IceTag3D™ accelerometric device in cattle lameness detection

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Abstract. The objective of the pilot study was to evaluate the possibility of using IceTag3D™ accelerometric device for the early detection of lame cows in dairy herd. The measurements were carried out in the experimental cowshed of Estonian University of Life Sciences in the free-stall section with milking parlour. The time the cow spent lying and standing, number of lying bouts, step count and the motion index of 33 dairy cows (14 lame and 19 sound cows) was registered during 15 days period. The measurements confirmed that the lame cows stand and move less than sound animals. As the same trend was in force for older cows it was impossible to differentiate the influence of lameness and age. To clarify the inequality in activity between lame and sound rear legs both legs of lame cows were equipped with loggers (eight cows). Great difference in recordings of diseased and healthy leg lying bouts (ratio 2.47) indicates that this parameter may be one possibility to identify leg disorders. However, further investigations are needed to synchronize video- and IceTag recordings and identify threshold values.

Key words: dairy cow, lameness, accelerometer.

INTRODUCTION

Lameness of dairy cows has been classified as very important welfare problem at loose housing. With increasing herd size the need for an objective, automatic lameness scoring grows considerably (Anonymous, 2001; Berckmans, 2004; Poikalainen et al., 2004, 2013; Kokin et al., 2007).

For cows' gait registration and analysis four basic approaches are suggested – using walk-through scales, systems with pressure sensitive walk-over mats, automatic analysis of video-signals, and activity monitoring using accelerometric systems.

Walk-through scales, based on vertical ground reaction force measurements of individual limbs were elaborated and are available commercially. Vertical forces measured over time with two parallel force plates are used to calculate a number of limb movement variables. To separate the results of individual animal within a group walking through the system special algorithm was developed (Rajkondawar et al., 2006).

The preliminary research of using mats with sensors responding to the foot pressure has been carried out by different groups (Maertens et al., 2007). At the University of Helsinki and Estonian University of Life Sciences a walk-over mat with quasipiezoelectric sensors was tested for automatic cows' gait registration (Poikalainen et al., 2010).

Research has proved that automatic use of video signals has great potential to be used for continuous monitoring of lameness. The automatic lameness detection methods by vision analysis of feet movement and back curve were elaborated. A strong linear regression exists between locomotion score given by automatic system and by experts (Maertens et al., 2007; Pluk et al., 2009).

Accelerometric systems monitoring locomotion activity, lying and standing behaviour can be used also for lameness estimation. However, their accuracy is not as good as in case of gait registration systems described above. It can be improved using three-dimensional accelerometers especially when attached to a leg (Chapinal et al., 2010).

Detailed information about the gait and activity gives valuable information about the leg health status of dairy cows. Moreover, by Nielsen et al. (2010) the activity data may provide important input to algorithms for automatic detection of lameness. Assessing walking peculiarities in cows by visual or video-based observations is very time consuming. It is the reason why sensitivity and specificity of automated recording devices for lameness detection have become a focus of recent research. Several commercially available data loggers record lying and walking behaviour in cattle. Loggers are attached around the neck (Martiskainen et al., 2009), body (Champion et al., 1997), or leg (Müller & Schrader, 2003; O'Driscoll et al., 2008; Pastell et al., 2009; Robert et al., 2009; Trénel et al., 2009). Loggers used on the leg are more common than those attached around the neck or the body and are able to measure lying and standing time quite precisely. These are less accurate when assessing other behaviours such as activity (Müller & Schrader, 2003; Robert et al., 2009; Trénel et al., 2009), unless the sampling interval is extremely short (every 10 ms; Scheibe & Gromann, 2006).

Loggers attached to the leg use mainly the accelerometers as the information source. In our experiments IceTag3D™ loggers were used. The objective of our pilot study was to evaluate the possibility of using this type of loggers for the early detection of lame cows in dairy herd.

MATERIAL AND METHODS

IceTag3D™ is a logger with accelerometric sensors that measures animal activity with sampling rate 16 Hz, and has data granularity up to 1 second. The logger is programmed to record the g-force in three dimensions. The waterproof loggers are usually attached to the lateral side of the cow's hind leg above the metatarsophalangeal joint by means of a special strap. The device memory is sufficient to store the results of 60 days measurements. For wireless download of data from the on-board memory of the IceTag logger to a personal computer (PC), where the dedicated IceTagAnalyser software is installed, a desktop unit IceReader is used.

