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METHODS FOR MEASURING THE BEHAVIOUR OF DAIRY COWS IN FREE STALL BARNS

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SUMMARY

Behaviour is one of the most commonly used and sensitive indicators of animal welfare. Methods of assessing behavioural activity have changed in recent years, favouring techniques that automate monitoring and recording of animal behaviour, respect to use video recording system. The objectives of the current study were to determine the capability of electronic recording devices (HOBO Pendant G and IceTag) to measure behavioural activity of cows in comparison with video recording system. Automatic recording devices showed data of high sensitivity (Se ≥ 0.961) and specificity (Sp ≥ 0.951) for lying and standing behavioural patterns displaying predictive values close to 1.00 (PPV ≥ 0.966 and NPV ≥ 0.945). Instead, moving behavioural pattern was inadequately recorded by the IceTag device (PPV ≤ 0.303).
Video recording systems provide a complete view of all behaviour and also of the position of the cows in the barn, but it is often time consuming and labour-intensive. Automated measurement of laterality may improve understanding the role of this aspect of lying as an indicator of cow comfort and might be useful for assessing the welfare of dairy cattle. Data loggers accurately measured all aspect of lying behaviour, while the locomotion behaviour (walking) is not well represented. The development of these data loggers may improve the information on activity of dairy cows reducing time and labour required for monitoring of behaviour.

Keywords: behaviour, data loggers, accelerometer technology, video recording system, automation of monitoring.

1 INTRODUCTION

Behaviour is one of the most commonly used and sensitive indicators of animal welfare (*Haley et al.,* 2001; *Krohn & Munksgaard*, 1993). The time spent lying down, the number of lying bouts, the average bout duration (*Haley et al.,* 2000), and the laterality of lying behaviour (*Tucker et al.,* 2009) can indicate underlying changes in cow comfort and welfare (*Fregonesi & Leaver,* 2001).

Despite the insights gained through these behavioural indicators of cow comfort, measuring behaviour in cattle using direct or video-based observations is time consuming. Methods of assessing behavioural activity have changed in recent years, favouring techniques that automate the sampling effort. Automated recording devices have become increasingly common to measure behaviour accurately, to record non-invasively and to overcome the time consuming limitation of video-based observations.

Developments in sensor technology, mainly accelerometer technology, offer new opportunities of automatic monitoring and recording of animal behaviour, respect to use video recording system (VRS). However, many of these systems are suited to measure only one or two behaviour patterns or activity states (*Munksgaard et al.,* 2005).

The objectives of the current study were to determine the capability of electronic recording devices (HOBO Pendant G and IceTag) to measure behavioural activity of cows in comparison with VRS for dairy cows.

2 MATERIALS AND METHODS

2.1 Housing, Animals and Management

The study was conducted at a commercial dairy farm (Mts Zeinstra, Stiens, The Netherlands, 53°15’ 50.00” N; 5°48’53.00” E). The barn, E-W oriented, concept featured a loose-housing layout with a total of 141 cubicles, 61 feeding places, two voluntary milking system (VMS) units (DeLaval International AB, Sweden) and an automatic feeding system for mixed rations (Mix Feeder mod. XL, Skiold Mullerup A/S, Denmark). At the time of the study the barn housed 107 lactating Holstein-Friesian cows (parity 2.4 ± 1.3, milk yield 33.0 ± 6.6 kg/d, day in milk 186.7 ± 99.7; mean ± SD) fed a single-group total mixed ration (TMR) that was supplied with a distribution frequency of 11 times per day with intervals between distributions, ranging from 1.5 h (early morning) to 4.5 h (night). The study was conducted during the spring (from 20 April until 22 April 2010). The daily average temperature was 8.4°C, whereas the maximum and minimum values recorded inside the barn were 17.1 and 2.3°C, respectively.

