Descriptive evaluation of camera-based lameness detection technology paired with artificial intelligence in dairy cattle

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Abstract

The aim of this study was to explore whether autonomous camera-based (AUTO) mobility scores could detect first lameness occurrence earlier in cows, by assessing the association between average weekly autonomous camera-based (AUTO) mobility scores and cows with a lesion for the first time. The AUTO scores data were collected from 2,982 cows in a single farm from April to December 2022, including cow ID, mobility score (0 to 100), and observation date and time. Historical farm hoof lesion data were collected from 2,204 cows and used to determine cow lesion history and date of lesion diagnosis (LD). To remove the confounding impact of chronicity, the study focused on cows with no history of lameness and categorized them into two categories: those with a first-time LD (LESION) and those seen by a hoof trimmer without an LD (TRIM). These categories were compared based on when the trimming occurred: within seven days of dry off (DOT) or at a random time based on farm staff observation. Individual AUTO scores were summarized into moving average weekly scores. All weekly AUTO scores were reported as median [IQR]. Comparisons were made for the LESION cows by lesion types. The lesion types for DOT (n = 60) were 3.3% toe ulcer (TOE), 1.7% white line disease (WLD), and 1.7% sole ulcer (SU), while the remaining had no reported lesion (93%; TRIM). For RT (n = 239), 63% were TRIM, 17% digital dermatitis (DD), 7.5% SU, 7.1% WLD, 4.2% foot rot (FR), and 4.2% TOE. Four weeks prior to RT, LESION had a similar median score (37.6 [18.3]) to TRIM (38.5 [13.7]). One week prior to RT, LESION had a higher median score (41.1 [17.5]) compared to TRIM (39.2 [15.5]). For DOT, four weeks prior, LESION had a higher median score (59.2 [2.1]) than TRIM (40.0 [9.9]), and this pattern persisted through 1 week prior. FR had the highest score (47.3 [22.9]) four weeks earlier, followed by SU (42.8 [19.0]), WLD (41.2 [13.5]), and DD (35.0 [14.1]). One week prior, these scores were increased for FR (57.1 [11.5]), SU (44.5 [12.4]), WLD (44.3 [26.8]), and DD (39.5 [10.6]). The results suggest that AUTO scores may have the potential to detect some lesions earlier. However, there is variation between cows and weeks that presents a challenge yet to be addressed.

Keywords: lameness detection, artificial intelligence, dairy cattle.

Introduction

Lameness is a common problem in dairy cows worldwide, with incidence rates in North America ranging from 10% to 55% (Keyserlingk *et al.,* 2012; Cook *et al.,* 2016; Adams *et al.,* 2017). Lameness can have a significant impact on cow productivity, health, and welfare, accounting for 10 to 20% of all involuntary culling (Green *et al.,* 2002; Cha *et al.,* 2010). Several studies have investigated the prevalence, risk factors, and impact of lameness in dairy cows. Adams *et al.* (2017) estimated that the prevalence of lameness in dairy herds in the United States was 18.8%. Cha *et al.* (2010) found that lameness was a major factor in culling dairy cows in Quebec, with 25% of cows being culled due to lameness. Cook *et al.* (2016) reported that lameness can reduce milk production by up to 10%. Green *et al.* (2002) found that lameness can increase the risk of mastitis and other health problems in dairy cows. Keyserlingk *et al.* (2012) found that lameness can reduce cow welfare by increasing stress and pain. Mostert *et al.* (2018) identified that lameness can have a significant economic impact on dairy farms, increasing calving interval, antibiotic usage and GHG emissions.

There are a number of things that can be done to improve dairy hoof health. The FARM program is a lameness prevention program that was developed by the US National Milk Producers Federation. The program requires that less than 5% of lactating cows be scored as severely lame. The FARM program includes several management practices that can help to prevent lameness, such as: providing cows with adequate bedding, using smooth flooring, providing regular hoof care and monitoring cow lameness. Genetic selection can also be used to improve dairy hoof health by selecting animals with good hoof health traits. These traits can be identified by using a variety of methods, such as ultrasound, hoof scoring, etc. and combined with pedigree and genomic data. Dairy farmers can help to improve the hoof health of their herds if they are able to identify and select those animals with more favorable hoof health genetics; however, there are several challenges that need to be addressed in order to make genetic selection effective. One challenge is the low heritability of hoof health traits. Heritability is a measure of how much of the phenotypic variation in a trait is due to genetics. The heritability of hoof health traits is estimated to be less than 1% when using producer-recorded incidence data. This makes it difficult to select for bulls with good hoof health traits. Another challenge is the consistency of reporting. Hoof health data is often not reported consistently across herds. This makes it difficult to compare the hoof health of different herds and to identify bulls with good hoof health traits. Despite these challenges, genetic selection is a feasible approach to improving dairy hoof health. By addressing the challenges of low heritability and inconsistent reporting, it is possible to identify bulls with favorable hoof health traits and to improve the hoof health of dairy herds. In 2017, the ICAR (International Committee for Animal Recording) updated its hoof lesion definitions to allow for more accurate recording of hoof health data. This update will help to improve the consistency of reporting. By addressing the challenges of low heritability and inconsistent reporting, it is possible to use genetic selection to improve dairy hoof health.