The IceReader is connected to a PC via standard USB connection. By swiping the logger over the IceReader, the user can activate or deactivate logger and download data from the IceTag to PC on a per-second basis. Data are exported to an Excel spreadsheet. For each recording the IceTagAnalyser computes:

1) the time the cow spent lying and standing, determined by the sensor passing a specific threshold between horizontal/vertical position;

2) lying bouts count determined by start and end time of each lying bout;

3) step count determined on the number of times the cow lifts her tagged leg, based on the acceleration of the animal leg;

4) the motion index which reflects the average magnitude of acceleration on each of the 3 axes (IceRobotics Ltd, Product Guide 2010).

Our measurements were carried out in the experimental cowshed of Estonian University of Life Sciences in the free-stall section with milking parlour. This section has 70 laying cubicles, 35 automatic feeders for mixed rations, 2 water troughs. Cows had *ad libitum* access to the feeders and water troughs. Cows were milked twice per day. A week before the experiments a professional hoof trimmer inspected the hooves, recorded the presence of injuries and trimmed the hooves. Cows' gait was assessed by using 5 numerical rating score system: 1–2 sound, 3–5 lame (Sprecher et al., 1997).

Two experimental groups of animals were formed:

1) to clarify the difference in moving activity in connection with leg health status one rear leg of each of 33 cows was equipped with a logger (14 cows lame – injured one rear leg, 19 cows sound, 15 days period);

2) to clarify the inequality in activity between lame and sound rear legs both legs of lame cows were equipped with loggers (subsample of first experimental group with eight cows, 10 days period).

In the first experimental group eight lame cows had hooves lesions diagnosis (digital dermatitis, lesion in the sole and white line disease), six lame cows were found out in addition by visual inspection. Five of them had rating score 4, nine animals had rating score 3.

In the second experimental group three cows had hooves lesion diagnosis and five cows were defined as lame by visual inspection. One cow had rating score 4 and seven cows had rating score 3.

The loggers were attached in sound animals mainly on the lateral side of the right hind leg. In cases of injury caused by the logger rubbing against the leg, the device has to be transferred to the left hind leg. In the first experiment in lame animals the loggers were attached to the healthy rear leg. The data from the IceTags were collected in April, 2013 with six days delay after fitting the loggers. Data were downloaded at the barn (Fig. 1).

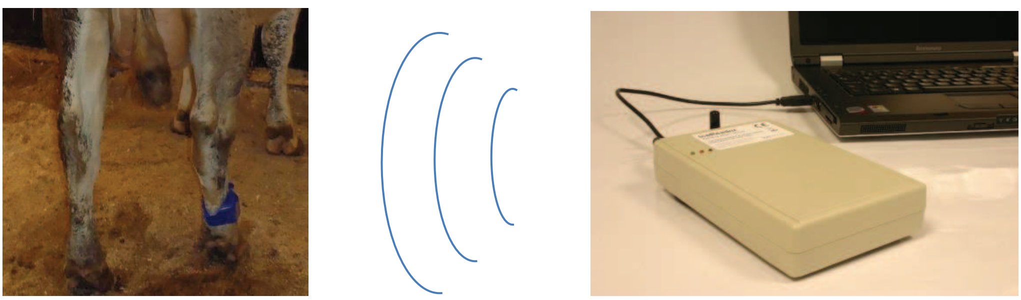

Figure 1. Eksperiment layout: IceTag sensor is attached to cow's right hind leg (left) and reading device (right) is communicating with it by radiolink.

After attaching the loggers five animals tried to get rid of them, shaking the loaded leg. By MacKay et al. (2012) cows showed an increase in time spent standing and decrease in time spent lying over the first two tagged days. Authors recommend that data may not be reliable until two days after the attachment of the device. In our experiments we analysed recorded data starting with the seventh day, allowing animals to adjust with the loggers for longer period.