2.2 Data Collection

The behaviour of the animals was recorded continuously by VRS during the complete study (3 d). To evaluate how accurate the electronic recording devices (IceTag and HOBO Pendant G) can determine lying, standing and moving behaviour compared to the observations with video recordings, 5 cows (parity 3.2 ± 1.2, milk yield 35.6 ± 5.5 kg/d, DIM 160.0 ± 127.6; mean ± SD) were equipped with 2D IceTag automatic recording devices and with a HOBO Pendant G Acceleration Data Logger.

The 5 cows that were equipped with an IceTag and HOBO device were marked with unique numbers dyed onto both sides of their bodies and on their rear ends to facilitate quick identification by the video recording analysis. Daily milk yield data, number of milkings, time and duration of individual visits to the milking robot for each cow, were obtained from the VMS software.

2.2.1 IceTag 2D

The IceTag unit is an electronic sensor device based on accelerometer technology to record and report animal activity. These devices determine for each recorded second the intensity of lying (% lying), standing (% standing), moving (% active) and number of steps based on 8 recordings per second. The devices had a rigid plastic housing designed to withstand the farm environment and were attached to the lateral side of the right hind leg above the fetlock by means of a strap with a buckle.

Activity data were downloaded with a dedicated USB cable and the IceTagAnalyser software (versions 2.009, IceRobotics, Edinburgh, UK) from the on-board memory of the IceTag unit to a PC on a per-second and per-minute basis and were exported to an Excel 2007 spreadsheet (Microsoft Corp., Redmond, WA). We followed the approach by *Trénel et al.* (2009) and classified the cow behaviour for each recording following the IceTag-recorded intensity thresholds for lying, (LI ≥ 50%), standing, (SI ≥ 37.5%), and moving (MI ≥ 50%). Lying bouts shorter than 24.8 s (Lying Period Criterion; *Trénel et al.,* 2009) on a per-second data and than 2 min (*Endres & Barberg,* 2007) on a per-minute data were not considered, assuming that the readings were associated to other movements at the time of recording.

2.2.2 HOBO Pendant G Data Logger

The HOBO logger (Onset Computer Corporation, Pocasset, MA) is a waterproof, 3-channel logger with 8-bit resolution which can record up to approximately 21,800 combined x-, y-, and z-axis acceleration readings or internal logger events. The logger uses a coupler and optical base station with USB interface transfer data to a computer. The data loggers were attached to the lateral side of the left hind leg of the cows by using Vet-flex (Kruuse group, Langeskov, Denmark), in a position such that the x-axis was perpendicular to the ground pointing towards the cow's back (dorsal direction), y-axis was parallel to the ground pointing in the cranial direction, and z-axis was parallel to the ground pointing towards the midplane. The loggers were programmed to record the g-force on the x, y, and z-axes at 1 min intervals following the experience of *Ito et al.* (2009).

The HOBO logger data were downloaded with Onset HOBOware software version 3.1.2 (Onset Computer Corporation), which converted the g-force readings into degrees of tilt. These data were exported into a MS Excel 2007 spreadsheet. The degree of vertical tilt (x-axis) was used to determine the lying position of the animal, such that readings < 60° indicated the cow standing, whereas readings ≥ 60° indicated the cow lying down (*Ito et al.,* 2009). We used the degree of z-axis tilt to determine the laterality of lying behaviour, such that readings ≤ 100° indicated the cow lying on the right side, while readings > 100° indicated the cow lying on the left side. We followed the approach by *Endres & Barberg* (2007) and ignored standing and lying bouts shorter than 2 min: we assumed that these readings were associated with leg movements at the time of recording. We didn't analyze moving behaviour for this device.

2.2.3 Video Recording

The video surveillance system consisted of four IR day/night weatherproof varifocal cameras (1/3" SONY Color CCD) with 42 infrared led for night vision (420SS-EC5, Vigital Technology Ltd., Sheung Wan, Hong Kong) and a recording PC running under Windows XP Professional. The cameras were provided with protective aluminium housing (IP66) and a varifocal lens of 4.0 to 9.0 mm. The four cameras were attached to beams of the barn about 5 m above the pen floor so that they covered the complete living area of the barn, including the entrance and exit of the VMS. The cameras were connected to a four channel video capture 4 EYES Pro card (AVerMedia Technologies, Inc., Milpitas, CA) that was integrated into the PC and that realized analogue to digital conversion of the signal for subsequent storage on a hard disk. Each camera was set to continuously record at 320 × 240 resolution and 6 frames/s.

