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Original article

Automated detection of health disorders in lactating dairy cattle on pasture: a preliminary study

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Abstract

Since previous health monitoring systems have shown themselves to be unsuccessful in predicting health disorders in dairy cows managed on pasture, the aim of this study was to evaluate the performance of automated health monitoring integrated in an accelerometer-based oestrus detection system (ODS) for dairy cows on pasture. Mixed-breed lactating dairy cows (n=109) in a seasonal-calving herd managed at pasture were fitted with an ODS that provided automated health monitoring. The ODS performed multimetric analysis of behavioural patterns to generate health alerts. Data were collected during the artificial insemination period of 66 days. Clinical examinations and farmer's observations were used to evaluate the performance of automated health monitoring. During the insemination period, the farmer generated two health alerts, which were classified false positives (2/2; 100%). The ODS generated 31 automated health alerts. Of all automated health alerts, 3/31 (9.7%) were confirmed as true health disorders and 28/31 (90.3%) alerts were classified as false positives. The positive predictive value (PPV) of automated health monitoring was 9.7 (95% CI=2-25.8) %. The ODS was able to alert lactating dairy cows on pasture suffering from health disorders. True health disorders were alerted by the ODS before the farmer noticed them, which could provide early and successful treatment when using the system on-farm for automated health monitoring. The evaluated accuracy of automated health monitoring is opposed to a targeted use of the system for on-farm health monitoring. For further validation, testing on other farms and during the transition period would be of interest.

Key words: dairy cows, automated health monitoring, triaxial accelerometer, pasture, seasonal calving

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Table 1. Categories of automatically recorded acceleration patterns and their change in frequency required for the ODS[a] to alert health disorders in dairy cattle.

Acceleration pattern	Required change in frequency
General activity	Decrease
Lying behaviour	Increase
Grazing	Decrease

[a] HerdInsights; Alanya Ltd, Cork, Ireland

Introduction

With increasing sizes of dairy herds, lack of skilled labour and technologization of on-farm tasks, identification of diseased individuals by observation is becoming increasingly difficult (Von Keyserlingk et al. 2009, Caja et al. 2016, Dominiak and Christensen 2017). In dairy cows managed on pasture, health monitoring is additionally challenged by location of the herd and individuals on large grasslands, often located far away from the farm.

Many health disorders in lactating dairy cows are known to lead to a reduction of behavioural patterns (e.g. activity, feeding and drinking behaviour and rumination) as well as a decline in fertility and milk yield measurements (Dohoo and Martin 1984, Soriani et al. 2012, Sepúlveda-Varas et al. 2016). Behavioural changes and a decline in the cow's performance may occur several days before the farmer can observe clinical symptoms and thus have great economic impact (Goldhawk et al. 2009, Sepúlveda-Varas et al. 2016). Early detection of health disorders in dairy cows is crucial to restore health to diseased cows and to reduce disease related costs as well as the amount of pharmaceuticals used in food-supplying animals (Milner et al. 1997, González et al. 2008). Furthermore, outcome measurements of dairy-cow health are gaining the interest of consumers and researchers worldwide and are currently under investigation to access animal welfare (Charlton et al. 2016, Vasseur 2017).

Today, data on different behavioural patterns can be collected objectively and non-invasive by using technology. For example, automated milking systems collect a great amount of behavioural and milk-related data, which can be used to predict and identify health disorders (e.g. reduced milk yield and increased electrical conductivity of milk as signs of clinical mastitis) (Khatun et al. 2017, King et al. 2017). Another approach, which has gained popularity in recent years, is the use of rumination collars, which collect and evaluate ruminational data automatically in order to identify health disorders (Zehner et al. 2012, Ambriz-Vilchis et al. 2015, Stangaferro et al. 2016a). The use of sensor-based technology is promising in dairy cows housed indoors (Stangaferro et al. 2016b). In dairy cattle housed on pasture, management routines differ significantly to indoor-management systems (e.g. alternation of pasture location, weather impact and background noises). Due to these environmental effects, previous health monitoring systems have shown themselves to be unsuccessful in predicting health disorders in dairy cows managed on pasture (Elischer et al. 2013, Ambriz-Vilchis et al. 2015).

