Investigating the impact of 1h daily outdoor access on the gait and hoof health of non-clinically lame cows housed in a movement restricted environment

A. Nejati,1 E. Shepley,2 G. M. Dallago,3 and E. Vasseur1*

Abstract: Tie-stalls, recognized as highly restrictive housing systems, could contribute to reduced locomotor skills in cows over time. While outdoor access is known to benefit clinically lame cows, its influence on non-clinically lame cows is lesser known. This study evaluated the influence of 1h daily outdoor access on the gait and hoof health of non-clinically lame lactating Holstein cows in tie-stalls. We examined 30 cows, blocked by parity and DIM, and evenly assigned them to one of 2 groups: Exercise (1h outdoor access 5d/wk for 5 weeks) or Non-Exercise. A visual scoring system assessed 6 gait attributes and overall gait (on scales of 0–5 and 1–5, respectively) at Pre-trial, Post-trial, and 8-week Follow-up stages. A total of 15 cows (9 Exercise, 6 Non-Exercise) underwent visual gait scoring, with logistical challenges and exclusion criteria leading to this selection. Hoof health for all 30 cows was evaluated through clinical examinations during pre-trial and follow-up hoof trims, documenting claw lesions. Additionally, hoof surface thermography captured dorsal views of the coronary band in the 1st and 5th weeks of the trial. Although no significant gait score changes were observed, Exercise cows demonstrated a 1-point improvement in overall gait score and 3 gait attributes after 5 weeks of outdoor access, which persisted at Follow-up. Sole hemorrhages were the only claw lesions observed, and their prevalence and severity remained consistent between Pre-trial and Follow-up for both groups. Thermography showed consistent coronary band temperature metrics across groups and over time. In conclusion, brief outdoor sessions resulted in noticeable, albeit not statistically significant, improvements in the gait of non-clinically lame cows in restrictive housing settings. Additionally, these sessions did not result in hoof lesion development, indicating no adverse effects. Further studies are warranted to evaluate the benefits of different outdoor access and to utilize precise gait and hoof health analysis technologies for a more accurate detection of subtle changes.

Cows housed in indoor housing systems experience different levels of confinement (Shepley et al., 2020). Tie-stall housing is generally considered the most restrictive with regards to dairy cow movement (Shepley et al., 2020), limiting cows in both voluntary movement and social and natural behaviors (Popescu et al., 2013). This continuous level of restriction can cause the cows’ locomotor abilities to decrease over time (Shepley & Vasseur, 2021a), even without leading to clinical lameness. Complementing existing indoor housing systems with access to additional space could alleviate this restriction and improve cow health and welfare (Palacio et al., 2023; Popescu et al., 2013; Shepley et al., 2020). This additional space may take the form of pasture access, where cows have access to fresh forage on which to graze as they range outdoors, or of an alternative outdoor access such as an exercise yard, where the openness of the space and animal density provide enhanced opportunities for movement to the cows (Smid et al., 2020).

Little is known about how providing enhanced opportunities for movement impacts the gait of dairy cows. The few studies available either center their focus on lame animals, highlighting the benefits of outdoor access for improving their condition, were conducted in free-stalls, or were assessed for year-round or seasonal access to pasture (Chapinal et al., 2013; Hernandez-Mendo et al., 2007). As a result, there is limited understanding of how improvements in movement opportunities provided via short exposures to outdoor yards affect the gait of non-clinically lame, movement-restricted cows in tie-stalls. The objective of this study was to investigate the impact of enhancing movement opportunity through the provision of 1h daily access to an outdoor exercise yard on the gait and hoof health of non-clinically lame lactating Holstein cows housed in tie-stalls. We hypothesize that cows given daily outdoor access for 5 weeks will improve their gait compared with those without such access. We also anticipate no negative impact on hoof health, assessed by hoof lesion prevalence/severity and hoof surface temperatures.

This study was part of a larger study conducted at the Macdonald Campus Dairy Unit (McGill University, Ste-Anne-de-Bellevue, QC) evaluating the effect of outdoor access on cows’ welfare and behavior. Ethical animal use was certified by the Animal Care Committee of McGill University and affiliated hospitals and research institutes (#2016–7794). For the study, 30 tie-stall-housed lactating Holstein cows representative of a typical herd DIM and parity distribution, were enrolled. Cows were selected based on their locomotor functionality, excluding cows with ulcerative hoof lesions, clinical lameness scored as a ≥3 on a 5-point scale, or confirmation susceptible to hinder their locomotion. Enrolled cows were grouped into 5 blocks (n = 6/block) by parity (average parity was 2.1, ranging from 1 to 4) and stage of lactation (DIM 166.3 ±