The behavioural activities (standing, lying, feeding, drinking, and walking) of the cows were classified as follows: Standing was considered to be body upright and supported by at least 3 legs, lying was defined as body contact with the ground on left or right side. Feeding was defined to be head over or in the bunk, and drinking as the head over or in the water trough. Moving/walking was defined as moving at least 3 legs forward in sequence. The standing behaviour was further subdivided in idle standing (standing in a stall with all 4 feet) and perching (standing in a stall with the rear 2 feet in the alley) and standing in the alley for all the other cases (*Cook et al.,* 2005).

2.3 Data analysis

To quantify the ability and the accuracy of the automatic recording devices to monitor the behavioural activities compared to VRS we analyzed the behavioural data for 24 h on day 2 for the 5 cows that were equipped with both the IceTag and HOBO. To determine the accuracy of devices we analyzed the behavioural activities of the 5 cows by video recording with the aid of the continuous sampling method (*Martin & Bateson,* 2007). A trained observer watched the video continuously and recorded the time (start and stop of the individual behavioural events), frequencies, and durations of different behaviour, with 1 s accuracy. From the behavioural data recorded by devices and video we created 4 comparisons: IceTag versus video recording data, at the level of 1 s; IceTag versus video recording data, at the level of 1 min; HOBO versus video recording data, at the level of 1 min; IceTag versus HOBO processed data, at the level of 1 min. The correspondence between IceTag, HOBO logger, and video recording data were analyzed by 2 × 2 contingency tables (TP = true positives, FN = false negatives, FP = false positives, and TN = true negatives; FREQ procedure of SAS, *SAS* 2004).We determined the sensitivity (Se = TP ⁄ (TP + FN); proportion of true positives that are correctly identified by the test) and specificity (Sp = TN ⁄ (TN + FP); proportion of true negatives that are correctly identified by the test) treating the video recordings as gold standard (*Altman & Bland,* 1994a). We calculated the predictive values as probability of correct positive, PPV = TP ⁄ (TP + FP), and negative, NPV = TN ⁄ (TN + FN), respectively (*Altman & Bland,* 1994b).

3 RESULTS

Video observation detected lying and standing as the most dominant behavioural pattern in all 5 dairy cows monitored with lying prevalence of 38% ± 3% (mean ± SE) and standing prevalence of 37% ± 5% (Table 1).

Behaviors	VRS	IceTag	HOBO
Lying (h/d)	9.05 ± 0.73	9.04 ± 0.73	9.05 ± 0.73
right side (h/d)	3.45 ± 1.06		3.43 ± 1.07
left side (h/d)	5.60 ± 1.51		5.63 ± 1.51
Lying bouts (No.)	7.33 ± 0.76	7.33 ± 0.76	7.27 ± 0.78
Standing (h/d)	14.41 ± 0.70	14.47 ± 0.74	14.95 ± 0.73
feeding (h/d)	4.99 ± 0.84		
drinking (h/d)	0.30 ± 0.10		
Idle-standing (h/d)	5.54 ± 1.49		
perching (h/d)	0.99 ± 0.44		

milking (h/d)	0.36 ± 0.09		
Walking/Moving (h/d)	0.54 ± 0.09	0.50 ± 0.05	

Table 1. Means and standard errors for time behaviours of 5 cows and 24 h monitored by VRS and electronic recording devices (IceTag and HOBO).

Feeding behaviour was intermediate (21% ± 3%) whereas moving and drinking had a low prevalence (2.2% ± 0.4%, 1.2% ± 0.4%; respectively). The time spent in milking was only 1.5% for an average of 2.53 milkings/d. Cows spent 62% of their lying time on the left side; 63% and 11% of their standing time on idle-standing and perching, respectively. A mean of 7.33 lying bouts were observed in the video data, with 6 to 10 lying bouts per cow. Across 5 cows, the shortest and longest observed lying bouts varied in duration between 6.7 min and 69.2 min, and between 101.2 min and 195.6 min, respectively.

