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Lameness in dairy cows: farmer perceptions and automated detection technology

Kate J. Dutton-Regester[1], Tamsin S. Barnes[1,2], John D. Wright[1] and Ahmad R. Rabiee[1,3]

[1]The University of Queensland, School of Veterinary Science, Gatton, Queensland, 4343, Australia; [2]The University of Queensland, Queensland Alliance for Agriculture and Food Innovation, Gatton, Queensland, 4343, Australia and [3]Rabiee Consulting, Horsley, NSW 2530, Australia

Research Reflection

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Author for correspondence:
Kate J. Dutton-Regester,
Email: katejanedr@gmail.com

Abstract

This Research Reflection provides an overview of three interrelated topics: (i) lameness in dairy cows, demonstrating the underpinning importance of the condition, (ii) dairy farmer detection, diagnosis and treatment of lameness and associated foot lesions as well as dairy farmer perceptions towards the condition and (iii) lameness detection technologies, and their potential application on farm to automate the detection of lameness in commercial dairy herds. The presented literature clearly demonstrates that lameness is a major health issue in dairy herds, compromising dairy cow welfare and productivity, and resulting in significant economic implications for dairy farmers. Despite this, dairy farmers fail to perceive lameness as a serious threat to their dairy business. This restricted perception of the importance of lameness may be a product of limited ability to detect lame cows. Many automated lameness detection technologies have been proposed to assist dairy farmers in managing their herds. However, limitations such as cost, performance and dairy farmer perception of the usefulness of these technologies, has lead to poor uptake. It can, therefore, be concluded that there is a need to more thoroughly evaluate the effectiveness of these technologies under on-farm conditions, potentially in the form of a demonstration farm network. This will allow generation of the necessary data required to show dairy farmers that these technologies are reliable and are economically rational for their dairy business.

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Introduction

Lameness causes significant economic burden to individual dairy farmers and the dairy industry and compromises dairy cow welfare (Willshire and Bell, 2009; Cha *et al.*, 2010). Prompt detection of lameness is critical for improving economic and welfare outcomes. As the first observable sign of lameness is a change in a cow's usual walking pattern, currently, lame cows are identified by visual observation by farm staff (Dutton-Regester *et al.*, 2018). However, changes in physical activity due to lameness occur at more advanced stages of the disorder (Dutton-Regester *et al.*, 2018), resulting in greater welfare and economic implications.

The rapid growth in livestock production has led to more cows and less farm staff per herd (Barkema *et al.*, 2015) and, as a consequence, herdsman have less time to monitor the health condition of their cows. The automation of lameness detection has the potential to reduce the need for manual labour and facilitate a more sustainable herd management programme (Rutten *et al.*, 2013).

This review encompasses three core sections. The first provides an overview of lameness in dairy cows, presenting the underpinning importance of the condition by summarising the associated economic and welfare implications. The second section discusses dairy farmer detection, diagnosis and treatment of lameness and associated foot lesions as well as dairy farmer perceptions towards the condition. The final section explores lameness detection technologies, and their potential application on farm to automate the detection of lameness in commercial dairy herds.

An overview of lameness in dairy cows

Lesions causing lameness

There are a number of lesions (any pathological or traumatic discontinuity of tissue or loss of function of a part) (Blood and Studdert, 1999) that can cause lameness in dairy cows. These lesions are often found on the lateral claw of the hind foot (online Supplementary Table S1). The most frequent lesions identified in dairy cows housed indoors include sole ulcer, digital dermatitis and white line disease (online Supplementary Table S2). Few studies have been

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conducted on pasture-based dairy cows and it is difficult to draw conclusions regarding common foot lesions of these cows.