1Department of Animal Science, McGill University, Sainte-Anne-de-Bellevue, Quebec, Canada, 2Department of Veterinary Population Medicine, University of Minnesota, St. Paul, MN, USA, 3Department of Animal Science, University of Manitoba, Winnipeg, Manitoba, Canada. *Corresponding author: Elsa Vasseur, 21111 Lakeshore Rd. Sainte-Anne-de-Bellevue, QC, H9X 3V9, elsa.vasseur@mcgill.ca. © 2024, The Authors. Published by Elsevier Inc. on behalf of the American Dairy Science Association®. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/). Received September 21, 2023. Accepted February 14, 2024.
Hoof thermography images ($n = 480$) were collected from the dorsal view of all 4 feet of all enrolled cows, with assessments conducted twice during both wk 1 and 5 of the trial, before cows were moved outside. All thermal images were taken using a FLIR E4 upgraded to E8 firmware infrared thermal imaging camera (IRC; emissivity value: 0.98; distance from object: 1 m; and reflected temperature: $20^\circ$C) with cows standing in their stalls for at least 10 min before imaging. To reduce the impact of dirtiness on thermography analysis, only thermal images obtained from clean or slightly dirty feet (as per Schreiner and Ruegg (2003) scale) were included. After excluding 47 images, a total of 433 images were retained for further analysis. Ambient temperature was collected by 4 Onset HOBO® MX2300 Temperature /RH Data Loggers (Onset Computer Corporation, Bourne, Massachusetts, USA). The thermal images were initially subjected to a method we term Direct Thermal Analysis using Thermo-CAM Researcher Professional 2.10 software (FLIR Systems, Inc., Wilsonville, Oregon, USA). In this method, 2 regions of interest (ROI) including the coronary band (CB) area and a control skin area above the CB were selected in the software. Four thermal variables were then extracted from the 2 ROIs for further analysis including CB maximum temperature (CB-Max), CB mean temperature (CB-Mean), CB standard deviation (CB-SD), and temperature difference ($\Delta T$) between CB-Max and mean temperature of skin control area. The $\Delta T$ was calculated to consider the within-animal temperature difference rather than absolute values (Alsaaod & Büscher, 2012; Nikkhah et al., 2005). In addition to this, and to further counter the influence of ambient temperature, which is a known factor affecting temperature measurements in infrared imaging (Alsaaod & Büscher, 2012), the thermal images were also subjected to another method, termed Normalization. This includes image processing and data extraction using MATLAB (R2021a, MathWorks Inc., Natick, MA, USA). The image processing consists of cropping a square area where the coronary band is located at the bottom third of the square and the skin above the CB at the top 2 thirds, conversion to greyscale, conversion to double precision, and pixel normalization to a scale of 0–1 (Figure 1). Four common statistical features - mean, standard deviation (SD), skewness, and kurtosis - were extracted from each processed image (Al-Obaidy, 2016; Nejati, 2021).

Statistical analysis was conducted using R (Team, 2021). Claw lesions were treated as a binary variable and analyzed using a mixed effect logistic model with block (1 to 5), treatment group (Non-Exercise and Exercise), period (Pre-trial and Follow-up), and the interaction between treatment and period as fixed effects and claw nested within cow as a random effect. Thermographic data were analyzed using a mixed effects model having block, limb position (fore and hind), treatment group and week (1 to 5), as well as an interaction between treatment group and week, as fixed effects, limb (1 to 4) nested within cow as a random effect, and ambient temperature as a covariate. However, to analyze thermographic data through normalization, the ambient temperature was not included in the model. The overall gait score and 6 gait attributes were analyzed using a mixed effect model having block, treatment group, period difference (Post-trial minus Pre-trial and Follow-up minus Pre-trial), as well as an interaction between treatment group and period difference as fixed effects, and cow as a random effect.

Residual analysis was conducted for all models to evaluate the assumptions that the within-group errors were homoscedastic, independent, and followed a normal distribution and to determine
that the random effects were normally distributed and independent. Heteroscedasticity was modeled by using a variance model with different variances for each level of a stratification variable. General, autoregressive of order 1, and compound symmetry correlation structures were also evaluated to model the possible time-dependencies among observations. Statistical significance was declared at $\alpha < 0.05$. Estimated effects were evaluated using marginal means (i.e., least squares means) with Bonferroni P-value adjustment for multiple comparisons.