Sensitivity, specificity and predictive values (positive and negative) for each combination of dataset, device and behaviour are reported in Table 2.

Item	Sensitivity (Se)	Specificity (Sp)	PPV	NPV
IceTag[1]-Video				
Lying	0.997 ± 0.001	1.000 ± <0.001	0.999 ± <0.001	0.998 ± <0.001
Standing	0.977 ± 0.004	0.951 ± 0.006	0.966 ± 0.004	0.967 ± 0.006
Moving	0.291 ± 0.012	0.982 ± 0.002	0.303 ± 0.037	0.982 ± 0.002
IceTag[2]-Video				
Lying	0.997 ± <0.001	1.000 ± 0.000	1.000 ± 0.000	0.998 ± <0.001
Standing	0.969 ± 0.005	0.995 ± 0.001	0.996 ± 0.001	0.958 ± 0.006
Moving	0.264 ± 0.022	0.979 ± 0.002	0.237 ± 0.037	0.982 ± 0.003
HOBO[2]-Video				
Lying	0.990 ± 0.004	0.996 ± <0.001	0.994 ± 0.001	0.993 ± 0.002
Right side	0.991 ± <0.001	0.998 ± 0.001	0.993 ± 0.001	0.997 ± 0.001
Left side	0.993 ± 0.003	0.999 ± <0.001	0.994 ± 0.002	0.997 ± <0.001
Standing	0.996 ± <0.001	0.986 ± 0.008	0.990 ± 0.004	0.994 ± 0.001
IceTag-HOBO[3]				
Lying	0.993 ± 0.001	0.994 ± 0.002	0.992 ± 0.004	0.995 ± <0.001
Standing	0.961 ± 0.003	0.991 ± 0.002	0.994 ± 0.001	0.945 ± 0.004

Table 2. Sensitivity, Specificity, sum of sensitivity and specificity, Positive Predictive Value (PPV) and Negative Predictive Value (NPV) for 2 x 2 contingency tables for correspondence of behaviour observations with IceTag, HOBO Pendant G processed data (test data) and video data (standard) and between IceTag processed data (test data) and HOBO Pendant G processed data (standard). Mean values and standard errors for 5 cows and 24 h observation period ([1] With a 1-s of frequency; [2, 3] With a 1-min of frequency).

Both recording devices provided data of high sensitivity (Se ≥ 0.961) and specificity (Sp ≥ 0.951) for lying and standing behavioural patterns displaying predictive values close to 1.00 (PPV ≥ 0.966 and NPV ≥ 0.945) which means a probability of behaviour corresponding to true near of 100%. In contrast, moving behavioural pattern was inadequately recorded by the IceTag device in both frequencies of 1 s and 1 min. Moving displayed low levels of Se and greater among-cow variability compared to lying and standing behaviour as indicated by larger standard errors. The probability that an IceTag recorded true moving behaviour was low (around 25-30%). Moving behaviour cover only small % of time and requires a more precise measuring method than lying and standing. This may be a reason for the low Se and PPV. An example of the behaviours (lying, laterality and moving) obtained from video and those recorded by data loggers is reported in Figure 1. Lying behaviour and laterality patterns periods can easily be distinguished in this figure.