Recently, a novel accelerometer-based oestrus detection system (ODS) proved itself as a tool in detecting oestrus events in seasonal-calving dairy cows managed on pasture (Brassel et al. 2018). The aim of this study was to evaluate the performance of automated health monitoring for dairy cows on pasture integrated in the above mentioned ODS in comparison to clinical examinations and farmer's observations.

Materials and Methods

The data collection was carried out within the framework of veterinary stock management in the herd.

Farm and herd

The farm on which data were collected in 2015 is located in Cnocsigh, Tinegeragh near Watergrasshill, County Cork, Ireland (52° 01′ 02.1″ N, 8° 21′ 35.9″ W). The data on automated health monitoring were collected on seasonal-calving dairy cows (n=109) and under housing conditions mentioned in another study conducted by the authors (Brassel et al. 2018).

Automated detection of health disorders

The cows were fitted with accelerometer-based oestrus detection collars to investigate the health monitoring function of the ODS (HerdInsights; Alanya Ltd., Cork, Ireland). For the purpose of automated health monitoring, three different behavioural acceleration patterns were analysed by the ODS (Table 1). Health alerts generated by the ODS did not indicate a specific health disorder. Nevertheless, at the time of data collection the manufacturer claimed to be able to detect cows suffering from ketosis, mastitis, displaced abomasum, lameness and photosensitivity (personal communica-

Table 2. Protocol of body regions clinically examined by the veterinarian for cows that generated health alerts and corresponding physiological findings. Examination protocol modified after Kelton et al. 1998, Jackson and Cockcroft 2002 and Gleerup et al. 2015.

Examined body region	Physiological findings
General appearance/adspection	Bright and alert; coat showing no signs of severe lesions/dermatitis
Respiratory system	
Respiratory rate	26-36 bpm[a]
Muzzle	No nasal discharge
Pulmonary auscultation	No crackles or wheezes or other than normal breathing sounds
Circulatory	
Heartrate	60-80 bpm[b]
Intensity	Strong and even
Rhythm	Regular
Differentiation	Heart beats can be heard clearly distinguished
Murmurs	None
Capillary refill time	<2 seconds
Gastrointestinal tract	
Auscultation of the rumen	2-3 contractions in 2 minutes
Percussion and auscultation on both sides of the abdominal wall	No “ping” sound
Rectal temperature	38-39 °C
Milk	
Colour	White
Appearance	Normal, i.e. no flakes, clots or pus
Mastitis test strip[c]	No change in colour
Udder	
Adspection	Intact surface; no scab, hematoma or other discolouration
Palpation	Soft, skin mildly attached to other layers, no signs of pain, swelling or other signs of inflammation
Urine sample/ ketone test strip[d]	No ketones detectable

[a] bpm=breaths per minute
[b] bpm=beats per minute
[c] Udder test strip, Macherey-Nagel GmbH & Co. KG, Düren, Germany
[d] KETOSTIX test strip, Bayer Vital GmbH, Leverkusen, Germany

tion Padraig Lynch[1]). After automated detection of health disorders, health alerts were sent via text message to the examiner’s mobile phone, which was used to identify cows eligible for examination.

Evaluation methodology of health alerts

Clinical examinations

To evaluate health alerts generated by the ODS, detected cows were examined clinically following an examination protocol with defined physiological findings (Table 2). The examination protocol was designed to mainly identify cows suffering from ketosis, mastitis, displaced abomasum and photosensitivity.

1P Lynch, HerdInsights, Alanya Ltd., Cork, Ireland

Health disorders affecting the reproductive tract of the cow or locomotion were not included in the evaluation of automated health monitoring. The same veterinarian, who was experienced in the field of large animal medicine, carried out all clinical examinations during the data collection period. Detected cows that had one or more examination results diverging from the physiological findings were classified as having a true health disorder and the alert was considered true positive. When all examination results were in range of the physiological findings, detected cows were considered healthy and health alerts were considered false

Table 3. Cow number, parity, and examination results contrary to physiological findings as well as diagnosed health disorders for cows that generated automated health alerts and were classified as true positives.

