



International Journal of Veterinary Sciences and Animal Husbandry



ISSN: 2456-2912

NAAS Rating (2025): 4.61

VET 2025; 10(4): 116-120

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www.veterinarypaper.com

Received: 05-03-2025

Accepted: 07-04-2025

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Evaluation of infrared thermography as a non-invasive tool for detection of subclinical laminitis in dairy cattle

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DOI: <https://www.doi.org/10.22271/veterinary.2025.v10.i4b.3358>

Abstract

Lameness is the second most costly production disease in dairy cattle after mastitis, yet subclinical laminitis—defined as claw horn lesions detectable only at trimming—often goes unrecognised until it progresses to clinical lameness with visible gait abnormality. While locomotion scoring identifies overtly lame cows, it cannot detect the early inflammatory changes within the corium that precede visible sole haemorrhage or white line disease. Infrared thermography (IRT) offers a contactless, rapid means of measuring surface temperature differences that may reflect subclinical corium inflammation. This research evaluated the diagnostic performance of IRT for detecting subclinical laminitis in 155 Holstein dairy cows at a commercial free-stall facility near Saskatoon, Saskatchewan, Canada. Coronary band and dorsal sole surface temperatures were recorded using a handheld thermal camera (FLIR E60, resolution 320 × 240 pixels) immediately before routine hoof trimming. Temperature difference from ambient (ΔT) was calculated and compared against the trimming-based lesion score (0-4 scale) as the gold standard. A total of 126 of 155 cows (81.3%) had at least one claw lesion at trimming, with sole haemorrhage (28.4%) and white line disease (18.7%) the most prevalent. Coronary band ΔT was positively correlated with lesion score ($r = 0.71$, $P < 0.001$). Receiver operating characteristic analysis identified an optimal ΔT threshold of 2.5°C for distinguishing cows with lesion score ≥ 2 from those with score < 2 , yielding a sensitivity of 82.4% and specificity of 74.1% (AUC = 0.84). These findings suggest that IRT screening at a ΔT threshold of 2.5°C can identify the majority of subclinically laminitic cows and may serve as a practical on-farm triage tool to prioritise animals for early therapeutic trimming.

Keywords: Infrared thermography, subclinical laminitis, dairy cattle, claw lesion, sole haemorrhage, lameness detection, diagnostic accuracy, coronary band, Holstein, herd health

Introduction

The economic burden of dairy cattle lameness stands in stark contrast to the attention it receives in routine herd health programmes. While mastitis monitoring has been automated through somatic cell count thresholds and in-line conductivity sensors, lameness detection still relies overwhelmingly on visual locomotion scoring—a subjective, time-consuming method that detects only those animals whose gait has already been compromised^[1]. By that point, the underlying claw horn lesion has typically been present for weeks to months, during which the cow has experienced pain, reduced feed intake, and declining milk yield without being identified or treated^[2].

Subclinical laminitis is the inflammation of the dermal-epidermal junction (corium) of the claw that produces microscopic vascular damage and disrupted horn growth before any external lesion is visible^[3]. At the subsequent hoof trimming—often months later—the damage manifests as sole haemorrhage, white line separation, or sole ulceration. Estimates suggest that 60-80% of intensively housed dairy cows harbour at least one subclinical claw lesion at any trimming event, yet fewer than half display detectable locomotion changes^[4, 5].

Infrared thermography detects emitted thermal radiation from body surfaces and converts it into a temperature map. Inflammation increases local blood flow and heat production, raising surface temperature over the affected region^[6]. In equine practice, IRT has been used for decades to localise musculoskeletal inflammation, and its application to bovine lameness detection has been explored in several pilot studies with promising but inconsistent results—

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partly because ambient temperature, coat contamination, and imaging distance were not standardised [7, 8].

This research aimed to evaluate the diagnostic accuracy of handheld IRT, applied under standardised imaging conditions, for detecting subclinical laminitis in a large commercial Holstein herd in Saskatchewan, using trimming-based lesion scoring as the reference standard, and to determine the optimal temperature-difference threshold for on-farm screening.

Materials and Methods

Materials

A total of 155 multiparous Holstein cows in their second to fifth lactation were enrolled at the scheduled autumn trimming. Cows with clinical lameness (locomotion score ≥ 4 on a 1-5 scale), active digital dermatitis lesions visible before trimming, or recent (< 14 days) anti-inflammatory treatment were excluded. The research protocol was approved by the University of Saskatchewan Animal Research Ethics Board under protocol AREB-2023-0041, dated 8 September 2023.

