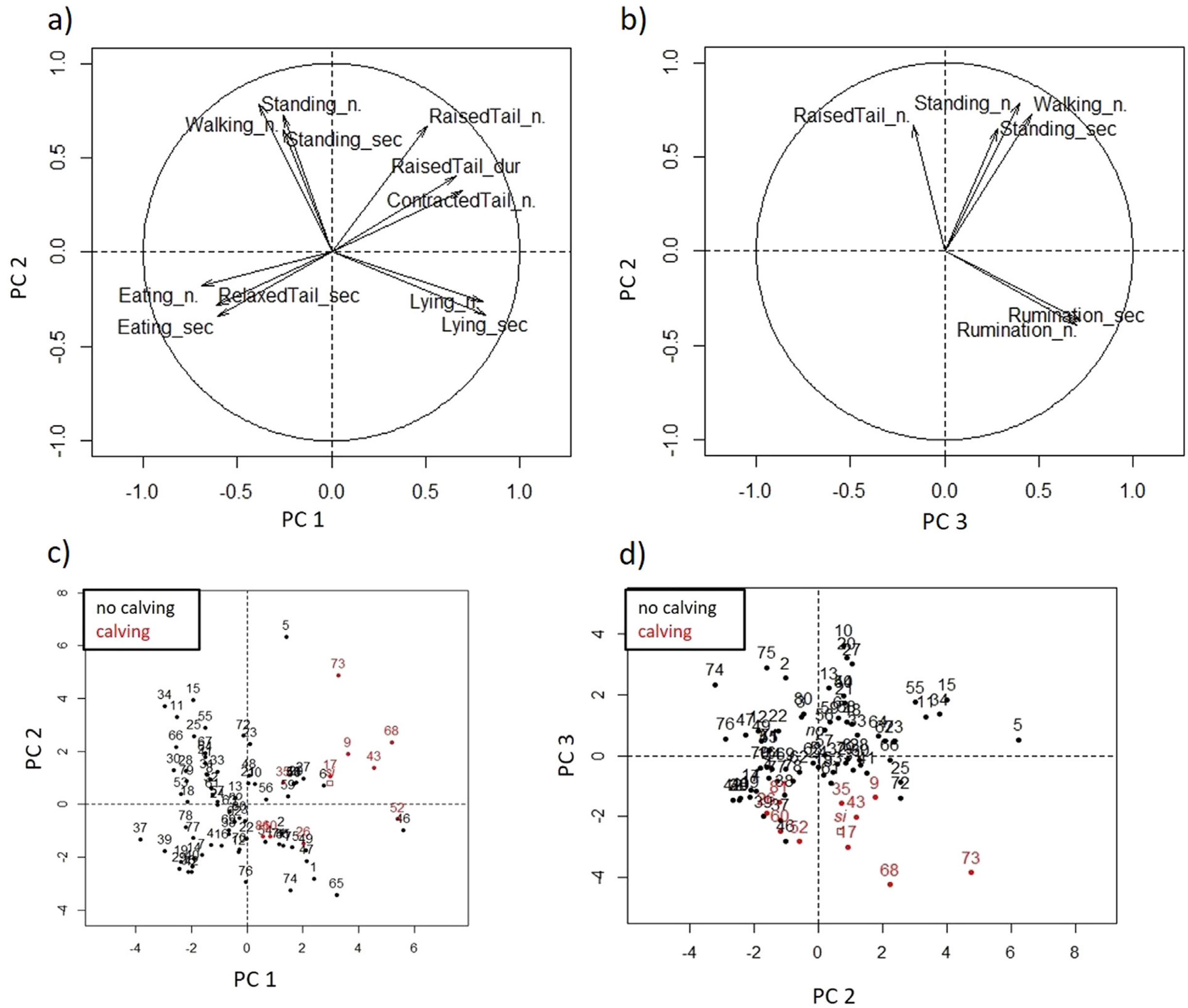

Fig. 4. Principal component (PC) loadings of cow behaviours and individual scores. The PCs were built using the frequency (_n) and duration (_sec) of standing, walking, eating, lying raised tail and rumination; the frequency (_n) of defecation, tail left, tail right and tail contraction as individual variables. The plots above show the variable loadings (with $\cos^2 > 0.5$) between the first three paired PCs. The plots below show the PC scores and indicate the 'calving' group (in red) or to 'no calving' group (in black) to which each observation belongs.