In case of four sound animals the legs equipped with the logger were changed during the experiment as signs of rubbing developed. Nielsen et al. (2010) also report that injuries will develop within a few days if the device is attached so tight that it cannot move up and down and around the leg.

Total of 481 and 80 measurements were collected for the first and second experimental group of animals, respectively.

The data registered by the IceTags were prepared for the analysis in MS Excel and processed using SAS software version 9.2 (SAS Inst. Inc., Cary, NC, USA). Least-square means were estimated from linear mixed models or generalized linear mixed model (for not normally distributed motion index) with fixed effect of lameness, lactation, experimental day and random effect of cow.

RESULTS AND DISCUSSION

Descriptive statistics of IceTags records for 33 cows are presented in Table 1.

The data in table describes variations in mean values of cows' standing and lying time in sec, number of steps, motion index and lying bouts calculated from axcelerometric parameters. The other main statistical parameters are also described.The variability of recorded activity of cows between the experimental days is great. The reason may be the changing environment in the experimental cowshed because of different tests going on simultaneously that disturbs the animals.

Table 1. Descriptive statistics of recorded activity data per day of 33 cows (481 measurements)

Variable	Mean	Standard dev.	Minimum	Lower quartile	Median	Upper quartile	Maximum
Standing, s	45,216	8,363	23,377	40,228	45,317	50,250	71,539
Lying, s	41,181	8,365	14,861	36,150	41,068	46,172	63,023
Steps	2,311	897	809	1,633	2,206	2,864	6,398
Motion index	6,682	3,029	1,844	4,596	6,156	8,314	21,248
Lying bouts	72	89	10	24	38	85	656

The values of the least-square means of the parameters recorded by the IceTags are presented in Table 2 depending on lameness and age of cows.

The age of cows is reflected by the lactation number (1, 2, and 3). The difference of mean lying time for sound and lame cows is about 29 min, the difference of mean lying time between first and second lactation is about 28 min and between second and third lactation – about 6 min per day.

Table 2. Least-square means with standard errors (SE) of recorded activity data per day of 33 cows

Item	Lying, sec		Standing, sec		Motion Index		Lying bouts		Steps	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Sound	40,446	1,843	45,952	1,843	6,788	634	54	11	2,335	196
Lame	42,167	2,110	44,228	2,111	5,423	581	46	11	1,905	183
Lactation 1	40,058	2,464	46,334	2,463	6,547	818	56	15	2,224	249
Lactation 2	41,748	2,028	44,651	2,027	6,102	628	41	9	2,260	209
Lactation 3	42,114	2,706	44,284	2,705	5,590	767	54	16	1,867	230

Thomsen et al. (2012) used IceTags to evaluate the relationship between gait rating scores (GRS 1–5), lying behaviour and indicators of hoof lesions in dairy cows. They concluded that gait rating scoring and duration of lying bouts may be used as tools in the management of hoof health in dairy herds. Blackie et al. (2011) found that the lame cows (GRS–3) spent significantly longer lying down compared to non-lame (GRS–1 or GRS–2) cows (13 h day^{-1} vs. 10.9 h day^{-1}, respectively). But the differences in lying times between lame and non-lame cows only differed significantly in the evening period (16:01–23:00). By Chapinal et al. (2010) lame cows tended to spend more time lying down because of longer lying bouts. There was no effect of lameness on frequency of lying bouts or the number of steps taken.

The results of our statistical analysis show also that there is the trend that the lame cows stand and move less than sound animals. We found also that the age of cows has clear effect to the activity: older cows' activity was lower. However, considering daily variations of cows' data the number of experimental animals was insufficient to identify the possible influence of lameness to activity data based on one sensor per cow measurements.

Descriptive statistics of IceTags records for lame and sound rear leg of lame cows are presented in Table 3.

Standing and lying time measured by diseased and healthy legs are similar, quite similar are also motion index and number of steps. Great difference is in recordings of lying bouts (Fig. 2): average ratio 2.47 (duration of each bout by diseased leg 5 min. 15 sec., by healthy leg 9 min. 44 sec.).