The implications of lameness

Lameness presents significant consequences for both dairy cows and dairy farmers. First and foremost, lameness is an essential welfare problem with multiple studies reporting signs of pain and distress in affected dairy cows. For example, lame cows demonstrate impaired mobility or abnormal gait (Whay *et al*., 2003), spend less time standing or walking (Navarro *et al*., 2013) and graze for shorter periods compared to non-lame cows (Hassall *et al*., 1993). Consequently, dairy cow productivity is compromised. For example, Reader *et al*. (2011) and Warnick *et al*. (2001) report daily losses in milk production of up to 1.6 and 1.5 kg, respectively, while Green *et al*. (2002) observed a milk loss of 160 to 550 kg over an entire lactation. Dairy cow reproductive potential has also been shown to be compromised with delayed cyclicity (incidence 17%) (Garbarino *et al*., 2004) and extended calving to conception intervals up to 40 d longer than non-lame cows (online Supplementary Table S3; Collick *et al*., 1989; Bicalho *et al*., 2007).

Not surprisingly, lameness is considered to be one of the most important health conditions of economic significance affecting the dairy industry (Ettema *et al*., 2010). In addition to reduced milk yield and compromised reproductive potential, the key factors contributing to the cost of a single case of lameness include treatment and increased labour costs, and forced culling (Esslemont and Kossaibati, 1996; Forbes, 2000; Whay *et al*., 2003). A number of studies have estimated the costs of a case of lameness, these ranged from fl104 (Enting *et al*., 1997), £113 (Kossaibati and Esslemont, 1997), £154 (Willshire and Bell, 2009), $75USD (Bruijnis *et al*., 2010), $178USD (Cha *et al*., 2010) and $AU200–$300 (Jubb and Malmo, 1991) (online Supplementary Table S4).

The dairy farmer – practices and perceptions

The detection of lameness and the diagnosis and treatment of lesions causing lameness

The observation of change in gait is typically the first indication that a cow is lame. This initial observation is typically performed by the dairy farmer during day-to-day farming practices. However, the literature suggests that the ability of the dairy farmer to observe lameness during day-to-day farming practices is relatively poor: according to studies by Wells *et al*. (1993), Espejo *et al*. (2006) and Leach *et al*. (2010), research-reported prevalence is up to three-fold higher than farmer-reported prevalence (online Supplementary Table S5).

In the management of foot lesions, ultimately, provision of appropriate intervention is the key. However, in order to establish appropriate treatment, accurate diagnosis is pivotal. A misdiagnosis may have no adverse consequence, if appropriate treatment is applied regardless of the diagnosis made. At the other end of the spectrum, incorrect diagnosis may result in more harm to both the cow (appropriate treatment is delayed, or unnecessary or harmful treatment is applied) and the dairy farmer (unnecessary financial repercussions, for example). Therefore, following the detection of a lame cow, it is important that the dairy farmer can identify the cause of lameness.

While there is a paucity of literature on farmer diagnosis of lameness lesions, available studies indicate that dairy farmers need more assistance in diagnosing and treating foot lesions causing lameness in their dairy herds. For example, Horseman *et al*. (2013) reported that most dairy farmers could not differentiate between solar abscess and white line disease. Arguably, this is not of significant consequence as it is agreed that treatment of the two diseases is very similar and therefore attempts to educate dairy farmers to diagnostically differentiate between them may add unwarranted complexity without significantly improving treatment outcomes. The alternative argument is that if dairy farmers develop the skills that can help them to understand the causes and pathologies of the two diseases, they may be able to choose a different approach to reduce the incidence of the two diseases and obtain better outcomes by applying a more specific treatment.

In another study, Dutton-Regester (2017) investigated the level of agreement relating to the diagnosis and treatment of foot lesions between a veterinarian and dairy farmer. She reported weak to moderate agreement between the pair, indicating that there were differences in opinion for diagnosing and treating lame cows. Of major concern was that the two most prevalent lesions (lesions of the sole and interdigital lesions) only achieved weak levels of agreement. This suggests that these lesions may frequently be misclassified by the dairy farmer, increasing the risk of incorrect treatment.

Dairy farmer perceptions towards lameness

The literature indicates that dairy farmers perceive lameness to be a relatively minor problem in their herds. For example, Leach *et al*. (2010) reported that while study investigators estimated the prevalence of lameness to be 36%, the majority of dairy farmers did not consider lameness to be a major problem within their herds. Similarly, Bennett *et al*. (2014) reported that of 163 dairy farmers, 93% did not consider lameness to be a major problem within their herds and (Bruijnis *et al*., 2013) found that of 145 dairy farmers, most reported being content with the current foot health status on their farms.

