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Effects of increased grazing intensity during the early and late grazing periods on the welfare of spring-calving, pasture-based dairy cows

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ABSTRACT

The objective of this study was to identify potential effects of increased grazing intensity, characterized by differing pasture availability and stocking rate, on indicators of welfare during both early and late grazing periods. Seventy spring-calving, pasture-based Holstein-Friesian and cross-bred dairy cows, averaging 35 ± 16 d in milk on the first day of data collection, were assigned to 3 treatments (20–26 cows/treatment) representing a range in grazing intensity: LO (high pasture availability, 980 kg DM/ha opening cover, 2.75 cows/ha, 90:10% pasture:concentrate diet), MOD (medium pasture availability, 720 kg DM/ha opening cover, 2.75 cows/ha, 90:10% pasture:concentrate diet), and HI (low pasture availability, 570 kg DM/ha opening cover, 3.25 cows/ha, 80:20% pasture:concentrate diet); representative of current, best practice and proposed production levels respectively for this system. Welfare indicators were locomotion score, digital dermatitis and white line disease, rumen fill, ocular and nasal discharge, integument damage to the neck-back and hock regions, and lying time. Data were collected during a 5-wk early grazing period in spring (EG) and a 7-wk late grazing period in autumn (LG). Average daily lying time was recorded for 8 to 10 focal cows per treatment. Results demonstrated only minor treatment effects. Cows on MOD [odds ratio (OR) = 3.11] and HI (OR = 1.95) were more likely to display nasal discharge compared with LO. Cows on MOD tended to have more damage to the skin on the neck-back region than LO (OR = 4.26). Total locomotion score (maximum = 25) was greater on LOW (7.1 ± 0.20) compared with HI (6.5 ± 0.19). Average lame cow prevalence for EG and LG respectively was 15.3 ± 3.12% and 39.2 ± 3.00% (LO), 20.0 ± 2.58% and 24.2 ± 5.69% (MOD), and 14.9 ± 4.79% and 17.0 ± 3.44% (HI). Cows on HI were less likely to have impaired walking speed than either LO (OR = 0.24) or MOD (OR = 0.29). Cows on both HI (OR = 0.36) and MOD (OR = 0.40) were less likely to display impaired abduction or adduction compared with those on LO. An interaction between treatment and period revealed longer lying times for cows on LO (10.6 h/d ± 0.39) compared with both MOD and HI (8.7 ± 0.43 and 8.4 ± 0.41 h/d) during EG only. The greatest effects were across grazing periods, with all indicators except rumen fill and locomotion score demonstrating improvements from EG to LG. This suggests cows were able to cope well with increasing levels of grazing intensity, and that regardless of treatment, a greater number of days on pasture led to improvements in welfare indicators.
Key words: grass-based, health, locomotion, lying time

INTRODUCTION

Agricultural intensification, the increase in production by unit of input such as animals, land or labor (Ma et al., 2020) is a regular occurrence in dairy production worldwide (Mee and Boyle, 2020). Pasture-based systems of production are reputed to be highly profitable (Dillon et al., 2008), but are reliant on achieving efficient pasture utilization. It has been reported that for every additional tonne of pasture DM per hectare utilized, there is an increase in net profit of €173/ha (Hanrahan et al., 2018). Much research has focused on intensification through improved pasture utilization by examining increases in stocking rate (McCarthy et al., 2016; Macdonald et al., 2017; Coffey et al., 2018), differing levels of pasture availability (Evers et al., 2021) or extending the length of the grazing season (Läpple et al., 2012; Claffey et al., 2020) to maximize grass intakes, and ultimately milk yield per hectare. However, for a dairy production system to be sustainable, such intensification must not come at the expense of animal welfare. Studies of intensification methods in grazing

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systems rarely include the impact on animal welfare as a primary focus. Therefore, there is a need for a greater understanding of the effects of grazing intensification on animal welfare.