Mobility scoring: there are numerous different scales used to score mobility, including continuous scales (0 to 1, 0 to 10, 0 to 100) and ordinal scales (2 levels up to 13 levels with ½ point increments). The choice of scale is often based on the specific purpose of the scoring system. For example, a continuous scale may be used to track changes in mobility over time, while an ordinal scale may be used to make comparisons between different animals. One challenge with mobility scoring is that there is a lack of consistency in how the scales are used. For example, the same scale may be used differently by different people or in different settings. This can make it difficult to compare scores across different studies or to make accurate assessments of mobility. Another challenge with mobility scoring is that there is a potential for bias. For example, the person scoring the mobility may be influenced by their own personal experiences. This can lead to inaccurate assessments of mobility. Despite these challenges, mobility scoring can be a useful tool for assessing and monitoring mobility. By using a consistent and unbiased scoring system, it is possible to obtain accurate and reliable information about mobility.

Hoof trimmer data

Hoof trimmer data can be used to collect information on specific lesions, such as sole ulcers, white line disease, and hoof cracks. This information can be used to improve the accuracy of mobility scoring and to identify cows that are at risk of lameness. The heritability of hoof lesions ranges from 1 to 14% (linear scale); 6 to 39% (threshold scale) depending on the lesion. This means that a portion of the variation in hoof lesions is due to genetics. By using hoof trimmer data to collect information on specific lesions, it is possible to identify bulls more or less susceptible to these hoof lesions. In 2015, Dhakal *et al.* found that the heritability of sole ulcers was 14%. This means that about 14% of the variation in sole ulcers is due to genetics. In 2018, Heringstad *et al.* found that the heritability of white line disease was 39%, indicating that about 39% of the variation in white line disease is due to genetics. The use of hoof-trimming records is recommended for maximum genetic gain (Heringstad *et al.,* 2018). This is because hoof-trimming records provide a more accurate assessment of hoof health than other methods, such as visual inspection. Hoof-trimming records with documentation of specific lesions can serve as a source of more accurate phenotypes to be used for genetic evaluation in order to identify those animals with favorable hoof health traits. These data are more labor-intensive and time-consuming to acquire, however.

The Council of Dairy Cattle Breeding (CDCB) and the University of Minnesota (UMN) are collaborating to develop a data pipeline that captures mobility and hoof health phenotypes. This data pipeline will be used to provide genetic evaluations for hoof health, provide hoof health management tools for dairy farms, and enhance the capacity of hoof trimmers. The data pipeline will be developed using a variety of methods, among others, hoof trimmer records and mobility scores obtained with a video analytic platform. The data pipeline will be used to develop genetic evaluations for hoof health, which will be used to identify animals with good hoof health traits. The data pipeline can also be utilized as a hoof health management tool for dairy farms by helping dairy farmers identify cows that are at risk of lameness and preventing lameness from occurring. The data pipeline will also be used to enhance the capacity of hoof trimmers, who will be trained to use standardized methods to identify and treat hoof lesions. The development of this data pipeline will have several benefits, including improved hoof health in dairy cows, increased productivity in dairy herds, reduced culling of lame cows, and reduced costs associated with lameness.

Objectives

This study had the following objectives:

- Describe how automatically derived scores lead up to the first diagnosis of a hoof lesion.
- Describe how consistent same-day scores are. The consistency of same-day scores is important because it allows for accurate tracking of the progress of an abnormal mobility and

- Can a camera system potentially be used to detect mobility problems or hoof lesions earlier to prevent them from becoming more serious and to improve the hoof health of dairy cows?