This perception of lameness is likely to inhibit dairy farmer motivation to improve the management of lesions causing lameness; for where there is no perceived problem, motivation remains low (Dutton-Regester *et al*., 2019). This is demonstrated by Bruijnis *et al*. (2013), reporting that farmers who believe their cows to have good foot health have lower intention to implement intervention. Conversely, farmers who believe their cows to have poor foot health have more interest in improving lameness detection and control strategies. Further, a recent study by Dutton-Regester *et al*. (2019) investigating dairy farmer intentions to make improvements to their current management practices of foot lesions, reported only moderate intention. They explain that this may be because dairy farmers feel that their current management of foot lesions is adequate as most ($n = 50$, 89%) indicated that they were already implementing at least one of the suggested management practices. Additionally, the incidence of lameness as estimated by the dairy farmers was low (when compared to estimates reported in the literature) with 75% ($n = 42$) suggesting that 10% or less of their herd was lame annually. Almost half of these dairy farmers (48%, $n = 20/42$) indicated that the incidence of lameness in their herds was 5% or lower annually.

Lameness management in the future

Up to this point, this review has clearly demonstrated that lameness is a major health issue in dairy herds and that dairy farmers have restricted perception of its importance to their

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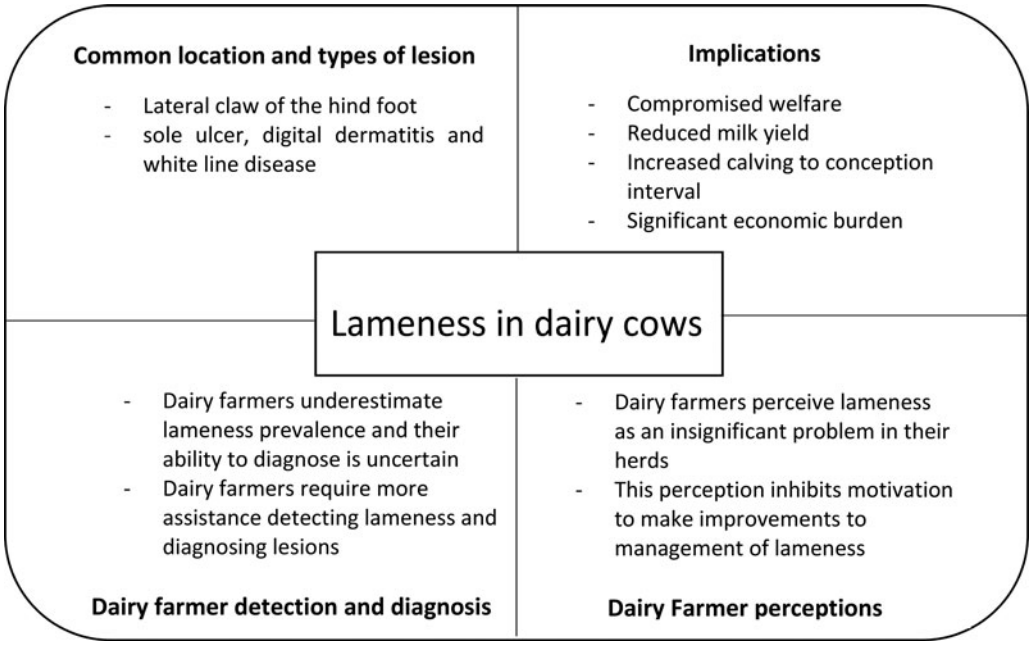


Fig. 1. Summary of the first two sections of this review, 'An overview of lameness in dairy cows' and 'The dairy farmer – practices and perceptions', highlighting key information.

herds (Fig. 1). Many technologies designed to assist dairy farmers in detecting lameness in their herds have been proposed (see Dutton-Regester *et al.*, 2018 and Alsaaod *et al.*, 2019 for reviews). These range from manually/visually-based traditional techniques such as observing for changes in gait (Leach *et al.*, 2009; Thomsen, 2009) to completely automated technologies that include force plate evaluation (Bicalho *et al.*, 2007; Pastell *et al.*, 2008) and infrared thermal imaging (Alsaaod and Buscher, 2012). While initial investment in many of the manual methods may be quite small, the ongoing costs can be substantial as they often require considerable training and can be time consuming to perform (Dutton-Regester *et al.*, 2018). However, more problematic, is that due to their subjective nature, by the time a lameness lesion is detected, it may have been present for a protracted period of time and already have had considerable impact on dairy cow welfare and productivity resulting in substantial economic loss (Dutton-Regester *et al.*, 2018).