Pasture-based systems are generally perceived to provide a more natural environment than indoor systems and as such to contribute to good welfare. Several studies have demonstrated the welfare benefits of pasture, including reduced lameness prevalence and severity of hoof problems (Olmos et al., 2009), improvement of lameness over time (Hernandez-Mendo et al., 2007), lower ocular discharge (Wagner et al., 2018), reduced clinical mastitis (Washburn et al., 2002), fewer instances of hock hair loss and lesions (Burow et al., 2013b; Armbrecht et al., 2019), and increased lying time and lying bout length (Olmos et al., 2009). However, the progression toward more intensive systems has the potential to negatively affect these positive effects of pasture access. In Ireland, where spring-calving, pasture-based dairy systems predominate, the dairy sector has experienced considerable changes since the removal of dairy production quotas in 2015. From 2008 to 2018, herd sizes, farm area, and stocking rates have increased from 54 cows, 50 ha, and 1.71 livestock units/ha, to 79 cows, 59 ha, and 2.06 livestock units/ha; increases of 46.3, 15.3, and 20.5% respectively (Connolly et al., 2009; Dillon et al., 2019). As with any system, such expansion and intensification may impose further stress on pasture-based cows. A 2017 survey of stakeholders within the Irish dairy sector, including farmers, veterinarians, and farm advisors, found that 77% of farms had expanded their herd size in the previous 3 yr without a corresponding increase in infrastructure such as housing or roadways (Boyle et al., 2017). Inappropriate and overcrowded housing facilities may increase the risk of integument damage which can carry-over into the grazing season (Rutherford et al., 2008; Kielland et al., 2009, 2010; Burow et al., 2013a; Armstrong, 2020). Increased stocking rates are crucial for increasing pasture utilization, yet may result in lower BW and BCS in individual cows due to reduced daily herbage allowance and DMI (McCarthy et al., 2012, 2014). Cows with reduced pasture allowance have been shown to have fewer and shorter lying bouts, as well as a longer latency to lie down after milking compared with a higher feed allowance (O'Driscoll et al., 2019).

The potential effect of farm system intensification on dairy cow welfare could also be influenced by seasonal changes between the early and late periods of the grazing season. In a spring-calving system, the calving season is timed to coincide with increasing grass growth; however, following initial turn-out, cows' feed demands may out-pace grass supply, requiring supplementation with silage or concentrates (Kennedy et al., 2005). Although grass growth rates are lower, pasture quality is high at this time of year compared with other periods, due to the higher OM digestibility, and CP level than in the late grazing season (autumn; Kennedy et al., 2006). Grass growth reaches its peak after 3 to 4 mo of increasing growth (approximately May), thereafter grass growth will begin to decline and remain low throughout the winter months (Hurtado-Uria et al., 2013; PastureBase Ireland, 2020). Furthermore, during the early grazing period in Ireland (spring), weather may be more variable, with heavy rainfall necessitating periods of on-off grazing where cows are housed for short periods (Kennedy et al., 2009). Cows also experience considerable physiological changes during the early grazing period, with both a rapid reduction in body condition, and a peak in milk production taking place within approximately the first 2 mo after calving (Roche et al., 2007, 2009). With such differences between the early and late grazing periods, it is possible that the influence of increased grazing intensity on welfare could manifest differently during each period.

To gain a better understanding of how intensification may affect dairy cow welfare at different points during their lactation, the objective of this study was to identify the effects of increased grazing intensity on animal-based indicators of welfare during both early and late grazing periods by imposing different levels of pasture availability and stocking rates. This was undertaken as part of an on-going farm system study. We hypothesized that cows under higher levels of grazing intensity would experience more negative effects on welfare indicators. Additionally, we hypothesized that the observed effects on welfare indicators would differ between the early and late periods of the grazing season.

MATERIALS AND METHODS

This study was approved by the Teagasc Animal Ethics Committee (TAEC169–2017) and was conducted in accordance with S.I. No. 543/2012 – European Union (Protection of Animals used for Scientific Purposes) Regulations 2012, and the European Directive 2010/63/EC. Data collection was conducted in conjunction with a system-level study investigating the effect of pasture availability and farm stocking intensity on spring-calving, pasture-based dairy production. This study investigated a subset of treatments from a single year of the concurrent multiyear farm system study. For further details of the farm system study design and management see Evers et al. (2021).

Study Design and Treatments

Data collection occurred during 2 periods; an early grazing period (**EG**) from March 18 to April 21, 2018, and a late grazing period (**LG**) from September 16 to November 10, 2018. The EG period began when grazing treatment groups were formed, and lasted until the end of the first grazing rotation, for a total of 5 wk. The LG data collection began at the start of the final grazing rotation and lasted until the start of housing. The length of the final grazing rotation was extended to facilitate greater accumulation of grass at the time of paddock closure. Data collection was not possible during the fourth week of the LG (due to unavoidable circumstances on the part of the observer), reducing the total number of study weeks during LG to 7.