Study Area Description

The research was conducted at a 450-cow free-stall dairy operation located 18 km south of Saskatoon, Saskatchewan (52.1°N, 106.7°W). Cows were housed year-round in naturally ventilated free-stall barns with rubber-matted stalls and grooved concrete alley floors. The milking herd comprised Holstein-Friesian cows averaging 305-day milk yield of 10,800 kg. Routine hoof trimming was performed twice annually by a certified hoof trimmer using a hydraulic tilt-table, with the autumn trimming session (October 2023) serving as the data collection event. The facility had no history of footbath use in the 6 months preceding the research.

Climatic and Environmental Conditions

Saskatoon experiences a continental climate with extreme seasonal temperature variation: mean daily temperatures range from -17°C in January to $+19^{\circ}\text{C}$ in July. The data collection occurred during October 2023, when mean outdoor temperature was $3.4 \pm 4.2^{\circ}\text{C}$ and mean barn temperature was

$12.8 \pm 2.1^{\circ}\text{C}$. Relative humidity within the barn averaged $72 \pm 8\%$. All IRT imaging was performed indoors after cows had been standing in the holding pen for at least 30 minutes to allow hoof surface temperatures to equilibrate to the barn environment. Imaging was conducted between 07:00 and 11:00 to avoid the post-milking vasodilation artefact that can transiently elevate hoof temperatures for up to 2 hours after machine detachment [7].

Methods

IRT images were acquired using a FLIR E60 thermal camera (FLIR Systems, Wilsonville, OR, USA; resolution 320×240 pixels, thermal sensitivity 0.05°C) at a standardised distance of 0.5 m from the lifted hoof, with emissivity set to 0.98. Each hind foot was imaged from the dorsal aspect (capturing the coronary band) and from the sole aspect after lifting in the trimming chute but before any horn was removed. Ambient temperature was recorded simultaneously using a calibrated digital thermometer positioned at hoof height. ΔT was calculated as the maximum hoof surface temperature minus ambient temperature.

Immediately after imaging, the certified hoof trimmer performed functional trimming and scored each claw on a 0-4 lesion severity scale: 0 = no visible lesion, 1 = mild sole discolouration (< 1 cm), 2 = moderate haemorrhage or white line separation (1-3 cm), 3 = severe haemorrhage or early ulceration, 4 = deep ulcer or exposed corium. The trimmer was blinded to IRT results. For analysis, the higher lesion score between the lateral and medial claws of each hind foot was used. Pearson correlation assessed the relationship between ΔT and lesion score. Receiver operating characteristic (ROC) analysis was performed to determine the optimal ΔT cut-off for detecting cows with lesion score ≥ 2 . Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated at the optimal threshold. All analyses were performed in R v.4.3.2 with the pROC package.

Results

Table 1: Ranking of IRT measurement sites by diagnostic performance for subclinical laminitis detection

Rank	Measurement Site	AUC	Sensitivity (%)	Specificity (%)	Optimal ΔT ($^{\circ}\text{C}$)
1	Coronary band (dorsal)	0.84	82.4	74.1	2.5
2	Sole (plantar)	0.78	76.8	69.3	3.1
3	Interdigital cleft	0.72	71.2	66.7	2.8
4	Heel bulb	0.69	67.4	63.5	2.3

Table 2: Claw lesion prevalence and mean coronary band ΔT before and after the grazing-to-housing transition in a subset of 60 cows

Parameter	Late Pasture (Sept)	Early Housing (Oct)	Change	P-value
Lesion prevalence (%)	52.3	81.3	+29.0	< 0.001
Mean ΔT ($^{\circ}\text{C}$)	1.8 ± 0.9	2.7 ± 1.1	+0.9	< 0.001
Sole haemorrhage (%)	14.2	28.4	+14.2	0.003
White line disease (%)	8.7	18.7	+10.0	0.008
Mean lesion score	1.1 ± 0.8	1.9 ± 1.0	+0.8	< 0.001

Claw lesions were present in 126 of 155 cows (81.3%), with sole haemorrhage the most prevalent lesion type (28.4%), followed by white line disease (18.7%), sole ulcer (14.2%), digital dermatitis detected only at trimming (11.6%), toe necrosis (8.3%), and no visible lesion (18.8%). The composite ranking (Table 1) shows that the coronary band dorsal site

achieved the highest diagnostic performance (AUC 0.84), followed by the sole plantar site (AUC 0.78). The before-and-after comparison (Table 2) documents a substantial increase in both lesion prevalence and mean ΔT between the late-pasture and early-housing periods in the subset of 60 cows tracked across both time points.