Conversely, while automated technologies may incur greater initial investment, they have the potential to detect lesions prior to manifestation of visually detectable clinical signs and impact on productivity. Further, the requirement for personal labour is minimised, resulting in less interruption to dairy farmers' day-to-day practices.

Fewer studies have investigated technologies to assist dairy farmers to identify lesions causing lameness. A pilot study by Dutton-Regester (2017) used mobile telephone technology to remotely diagnose and treat lameness in a commercial dairy herd. Digital images of foot lesions obtained on-farm by the dairy farmer were transmitted to an off-site veterinarian for assessment. While this approach showed potential, there are complicating issues to consider before such technologies can be implemented. Complex legal and ethical issues including competing jurisdiction requirements, confidentiality of the veterinarian-client relationship, and drug dispensing regulations are problematic (Dutton-Regester *et al.*, 2017). Cost effectiveness (Wootton *et al.*, 2000) and acceptance of the technology by both dairy farmer and veterinarian (Lowitt *et al.*, 1998) are also considerations. Additionally, this technology requires considerable time-consuming input from the dairy farmer.

Given the limitations associated with manual technologies, in our view, automated technologies are the future for lameness detection in dairy herds. We predict they will play an essential role in supporting dairy farmers to reduce the prevalence of lameness in their herds. The remainder of this review will discuss potential automated technologies and barriers preventing their implementation.

Application of automated technologies for improving lameness management

Automated lameness detection technologies

Over the past two decades, automated lameness detection technologies have been extensively researched to demonstrate the accuracy and application of these systems at the farm level (See Alsaaod *et al.*, 2019 and Rutten *et al.*, 2013 for comprehensive reviews). These technologies can be categorised into four main classes: (i) Kinematic methods, which assess changes in the position of specific body segments over time, and include image-processing technologies, pressure-sensitive walkways, and accelerometers; (ii) Kinetic methods, where force is applied to the body, and include ground reaction force systems, force-scale weighing platforms and kinetic variations of accelerometers; (iii) Indirect methods including thermography, feeding behaviour detection technologies, grooming behaviour detection technologies and individual cow milk production measuring technologies (Alsaaod *et al.*, 2019) as well as, more recently, (iv) machine learning (ML) algorithms. While the kinematic, kinetic and indirect methods have been reviewed elsewhere (see Alsaaod *et al.*, 2019), here we briefly discuss advances in the application of ML for lameness detection.

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Machine learning, a sub-set of artificial intelligence, is an application that employs algorithms generated by computer systems to perform specific tasks without using explicit instructions but instead relying on statistical patterns and inference; learning increases over time as data are accumulated (Liakos *et al.*, 2017). In veterinary medicine, ML has been used in a number of applications (Kalipsiz *et al.*, 2017), including lameness detection in dairy cows (Liakos *et al.*, 2017; Warner *et al.*, 2018; Byabazaire *et al.*, 2019). The most recent lameness application utilises leg-mounted sensors to measure step count, time in recumbency and positional changes (standing-lying-standing) over a set period of time to enable early detection of lameness (Liakos *et al.*, 2017; Byabazaire *et al.*, 2019). The predictive capability of ML makes this technology highly suitable for application on-farm, with great potential to improve the welfare of dairy cows. Recently, a Canadian study (Warner *et al.*, 2018) demonstrated 90% specificity in dairy farms with high risk of lameness, suggesting only a small percentage of dairy cows were misclassified. However, ML is currently not without its' challenges, including heterogeneity in the type and frequency of data collection, feature customisation, and algorithm sensitivity and specificity of lameness detection (Byabazaire *et al.*, 2019).