The average overall gait score of Exercise cows numerically decreased from 2.78 ± 0.28 (SEM) at Pre-trial to 1.78 ± 0.17 and 1.72 ± 0.17 at Post-trial and Follow-up, respectively, while the overall gait score of Non-Exercise cows changed from 2.92 ± 0.2 at Pre-trial to 2.83 ± 0.21 and 2.5 ± 0.29 at Post-trial and Follow-up, respectively (Figure 2). The same numerical decrease occurred for 3 gait attributes – tracking-up, asymmetric steps, and reluctance to bear weight (Figure 3). However, neither the overall gait score nor any of the 6 gait attributes differed significantly between treatment groups or periods ($P > 0.05$). It is worth noting that no cows in our study were obviously lame (gait score ≥4) at any point during the study period. Regarding lameness prevalence, at Pre-trial a total of 8 cows (5 Exercise and 3 Non-Exercise cows) were scored as moderately lame (gait score = 3 or 3.5). At Post-trial and Follow-up, 4 and 2 Non-Exercise cows were scored as moderately lame, respectively, while no Exercise cows were scored as moderately lame. Moreover, enhanced tracking-up, reduced asymmetry, and balanced weight bearing in the Exercise group indicate not only a progression toward smoother, more fluid movement but also a restoration of walking confidence, highlighting the potential of exercise to elevate both mobility and welfare. Our research studied the impact of relatively short periods of daily outdoor access (1 h/d, 5 d/wk) on the gait of dairy cows, distinguishing it from most previous studies that focused on seasonal or year-round full-time outdoor access (Chapinal et al., 2013; Hernandez-Mendo et al., 2007; Olmos et al., 2009). While these studies did indeed find an association between outdoor access and improved hoof and/or leg conditions, these improvements were thought to be intrinsically linked to the long-term exposure to conditions of the outdoor access itself, such as more comfortable footing and softer surfaces which provide better traction than most indoor housing features (Shepley & Vasseur, 2021b). These factors may have influenced the significance of the results in the present study, as all cows, regardless of treatment group, still spent the majority of their time indoors.

Cows were enrolled in our study with relatively low starting gait scores (i.e., sounder gait) and therefore had less room for improvement than noticeably lame cows would under the same conditions, resulting in small overall score changes. Moreover, traditional tools such as visual gait scoring, which were designed to aid in routine farm management by identifying lame vs non-lame cows, may exacerbate this issue by not being granular enough to detect slight changes in mobility. Previous studies reporting significant results
and Non-Exercise cows (10% to 8.04%; \( P \)) were observed for both Exercise (7.50% to 6.67%; \( P \)) and none for score 4. No significant changes in the prevalence of lesions of 7.9% at the claw-level, considering 8 claws per cow, during the trial and Follow-up – Pre-trial for both treatment groups, Non-Exercise and Exercise, illustrated with least squares means (points) and standard error bars. Clinical hoof assessment showed an overall lesion prevalence of 7.9% at the claw-level, considering 8 claws per cow, during the 2 data collection periods. All observed lesions were sole hemorrhages (SH), located in zones 4 (37 claws) and 5 (1 claw). Of the 38 SH, half were on hind claws (17 lateral, 2 medial) and half on front claws (all medial). The distribution of lesion severity was as follows: 55.3% for score 1, 34.2% for score 2, 10.5% for score 3, and none for score 4. No significant changes in the prevalence of SH were observed for both Exercise (7.50% to 6.67%; \( P = 0.58 \)) and Non-Exercise cows (10% to 8.04%; \( P = 0.16 \)) from Pre-trial to Follow-up. Furthermore, the severity of lesions did not show any significant differences across the periods or treatment groups (\( P > 0.05 \)).

There is limited literature available reporting the claw-level prevalence of lesions in tie-stall-housed cows, making it challenging to directly compare our results. An epidemiological study by Cramer et al. (2008) reported results from tie-stall dairies, with a prevalence of 25.7% for any hoof lesions and 7.1% for SH at the cow level. When compared with other hoof lesions typically reported, SH is considered a less severe lesion (Nocek, 1997), and its mild scores are often underreported by hoof trimmers (Solano et al., 2016). Therefore, it is possible that our methodology, specifically designed to detect even mild SH with slight discolorations at the claw-level, resulted in a higher cow-level prevalence of SH (40%) in our study compared with the aforementioned epidemiological study.

The absence of significant effects of outdoor access on hoof lesions aligns with our hypothesis, which emphasizes the lack of a detrimental effect of partial outdoor access on hoof health. This finding supports the results of Loberg et al. (2004), who observed no significant impact of various levels of outdoor access on claw lesions in tie-stall-housed cows. Bieflfeldt et al. (2005) similarly found no significant differences in claw sole disorders between cows housed in tie-stall barns with and without outdoor access for exercise. However, a literature review on the effect of movement opportunity on cow health and comfort showed that pasture access positively affects hoof health (Shepley & Vasseur, 2021b), possibly due to more comfortable footing on pasture and increased blood flow in the legs improving hoof health. The lack of significant positive changes in our study may be attributed to the fact that the cows began the trial with a low prevalence and severity of claw lesions, thus providing limited scope for improvement.