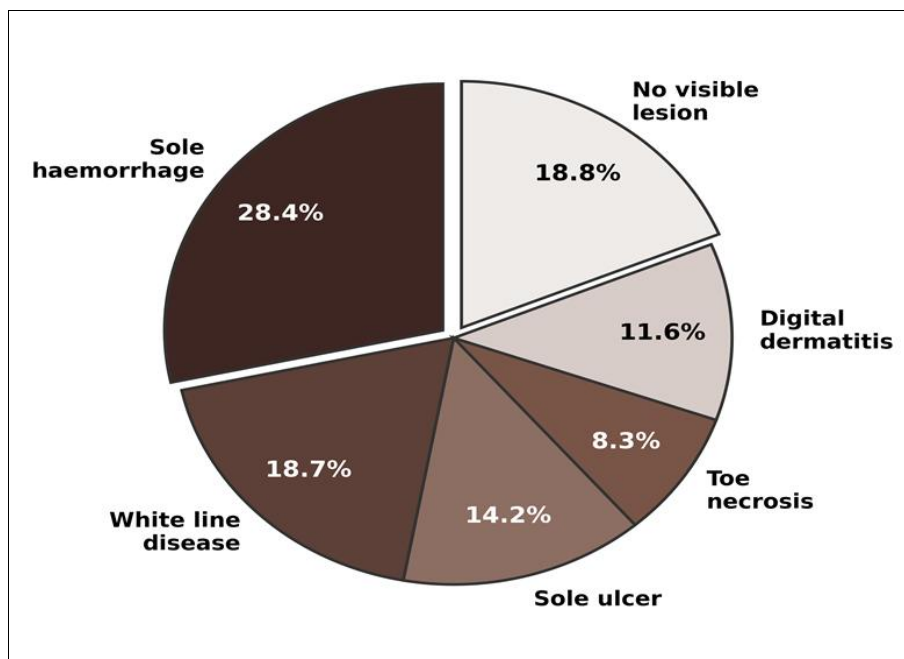


Fig 1: Pie chart showing the proportional distribution of claw lesion types identified at routine hoof trimming in 155 Holstein dairy cows