Methods

Hoof Trimming data

Hoof trimmers were recruited by Dr. Gerard Cramer, at the University of Minnesota to participate in the project. Hoof trimmers received specific training on how to identify and report hoof lesions according to ICAR standards. Hoof trimmer data was collected from one pilot herd in Iowa from 2017/06/16 to 2022/11/30 (ongoing). The data was merged with on-farm software data based on cow ID and calving date. The data collected from the hoof trimmers included the following information: cow ID, trimming date, presence and type of lesions and treatments administered. Historical farm hoof lesion data were collected from 2,204 cows and used to determine cow lesion history and date of lesion diagnosis. To remove the confounding impact of chronicity, the study focused on cows with no history of lameness and categorized them into two categories: those with a first-time lesion diagnosis (LESION) and those seen by a hoof trimmer without a lesion diagnosis (TRIM). Lesions diagnosed included sole ulcer (SU), digital dermatitis (DD), foot rot (FR), white line disease (WLD), toe ulcer (TOE) and unknown. These categories were compared based on when the trimming occurred: within seven days of dry off (DOT) or at a random time (RT) based on farm staff observation and recommendation for trimming.

Video analytics platform (CattleEye) data

A video analytics platform was used to monitor locomotion in cows and identify those that may require further checking/intervention. The platform included a mobility scoring module that analyzed video footage of cows walking through a standard 2D security camera mounted over the exit of a milking parlor. The data was analyzed by a computer algorithm trained to identify cows that were walking abnormally, these cows were then flagged for further checking. The data collected by CattleEye contained Cow ID, Date, Time, and mobility score (1-100; AUTO). The video analytics platform scoring performance has been validated and performs as well as a human mobility score estimator (Anagnostopoulos *et al.,* 2022). The study data presented herein was collected in one farm from April 16, 2022 to December 29, 2022. Individual AUTO scores were summarized into moving average weekly scores. All weekly AUTO scores were reported as median [IQR].

Results

Comparisons were made for the LESION cows by lesion types. The lesion types for DOT (n = 60) were 93% TRIM, 3.3% toe ulcer (TOE), 1.7% white line disease (WLD), and 1.7% sole ulcer (SU). For RT (n = 239), 63% were TRIM, 17% digital dermatitis (DD), 7.5% SU, 7.1% WLD, 4.2% foot rot (FR), and 4.2% TOE. Four weeks prior to RT, LESION had a similar median score (37.6 [18.3]) to TRIM (38.5 [13.7]). One week prior to RT, LESION had a higher median score (41.1 [17.5]) compared to TRIM (39.2 [15.5]). For DOT, four weeks prior, LESION had a higher median score (59.2 [2.1]) than TRIM (40.0 [9.9]), and this pattern persisted through 1 week prior. FR had the highest score (47.3 [22.9]) four weeks earlier, followed by SU (42.8 [19.0]), WLD (41.2 [13.5]), and DD (35.0 [14.1]). One week prior, these scores were increased for FR (57.1 [11.5]), SU (44.5 [12.4]), WLD (44.3 [26.8]), and DD (39.5 [10.6]).

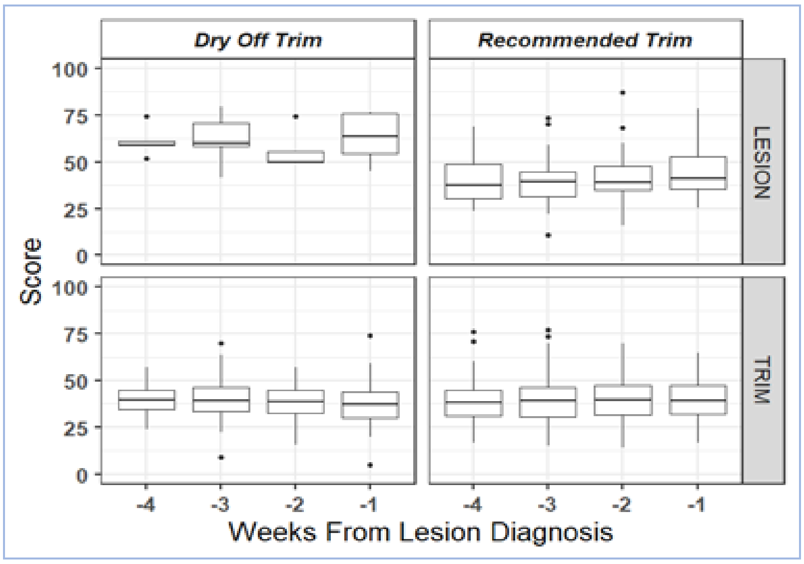

Figure 1. Median [IQR] of video analytics platform mobility scores by trimming type, lesion diagnosis and weeks before lesion diagnosis.