Overcoming barriers to on-farm implementation

A simulation study by Van De Gucht *et al.* (2018) showed that high performance was one of the primary determinants of uptake by dairy farmers of new technologies. Regardless of this finding, relevant information regarding performance of investigated technologies is limited with many studies failing to report measures of accuracy, or the population sample size was too small to be meaningful thereby limiting the power and generalisability of results (Alsaaod *et al.*, 2019). Further, our recent systematic review investigating lameness detection technologies found that pertinent information such as animal selection and spectrum of disease, as well as characteristics of dairy herds under investigation was poorly described in the majority of the studies reviewed, making it difficult to determine the quality of reported performance measures (Dutton-Regester *et al.*, 2018). Given that Van De Gucht *et al.* (2018) demonstrated that high performance was a major determinant in farmers deciding to use new technologies, it is essential that future studies are designed to produce the highest quality information to enable farmers to be confident in their decision-making when embracing new technologies. As recommended in our systematic review, again we reiterate the importance of using the STARD guidelines (Standards for Reporting of Diagnostic Accuracy) when authors are investigating new lameness detection technologies.

In addition to performance, not surprisingly, Van De Gucht *et al.* (2018) also showed cost to be an important determinant for the uptake of a new technology. This is consistent with findings from our recent study which found cost to be a potential barrier for some dairy farmers in making changes to their current management of lameness (Dutton-Regester *et al.*, 2019). Therefore, a reliable cost-benefit analysis of available technologies is pivotal for dairy farmers in deciding which technology can be financially sustainable in the long-term. Farmers' willingness to invest in new technologies will depend on the magnitude of return if they utilise these on their farms, which can be measured by willingness to pay (WTP). A survey by Bennett *et al.* (2014) explored UK dairy farmers' WTP to reduce the prevalence of lameness and reported these varied significantly between farmers, with mean WTP of UK£411 per lame cow and a median of UK£249. However, farmers expressed a substantial WTP to avoid the inconvenience associated with lameness control (median WTP UK£97 per lame cow). The variations in WTP could be due to differences in farming practice, farmers' perception of cost of lameness and other attributable risk factors at each farm. In order to enhance WTP, dairy farmers are required to have a better understanding of the direct and indirect costs of lameness and the potential benefits of automated detection technologies to be convinced that the chosen system would be a valuable investment.

Van De Gucht *et al.* (2017) also found that dairy farmers were favourably inclined to using automated lameness-detection technologies after learning more about the consequences of late detection of lameness and associated costs. This reinforces the idea of implementing a demonstration farm network, as proposed in our recent paper (Dutton-Regester *et al.*, 2019). This proposed network would have the capacity to show dairy farmers how lameness detection technologies can be successfully implemented on-farm. These farms could collect data regarding lameness incidence, lameness lesion type and severity, cost per case of lameness, duration of and repeat cases of lameness, milk yield per cow and calving to conception intervals, allowing farmers to compare their averages to those from farms utilising automated lameness detection technologies. Further, these demonstration farms would have the capacity to collect data regarding costs (both fixed coast such as purchase of equipment and variable costs including training and labour) associated with incorporating these technologies on-farm, giving dairy farmers the ability to assess the financial worth of implementing these technologies. By providing this information, dairy farmer perceptions concerning the importance of lameness may be heightened, removing the uncertainty around the advantages of automated lameness detection technologies.

Conclusion

Lameness is a major health issue in dairy herds, compromising dairy cow welfare and productivity and resulting in significant economic loss to the dairy industry. Many automated lameness detection technologies have been proposed to assist dairy farmers in managing their herds. However, limitations such as cost, performance and dairy farmer perception of the usefulness of these technologies, can make them unattractive to dairy farmers. There is a need to more thoroughly evaluate the effectiveness of these technologies under on-farm conditions, possibly in the form of a demonstration farm network, in order to generate the necessary data required to show dairy farmers that these technologies are reliable and are economically rational for their dairy business.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S0022029920000497.

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