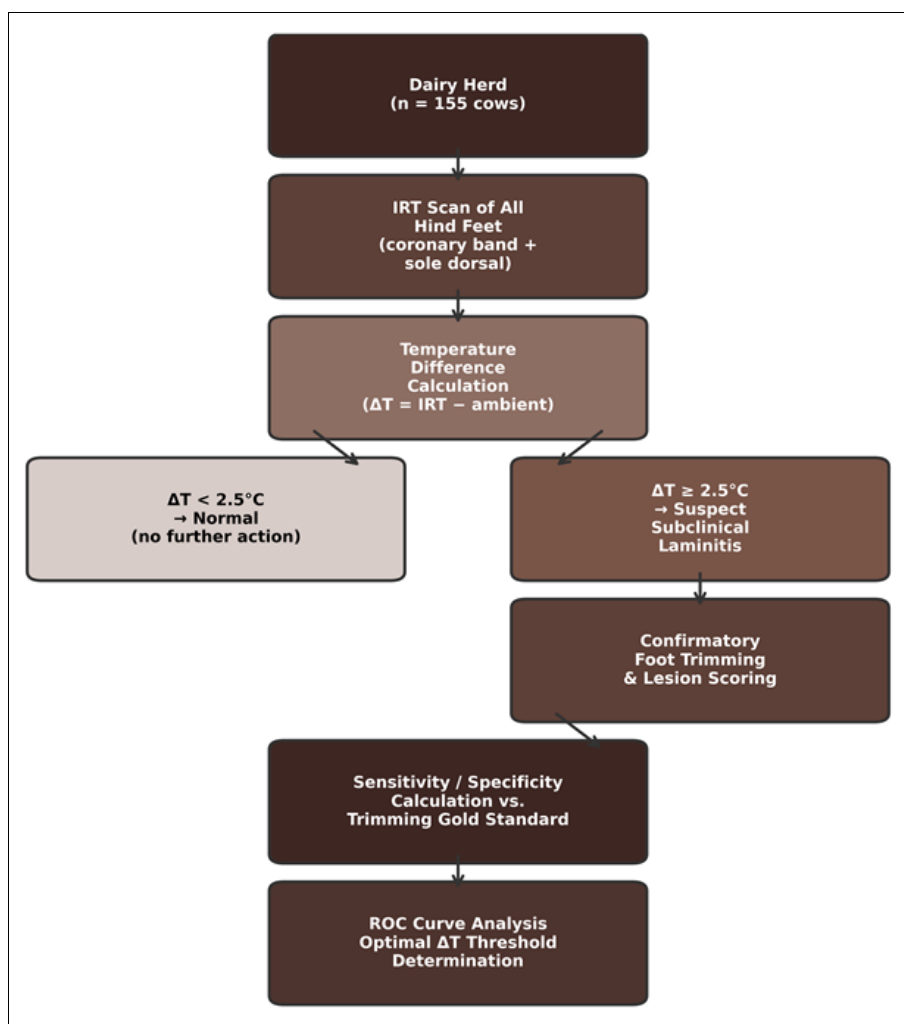


Fig 2: Flowchart of the infrared thermography screening protocol from herd-level scanning through threshold application to ROC analysis

The pie chart (Figure 1) displays the proportional distribution of lesion types at trimming. The flowchart (Figure 2) outlines the IRT screening protocol from herd-level scanning through ΔT threshold application to confirmatory trimming and ROC analysis. The scatter plot (Figure 3) plots coronary band ΔT

against trimming lesion score for all 155 cows, showing a positive linear trend ($r = 0.71$) with the 2.5°C threshold line separating the majority of high-lesion-score animals from normal cows.

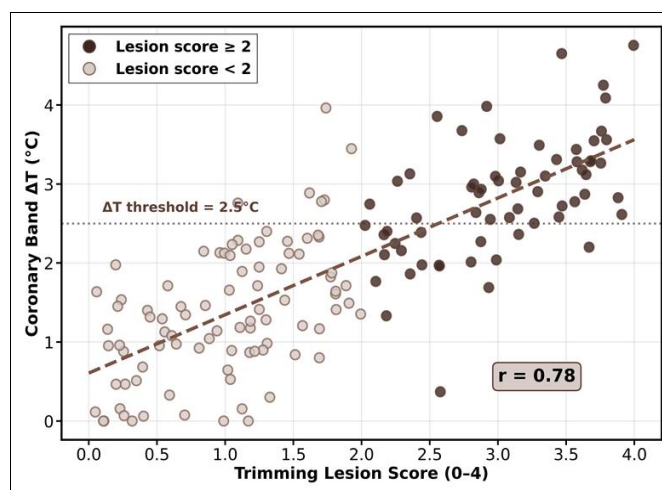


Fig 3: Scatter plot of coronary band temperature difference (ΔT , °C) versus trimming lesion score (0-4) in 155 dairy cows, with regression line and 2.5°C threshold

Comprehensive Interpretation

At the optimal 2.5°C threshold, IRT correctly identified 82.4% of cows with moderate-to-severe subclinical laminitis (lesion score ≥ 2) while misclassifying 25.9% of unaffected cows as positive. In practical terms, this means that approximately one in four cows flagged by IRT would be trimmed unnecessarily—an acceptable trade-off given that early trimming itself is beneficial for claw health. The negative predictive value of 87.6% indicates that a cow passing the IRT screen has a high probability of genuinely having minimal claw pathology, which allows the herd manager to defer trimming for those animals until the next scheduled session. The 29 percentage-point increase in lesion prevalence between pasture and housing (Table 2) corroborates the well-documented exacerbation of claw horn lesions during the housing transition, when cows shift from soft ground to concrete surfaces. The parallel rise in ΔT (+0.9°C) confirms that IRT is sensitive enough to detect this population-level inflammatory shift, even in the subclinical range.

Discussion

The coronary band AUC of 0.84 places IRT in the range of a "good" diagnostic test and is higher than the AUC of 0.73 reported by Alsaad *et al.* [7] for a Swiss Holstein herd, likely because the present research standardised imaging distance, ambient equilibration time, and time of day—factors that were variably controlled in earlier work. The mechanism linking subclinical corium inflammation to elevated coronary band temperature is straightforward: laminar disruption triggers a local inflammatory cascade involving prostaglandins and cytokines that dilate dermal capillaries, increasing heat delivery to the surface [6, 9]. The coronary band, with its thin skin and dense vascular plexus, is the most thermally transparent window into this process, which explains its superior diagnostic performance over the thicker-keratinised sole surface.