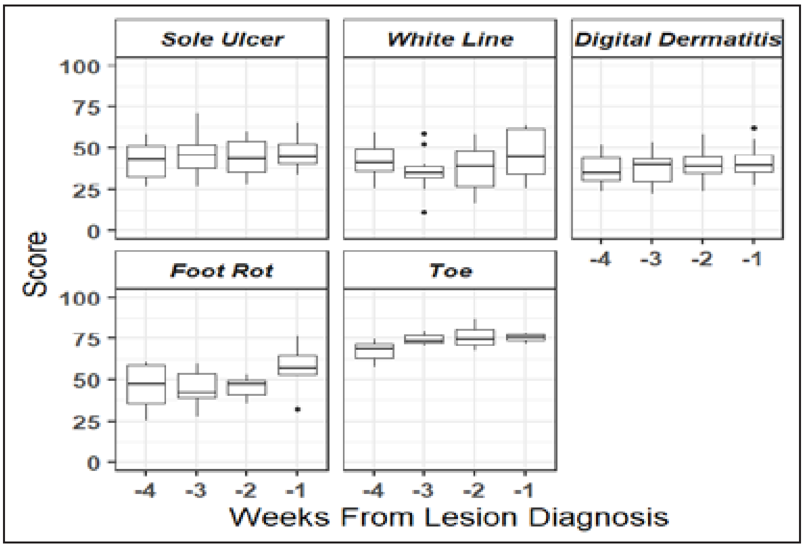

Figure 2. Median [IQR] of video analytics platform mobility scores by lesion diagnosis and weeks before lesion diagnosis.

Conclusions

The results suggest that AUTO scores may have the potential to detect some lesions earlier. However, there is variation between cows and weeks that presents a challenge yet to be addressed.

References

Adams, L. G., Cook, B. J., and LeBlanc, S. J. (2017). Lameness in dairy cows: A review of prevalence, risk factors, and impact. Journal of Dairy Science, 100(8), 5375-5389.

Anagnostopoulos, A., B.E. Griffiths, N. Siachos, J. Neary, R.F. Smith, and G. Oikonomou. (2023). Initial validation of an intelligent video surveillance system for automatic detection of dairy cattle lameness. Frontiers in Veterinary Science 10. Cha, Y., LeBlanc, S. J., and LeBlanc, J. M. (2010). Lameness and culling in dairy herds in Quebec. Journal of Dairy Science, 93(1), 275-282.

Anagnostopoulos, A., B.E. Griffiths, N. Siachos, J. Neary, R.F. Smith, and G. Oikonomou. 2023. Initial validation of an intelligent video surveillance system for automatic detection of dairy cattle lameness. Frontiers in Veterinary Science 10.

Cook, B. J., Adams, L. G., LeBlanc, S. J., and LeBlanc, J. M. (2016). Lameness in dairy cows: A review of prevalence, risk factors, and impact. Journal of Dairy Science, 99(12), 8679-8694.

Dhakal, R., Ottoboni, L., Lim, E. T., Replogle, J. M., Raj, T., *et al.* (2015). Heritability of lameness traits in Holstein-Friesian dairy cattle in the United States. Journal of Dairy Science, 98(8), 5064-5073.

Green, J. L., LeBlanc, S. J., and LeBlanc, J. M. (2002). Lameness and culling in dairy herds in Ontario. Journal of Dairy Science, 85(11), 2896-2903.

Heringstad, B., C. Egger-Danner, N. Charfeddine, J.E. Pryce, K.F. Stock, J. Kofler, A.M. Sogstad, M. Holzhauer, A. Fiedler, K. Müller, P. Nielsen, G. Thomas, N. Gengler, G. de Jong, C. Ødegård, F. Malchiodi, F. Miglior, M. Alsaaod, and J.B. Cole. 2018. Invited review: Genetics and claw health: Opportunities to enhance claw health by genetic selection. Journal of Dairy Science 101:4801–4821. doi:10.3168/jds.2017-13531.

Keyserlingk, M. A. G., LeBlanc, S. J., and LeBlanc, J. M. (2012). Lameness in dairy cows: A review of prevalence, risk factors, and impact. Journal of Dairy Science, 95(12), 5909-5925.

Mostert, S. J., Steyn, P. J., and Cloete, S. W. (2018). The impact of lameness on production, health, and welfare of dairy cows: A review. Journal of Dairy Science, 101(1), 223-238.