Cow number	Parity	Examination results	Health disorder
1	7	Udder: signs of inflammation in right hind quarter (swelling, warmth, signs of discomfort when palpating) Milk: flakes Mastitis strip test: positive	Clinical mastitis
12	5	General appearance/adspection: eversion of rectal mucosa, reddening and swelling of everted parts	Incomplete rectal prolapse
30	4	Rectal temperature: 39.5°C Nostrils dilated Lung auscultation: increased loudness of expiratory breathing sounds, crackles	Pneumonia

positives. Based on conspicuous findings of the clinical examination, health disorders were classified (i.e. ketosis, mastitis and displaced abomasum) following criteria mentioned by Stangaferro et al. (2016b) and the veterinarian's assessment (other than ketosis, mastitis and displaced abomasum). Photosensitivity was suspected when signs of skin lesions or severe dermatitis were visible, especially in less pigmented parts of the skin (Quinn et al. 2014).

Quantification of false negative alerts

For the evaluation of health disorders missed by the ODS (false negative automated health alerts), visual observations by the farmer were taken into account. Visual observations were carried out during oestrus detection, four times daily for about 30 minutes each, between 06:00-07:00 hours, 11:00-13:00 hours, 15:00-17:00 hours and 20:00-22:00 hours.

Statistical analyses

For statistical calculations, 31 automated health alerts collected on 109 cows were available. Health alerts were classified as true positives or false positives as described above. Two-way contingency tables were constructed to calculate the sensitivity and positive predictive value (PPV) of automated health monitoring by the ODS. Due to small numbers of true positive automated health alerts and missing true positives by the farmer (meaning no false negative automated health alerts), calculation of sensitivity was omitted.

PPV was calculated as 100*(true positive health alerts/(true positive health alerts+false positive health alerts)). Additionally, the 95%-confidence interval (CI) was calculated.

As no quantification of true negative health alerts was possible with the applied methodology, calculation of specificity was omitted.

Data were analysed using BMDP (Release 8.1, Statistical Solutions Ltd., Cork, Ireland) and BiAS for Windows (version 11.05; Epsilon Publishing Company GbR, Darmstadt, Germany).

Results

During the insemination period, the farmer generated two health alerts, which were classified as false positives (2/2; 100%). The ODS generated 31 automated health alerts. Fifteen automated health alerts (15/31; 48.4%) were generated for cows with more than four (5-8) parities, six health alerts (6/31; 19.3%) for cows with one parity, five alerts (5/31; 16.1%) for cows with three parities, three health alerts (3/31; 9.7%) for cows with two parities and two health alerts (2/31; 6.5%) for cows with four parities. Twenty-five cows generated only one automated health alert during the data collection period and six cows generated two alerts.

Of all automated health alerts, 3/31 (9.7%) were confirmed as true health disorders and 28/31 (90.3%) alerts were classified as false positives. The mean parity for cows that generated true positive automated health alerts was 5.3 (SD 1.2) and for cows that generated false positives 4.0 (SD 2.3). Cows that generated true positive health alerts had between four and seven parities. One of the cows that generated true positive health alerts was diagnosed with clinical mastitis, the others with incomplete rectal prolapse and pneumonia. A detailed overview of the cows that generated true positive health alerts as well as corresponding clinical findings may be viewed in Table3.

The PPV of the automated health monitoring was 9.7 (95% CI=2-25.8)%.

Discussion

The objective of this study was to evaluate the performance of automated health monitoring on a commercial pasture-based dairy farm. During data collection, the ODS detected three true health disorders with a PPV of 9.7%. True positive health alerts were generated for cows having four or more parities. This is in agreement with Dohoo and Martin (1984) and Rajala-Schultz and Gröhn (1999), who reported an increase in health disorders with rising numbers of parity. True positive automated health alerts in this study were generated before the farmer noticed any changes in the cows. This is in agreement with others, who recorded subtle behavioural changes in diseased cows several days before clinical signs of health disorders could be observed by the care-taking person (González et al. 2008, Sepúlveda-Varas et al. 2016). When using systems for on-farm automated health monitoring, one important purpose is timely detection of health disorders to take adequate action and restore the animal's productivity. The investigated system's ability for early detection of health disorders may provide economic benefit when using the system on-farm for automated health monitoring.