As shown in the individual graph of Fig. 4c, the high scores of parturient cows on the first PC, which is highly correlated with lying behaviour, and raised and contracted tail positions ($R = 0.70$ for both variables), indicated that this component could be used to identify the behavioural pattern of cows around calving. The second PC is correlated with standing ($R = 0.78$ and 0.65 for frequency and duration, respectively) and walking ($R = 0.73$ and 0.42 for frequency and duration, respectively) behaviours while the third PC could indicate the relaxed state, being positively correlated with rumination ($R = 0.70$ for frequency and $R = 0.70$ for duration) and relaxed tail duration ($R = 0.44$, vector not shown in the graph). As a confirmation of this, all the parturient cows presented negative scores on the third PC (individual graph of Fig. 4d).

In accordance with other studies (Soriani et al., 2012; Clark et al., 2015; Borchers et al., 2017; Fadul et al., 2017) RT, monitored by the HR-Tag device, significantly decreased 8 h before calving (Figs. 2f and 3b). In fact, RT was a significant predictor of delivery time in the present study. In particular, Fadul et al. (2017) pointed out a decrease in rumination chewing in the last 3 h before calving; Clark et al. (2015) observed a decline in the duration of RT of approximately 33% over the day prior to calving and the day of calving. Significant differences in RT and AT were also observed by Soriani et al. (2012) during the transition period (−20 day to +40 day), using the same HR-Tag data logger. In addition, the lowest RT values were recorded 8 h before calving by Borchers et al. (2017). Furthermore, an increase in RT 8 h after calving was observed in the same study. In the present study, no significant differences in AT were observed between calving and the previous hours. The differences in RT, detected by automated collars 8 h before calving, suggested that the continuous monitoring of rumination by automatic devices is a useful implement in precision livestock farming to evaluate animal welfare and to efficiently predict physiological or pathological conditions (Giaretta et al., 2019).

Farmers currently rely on expected calving dates and on direct observations to identify and manage calving cows. The automatic detection of physiological behaviours has the potential of providing farmers with a more accurate indicator of the day of imminent calving when compared to the expected calving date. This study demonstrated the effectiveness of the MD in identifying imminent calving, and found important differences in the behaviour between calving time and the previous hours. The ability to identify parturient cows and to predict calving time would allow farmers to monitor the progression of calving and intervene when necessary. The highest number of alarms associated with the only case of dystocic calving should be additionally investigated to evaluate whether the MD could be useful in identifying calving difficulties in association with behavioural assessment (Wehrend et al., 2006; Barrier et al., 2012). These automated devices (MD and HR-Tag), monitoring the behavioural changes around calving, could improve the survival, health and welfare of calving cows and new births. Additional studies would be useful in investigating calving behaviour under different conditions, such as among primiparous and multiparous cows, or between dystocic and eutocic calvings.

Conclusion

The use of the MD could be a useful tool for detecting imminent calving. Thus, this device can give farmers the real possibility of intervening during animal parturition. In addition, the present data demonstrated changes in various behaviours around calving, such as tail raising and contraction, and eating behaviour. The objective detection of tail movements by the MD, in association with the HR-Tag, for assessing rumination might be useful in identifying imminent delivery and promptly intervening in cases of calving complications. Overall, in the long term, these tools (MD and HR-tag) could increase the efficiency of calving by saving work time, consequently reducing costs and improving the fertility and welfare of dairy herds.

Ethics approval

The experimental procedures comply with the ethical standards on animal experimentation in accordance with EU Directive 2010/63/EU for animal experiments.

Data and model availability statement

None of the data was deposited in an official repository.

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Author contributions

Elisa Giaretta: Data curation, software, validation, writing – original draft preparation. Giovanna Marliani: Data curation, methodology, software. Gabriella Postiglione: Conceptualization. Giuseppe Magazzù: Conceptualization, data curation, investigation, visualisation. Fabio Pantò: Data curation, investigation. Gaetano Mari: Supervision. Andrea Formigoni: Supervision. Pier Attilio Accorsi: Supervision. Attilio Mordenti: Project administration, writing – reviewing and editing.

Declaration of interest

The authors declare no potential conflicts of interest.

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