Table 3. Descriptive statistics of lame cow activity per day by lame and sound rear legs recordings (eight cows with total of 80 measurements)

Characteristic	Leg	Motion Index	Standing, h	Lying, h	Steps	Lying bouts
Average	diseased	5,281	11:50:11	12:09:49	1,998	139
	healthy	5,170	11:59:55	12:00:10	2,061	74
Min	diseased	4,257	10:09:33	10:16:02	1,642	65
	healthy	4,600	10:16:29	10:03:57	1,701	34
Max	diseased	7,004	13:43:58	13:50:27	2,554	217
	healthy	7,415	13:56:03	13:44:23	2,639	111
Standard dev.	diseased	821	1:03:40	1:03:40	274	45
	healthy	856	1:06:24	1:06:34	282	22
Ratio diseased/healthy (average)		1.07	0.99	1.02	0.96	2.47

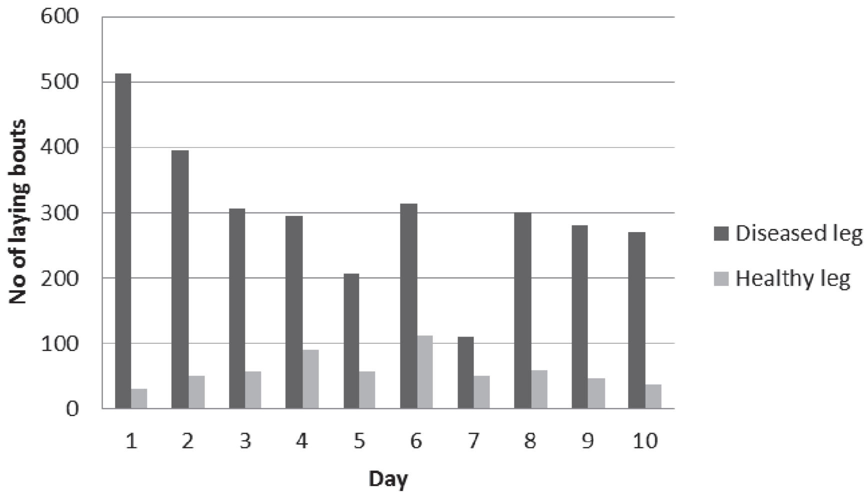

Figure 2. The difference of number of laying bouts between the lame and sound legs.

The number of lying bouts is abnormally great. By Higginson et al. (2010) the difference in data of lying bouts between legs in the alternate leg device placement was caused by the movement of the upper leg while the lower leg was immobile. Trénel et al. (2009) recommended to use filtering procedures in studying the number and duration of lying and upright periods obtained from the IceTag device as the data may contain minor movements; for example, shifts in lying position or grooming while lying.

Tolkamp et al. (2010) used IceTag sensors with indicated minimum lying bout criterion of 4 min. If short 'lying' episodes (i.e. < 4 min) are recorded in standing cows, such episodes should not be considered to separate standing episodes. Standing episodes were, therefore, re-calculated. All lying episodes of less than 4 min. were ignored. This reduced the number of lying episodes up to 88%, but had only minor effects on total estimated lying and standing time (between 0.5 and 3.2%). By Ito et al. (2009) standing and lying bouts of < 2 min were ignored because these readings were likely associated with leg movements at the time of recording. They used HOBO Pendant G Data Logger.

Obviously lame cows lay down on a side so that healthy leg stays below, allowing the painful lame leg to move freely. According to our measurements this parameter may be one possible indicator by which to identify the diseased leg.

CONCLUSION

Taking into account the great variation of cow data (number of steps, motion index, lying bouts, time for standing and lying) between experimental days, the total number of measurements for our experimental animals was not sufficient to identify the influence of lameness by these parameters based on one sensor per cow measurements. By the results of statistical analysis there is trend that the lame cows stand and move less than sound animals. However, as the same trend was in force for older cows it was impossible to differentiate the influence of lameness and age.

Great difference in recordings of diseased and healthy leg lying bouts (ratio 2.47) indicates that this parameter may be one possibility to identify leg disorders. However, further investigations are needed to synchronize video- and IceTag recordings and identify threshold values.

Our experiments gave us the valuable information for planning the measurement series in future studies.

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