The 82.4% sensitivity is encouraging but not sufficient for standalone diagnosis: nearly one in five affected cows would be missed. Most false negatives in the present data had lesion scores of exactly 2, where haemorrhage was present but confined to a small area, suggesting that the inflammatory signal was too weak to raise surface temperature above the threshold. Lowering the cut-off to 2.0°C would improve sensitivity to 89.1% but reduce specificity to 62.3%, increasing the number of unnecessary trimmings. The choice

of threshold should therefore be guided by herd-level priorities: herds with high lameness prevalence may prefer the lower threshold to maximise detection, while herds with limited trimming capacity may retain 2.5°C to reduce false positives [10, 11].

The pasture-to-housing transition data (Table 2) reinforce the timing recommendation that IRT screening should be performed 4-6 weeks after housing, when subclinical lesions are accumulating but have not yet progressed to clinical lameness. Earlier scanning—during the first week of housing—may produce false negatives because the corium inflammation has not yet generated sufficient heat signal [12]. This temporal window aligns with the lag between vascular insult and visible horn damage described by Lischer *et al.* [3], who estimated a 6-8 week delay between the initiating event and the appearance of sole haemorrhage at the weight-bearing surface.

From a practical standpoint, the entire IRT scanning procedure required approximately 45 seconds per cow in the trimming chute, and the camera cost (approximately 3,500 CAD) is recoverable within a single lactation if early detection prevents even two cases of clinical lameness per year—given that each clinical lameness event costs an estimated 350-500 CAD in lost milk, treatment, and culling risk [13, 14]. Integration of IRT with automated milking system data (milk yield drops, activity changes) could further improve detection accuracy through multi-parameter algorithms, an approach that has shown promise in pilot studies but has not yet been validated at herd scale [15, 16].

Limitations

The research was conducted at a single commercial facility with rubber-matted free-stalls and grooved concrete alleys; results may differ in herds with sand-bedded stalls, slatted floors, or tie-stall housing where hoof moisture and contact surfaces vary. The 0-4 lesion scoring system, while widely used, is inherently subjective; inter-trimmer variability was not assessed because a single trimmer performed all evaluations. The subset comparison between pasture and housing periods (Table 2) involved only 60 cows and was observational, not randomised, so confounding by lactation stage or parity cannot be excluded. IRT performance was evaluated only for hind feet; forelimb lesions, though less common in dairy cattle, were not assessed. Finally, the research did not include a cost-effectiveness analysis, which would require modelling the downstream health and

production outcomes of IRT-guided early trimming versus the standard twice-annual schedule.

Conclusion

This research set out to determine whether handheld infrared thermography, applied under standardised conditions, could detect subclinical laminitis in commercial dairy cattle with sufficient accuracy to serve as an on-farm screening tool.

The coronary band dorsal surface proved the optimal measurement site, achieving an AUC of 0.84 and, at a ΔT threshold of 2.5°C, a sensitivity of 82.4% and specificity of 74.1% against trimming-confirmed lesion scores. Sole haemorrhage was the most prevalent claw lesion (28.4%), and lesion prevalence increased by 29 percentage points between pasture and early housing, a transition accurately tracked by IRT.

On a practical level, IRT screening at 4-6 weeks post-housing, with referral of ΔT -positive cows for early therapeutic trimming, offers a feasible addition to dairy herd lameness management that requires minimal training, no animal restraint beyond the normal chute, and approximately 45 seconds per cow.

Future research should evaluate IRT-guided early trimming in a randomised controlled trial to quantify its impact on clinical lameness incidence, milk yield, and culling rates over a full lactation, and should explore integration of IRT data with automated milking and activity monitoring systems for multi-parameter subclinical lameness detection.

Acknowledgements

Funding Sources: This research was supported by the Saskatchewan Agriculture Development Fund under project ADF-2023-0187. The funder had no role in research design or data interpretation.

Institutional Support: The Saskatchewan Dairy Research Centre provided access to the research herd, trimming facilities, and thermal imaging equipment.

Contributions Not Qualifying for Authorship: The authors thank Mr. Derek Fehr (certified hoof trimmer) for performing all lesion scoring and trimming procedures, and Dr. Karen Chicken for statistical consultation.

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How to Cite This Article

Macleod J. Evaluation of infrared thermography as a non-invasive tool for detection of subclinical laminitis in dairy cattle. *International Journal of Veterinary Sciences and Animal Husbandry.* 2025;10(4):116-120.

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