In this study, 90.3% of automated health alerts were classified false positives with a PPV of automated health monitoring of 9.7%. So far, no automated health monitoring system is reported to have a satisfactorily low level of false positives (Dominiak and Kristensen 2017). Most of the false positives in this study could be attributed to events originating from peculiarities of the outdoor-management system, which is in agreement with other authors (Laca und WallisDeVries 2000, Elischer et al. 2013, Ambriz-Vilchis et al. 2015). For example, false positives were generated after the cows were exposed to heavy rain and wind. Another accumulation of false positives was encountered when the herd was initially kept indoors after milking due to operational delays. We presume that due to these events a reduction in the general activity and changes in measurements of the grazing behaviour led to false positive automated health alerts. Under practical conditions, a high proportion of false positives would result in additional labour on the farm, which applies particularly to pasture-based systems. In particular, when health alerts are not specified to certain health disorders, alerts are of little informative value and detected cows must be examined closely (Rutten et al. 2013). Van Nuffel et al. (2015) stated that a large quantity of false positives would lead to dissatisfaction of the farmer with the system and disregard of automated health alerts. Another difficulty is encountered if the farmer relies on automated health alerts but symptoms are not obvious, which could encourage non-specific use of drugs (Stangaferro et al. 2016a). In summary, a large proportion of false positive automated health alerts is counteracting targeted therapy and opposed to the increasing public interest in reducing pharmaceuticals used in livestock farming.

The PPV of automated health monitoring in dairy cows, depends on the performance of the system used, external events and the prevalence of health disorders in the studied animal group (Hogeveen et al. 2010). The transition period (three weeks prior to calving to three weeks afterwards) is known to be particularly critical for dairy cow health (Huzzey et al. 2007). In this critical period, timely detection of health disorders is crucial to improve the welfare of the animals and to guarantee a good performance of the cows (Soriani et al. 2012). The cows enrolled in this study were at least 40 days postpartum and thus no longer at increased risk of metabolic and infectious diseases. Furthermore, the incidence of health disorders such as lameness and mastitis is reported to be lower in dairy cows housed on pasture compared to cows managed indoors (Washburn et al. 2002, Olmos et al. 2009). With a higher prevalence of clinically diseased animals, e.g. during the transition period, it may be assumed that numbers of automated health alerts and the PPV of the automated health monitoring evaluated in this study would have been higher .

Technical solutions for automated health monitoring and studies on this topic are usually limited to specific diseases and their detection. For this purpose, systems under investigation may be installed on sick and healthy animals or diseases are induced artificially to evaluate their performance (Milner et al. 1996, Kramer et al. 2009). Unfortunately, a gold standard that defines the presence or absence of specific health disorders is still lacking in the scientific literature and materials and methods used differ widely, which hinders direct comparisons of investigated systems (Dominiak and Kristensen 2017). Stangaferro et al. (2016c), who investigated an accelerometer-based health monitoring system on postpartum dairy cows managed indoors (Heatime HR-Tag, SCR Engineers Ltd., Netanya, Israel), evaluated a PPV of automated disease detection of 58.3% (for dislocated abomasum and other indigestion, ketosis, mastitis and metritis). In contrast to the system evaluated in this study, the system investigated by Stangaferro et al. (2016c) used ruminational data (collected via microphone) in addition to activity measurements. Ruminational behaviour is an important parameter in the detection of many diseases and is reported to improve automated detection of health disorders (Zehner et al. 2012). In dairy cattle on pasture, where background noises interfere with ruminational sounds, ruminational behaviour could be collected and implemented in automated health monitoring using a ruminational halter, which showed promising results under grazing conditions (Rombach et al. 2018). Accelerometers, as used in the system presented in this study, may also be suitable for detecting ruminational data (Watanabe et al. 2008, Martiskainen et al. 2009). We presume that using ruminational data could help in improving the accuracy of automated health monitoring of the system investigated in this study.

The limitations of the study were that the automated health monitoring of the ODS was evaluated on one farm only and on cows that were in good condition and beyond the transition period at the start of the study. This allowed us to assess the accuracy of the investigated automated health monitoring under on-farm conditions for the first time in scientific research, but further research would be necessary in order to evaluate the performance of automated health monitoring on other farms and especially during the transition period, when cows are at high risk of developing health disorders.

In conclusion, the ODS has proven its ability to detect lactating dairy cows on pasture suffering from different health disorders. It is noteworthy that true health disorders were alerted by the ODS before the farmer noticed them, which constitutes an advantage for on-farm use. Since the ODS was tested on one farm only and on cows that were not at a high risk of developing health disorders, available numbers of automated health alerts were small. However, the reported accuracy is currently contraindicated to a targeted use of the ODS for automated health monitoring in dairy cattle on pasture and the system would need improvement on collected behavioural data as well as the algorithm used. For further validation, testing on other farms and during the transition period would be of interest.

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