Using the Direct Thermal Analysis method on the thermography images, we found no statistically significant differences between treatment groups and time (Pre-trial vs Post-trial) for all thermal variables. All thermal variables were statistically affected by ambient temperature (\( P < 0.001 \)), which is consistent with previous studies (Alsaaad et al., 2015; Landgraf et al., 2014). However, when using the Normalization method, the analysis of normalized images revealed a statistically significant interaction in kurtosis between treatment groups and weeks (\( P < 0.0001 \)). Kurtosis represents the width of the tails, or tailedness, of a normal distribution curve. A higher kurtosis often appears as a sharper peak and longer tails, indicating a population with more extreme outliers, while a lower kurtosis often appears as a flatter curve with shorter tails and indicates a population with less extreme outliers, ultimately representing a more homogenous population (Westfall, 2014). In our study, kurtosis values decreased for both Non-Exercise and Exercise groups from Pre-trial to Post-trial. Within each week, treatment groups were only statistically different on Pre-trial, such that Exercise cows started the trial with a higher kurtosis value than Non-Exercise cows at Pre-trial. Although the reduction in kurtosis between Pre- and Post-trial was higher in Exercise (from 2.61 ± 0.04 to 2.44 ± 0.04) than in Non-Exercise cows (from 2.44 ± 0.04 to 2.35 ± 0.04), there are uncertainties regarding the effect of exercise on the kurtosis values. Indeed, kurtosis as sole metric may not be sufficient to interpret the results further. One of the possible risk factors of providing outdoor access on cow’s hoof health is the impact of walking on hard, rough, fro-

---

**Figure 2.** Changes in overall gait score between periods (Post-trial – Pre-trial and Follow-up – Pre-trial) for both treatment groups, Non-Exercise and Exercise, illustrated with least squares means (points) and standard error bars.
zen, and uneven surfaces that could lead to mechanically induced laminitis (Shearer et al., 2015) which can be identified by hoof surface thermography even at early stages (Nikkhah et al., 2005; Wood et al., 2015). We hypothesized that outdoor access would not compromise cow’s hoof health by causing laminitis-associated inflammation that would increase hoof surface temperature. Consistent with our hypothesis, the thermography results using both analytical approaches suggest that hoof surface temperature is not influenced by application of 1hr/d outdoor access.

The present study sought to determine whether gait score (overall gait score and 6 gait attributes) and hoof health (claw lesion and hoof surface temperature) differed after the provision of a 5-week period of daily outdoor exercise to tie-stall-housed dairy cows. Both overall gait score and 3 key gait attributes improved after only 5 weeks of exposure and this improvement was maintained 8 weeks after the completion of the trial; however, these were only numerical changes observed using visual gait scoring and were not statistically significant. The lack of significant difference in gait changes may be due to the small sample of cows selected for gait analysis. Also, as the objective of this study was not to look at routine exercise provision as an aid for lameness recovery, the study enrolled only cows with lower starting gait scores (i.e., sounder gait), therefore with less room for visual improvement. More objective alternative methods to visual gait scoring, which was primarily designed to identify lame cows in routine on-farm assessment, need to be used to further investigate locomotion re-

**Figure 3.** Changes in scores for 6 gait attributes (A) swinging out, (B) joint flexion, (C) back arch, (D) tracking up, (E) asymmetry step, and (F) reluctant to bear weight, between periods (Post-trial – Pre-trial and Follow-up – Pre-trial). The data are depicted for both treatment groups, Non-Exercise and Exercise, using least squares means (points) and standard error bars.
covery in tie-stall cows when provided with increased movement opportunities. Daily outdoor exercise had little impact on hoof health conditions. Indeed, no significant changes in clinical assessment of hoof lesions nor in the hoof thermography, which was intended to detect temperature increases caused by laminitis, were found. Innovative measures and technology such as thermography and kinematics need to be further explored in future research looking at hoof and leg health changes in non-lame cows to observe detailed and subclinical effects of increasing opportunity of movement.

References

NOTES
A. Nejati https://orcid.org/0000-0002-7310-0454 E. Shepley https://orcid.org/0000-0002-9663-7385 G. M. Dallago https://orcid.org/0000-0002-5725-0815 E. Vasseur https://orcid.org/0000-0002-5087-6508

We would like to thank Sirine El Hamdaoui, Anna Bradtmueller, and Rachel van Vliet for their assistance with the animals and with the collection of the study data. In addition, we would like to thank Rachel van Vliet with her help editing the manuscript. We would also like to acknowledge the staff of the McGill University Macdonald Campus Dairy Complex (Sainte Anne de Bellevue, QC Canada) for their animal husbandry and management. The authors have not stated any conflicts of interest.

JDS Communications TBC, TBC