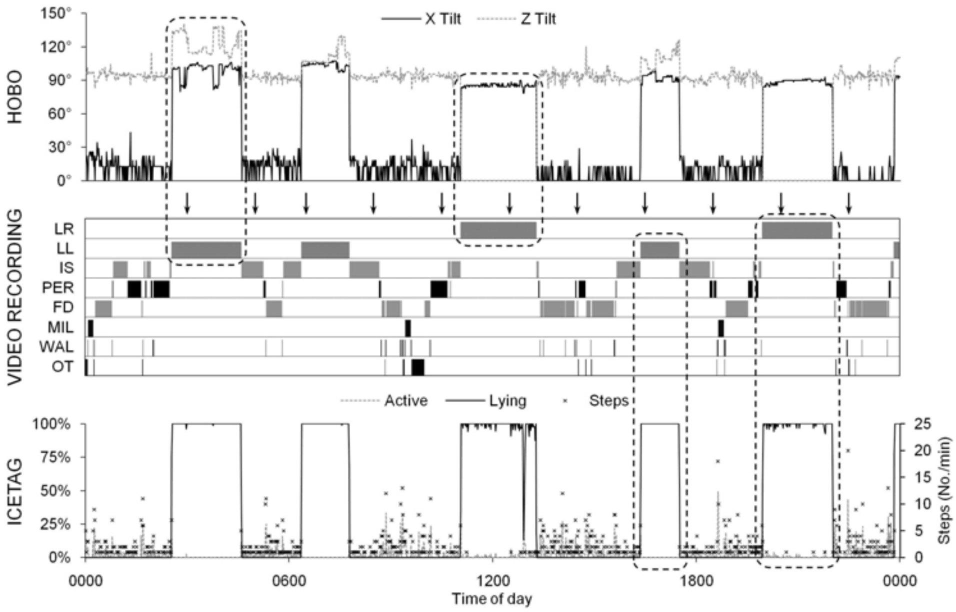

Figure 1. Daily activity pattern of 1 cow during the observation period (24 h) recorded by video, IceTag and HOBO. Behaviour recorded by video recording were time lying right (LR) and left (LL), idle standing in the cubicle (IS), perching (PER), feeding and drinking (FD), milking (MIL), walking (WAL), and others (OT) behaviour such as standing in a waiting area or in the alley. Bold arrows indicate times at which the total mixed ration (TMR) was delivered during the day. Dashed boxes indicate the lying time recorded from VRS, IceTag and HOBO. The TMR was supplied with a distribution frequency of 11 times per day (0300, 0500, 0630, 0830, 1030, 1230, 1430, 1630, 1830, 2030, and 2230).

4 DISCUSSION

Electronic data loggers have become increasingly common to measure lying behaviour, to record non-invasively and to overcome the time consuming limitation of video-based observations. The results of validation studies using video observations as a control have shown high levels of correspondence between video recording and automatic devices when considering the total duration of behavioural activities (*Müller & Schrader,* 2003; *McGowan et al.,* 2007; *Ledgerwood et al.,* 2010). The HOBO and the IceTag devices accurately measured lying and standing behaviour in lactating dairy cows kept in a highly automated loose-housing barn. Measures of lying and standing behaviour derived from the 2 data loggers were strongly correlated. Our results for the comparison of the 2 devices did not show a difference between the data from left leg and those from the right leg which indicates that there was no effect of the positional application. *Müller & Schrader* (2003) showed a slightly lower correlation between the recordings of the devices attached to different legs. The HOBO logger can accurately describe the laterality of lying behaviour as already demonstrated by *Ledgerwood et al.* (2010).

Video recording systems provide a complete view of all behaviour and also of the position of the cows in the barn, but it is often time consuming and labour-intensive. In this study the time used to analyze the behaviour of 1 cow for 24 h by a trained observer was 8.4 h. However the choice of the system to monitor behaviour is not only influenced by the time and labour required but also based on the objectives of the particular study, type and structure of experiment and economical factors. Combination with other network of information (such as from VMS) may be helpful to improve the quality and understanding of daily cow behaviour (*Liberati & Zappavigna,* 2009).

5 CONCLUSIONS

Automated measurement of lying behaviour by data loggers are time and labour-saving and improve understanding of cow comfort. Data loggers accurately measured lying time, number of lying bouts, and bouts structure; laterality of lying behaviour is accurately measured by 3-axis accelerometers, while the locomotion behaviour (walking) is not well represented. Unfortunately, these devices cannot measure other important behaviour like feeding behaviour, different aspects of standing (perching or idle standing), and location which can be measured by VRS.

The development of these data loggers may improve the information on activity of dairy cows and a useful tool to improve automatic livestock management system for efficient monitoring and control of modern and automated dairy farms.

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