The full system study consisted of a 3 × 2 factorial arrangement of treatments with 3 levels of pasture availability and 2 levels of farm system intensity. Pasture availability was categorized as low (**LPA**) at 570 kg DM/ha spring opening cover, reflecting the current production level on farms based on nationally collected data (PastureBase Ireland; Hanrahan et al., 2017); medium (**MPA**) at 720 kg DM/ha spring opening cover, reflecting recommended best practice established through previous research (Tuñon et al., 2014); or high (**HPA**) at 980 kg DM/ha spring opening cover, reflecting proposed levels of increased autumn grass availability suitable for a higher stocking rate system (Evers et al., 2021). Levels of farm system intensity were: medium, maintaining a stocking rate of 2.75 cows/ha (20–22 cows/group), and provided a 90:10% pasture:concentrate diet with a 4.0- to 4.5-cm postgrazing sward height); or high, maintaining a stocking rate of 3.25 cows/ha (23–26 cows/group; consistently 0.5 cows/ha greater than medium), an 80:20% pasture:concentrate diet (additional 1.8 kg DM/cow per day of concentrates compared with medium) and a postgrazing sward height of 3.5 to 4.0 cm. During EG, cows on medium intensity received a total of 116 kg DM (0–4 kg DM/cow per day) of concentrates, and cows on high intensity received 186 kg DM (2–6 kg DM/cow per day). During LG cows received a total 280 kg DM (5 kg DM/cow per day) and 392 kg DM (7 kg DM/cow per day) of concentrates on medium and high intensity systems respectively. This experimental design resulted in 6 treatment groups: LPA-medium, LPA-high, MPA-medium, MPA-high, HPA-medium, and HPA-high. Each treatment group had an equal total grazing area of 8 ha distributed across 17 grazing blocks (approximately 0.47 ha/paddock). Paddock characteristics (including soil and sward type, location and distance from parlor) were balanced between groups, and differing treatment groups were grazed in adjacent paddocks of similar area, residence time, rotation length and pasture allowance. A more detailed description of treatments including how differences in pasture availability were established can be found in Evers et al. (2021).

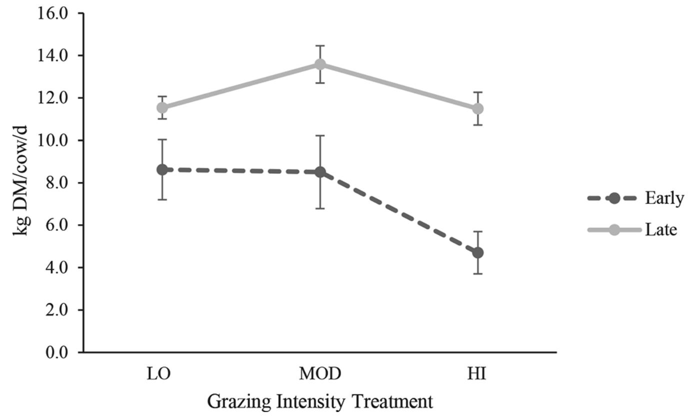

Figure 1. Mean daily herbage allowance (kg DM/cow/d ± SE) by grazing intensity (LO, MOD, HI) for early and late grazing periods. Early grazing period ranged from March 18 to April 21, 2018, and the late grazing period from September 16 to November 10, 2018. LO and MOD grazing intensity treatments had a stocking rate of 2.75 cows/ha (20–22 cows/group), 90:10% pasture:concentrate diet, and 4.0–4.5 cm postgrazing sward height; HI had a stocking rate of 3.25 cows/ha (23–26 cows/group; 0.5 cows/ha greater than MOD or LO), 80:20% pasture:concentrate diet (additional 1.8 kg DM/cow per day of concentrates compared with MOD or LO), and postgrazing sward height of 3.5–4.0 cm. Pasture availability was differentiated by opening spring cover, with 980 kg DM/ha for LO, 720 kg DM/ha for MOD, and 570 kg DM/ha for HI grazing intensity treatments.

To achieve our aim of examining potential effects of intensification on measures of animal welfare in the current study, 3 of these treatment combinations were selected, which represented the greatest range in grazing intensity (the combination of pasture availability and farm system intensity) among all the treatments. The selected treatments were LPA-high, MPA-medium, and HPA-medium, which from this point on will be referred to as **HI**, **MOD**, and **LO**, respectively. The highest-intensity grazing group (HI) was characterized by low pasture availability and high-intensity farm system, the moderate-intensity grazing group (MOD) was characterized by medium pasture availability and medium-intensity farm system, and the lowest-intensity grazing group (LO) was characterized by high pasture availability and a medium-intensity farm system. Mean daily herbage allowance (kg/DM per cow per day) for each of these 3 selected treatments during both EG and LG are depicted in Figure 1.

Animals

Seventy lactating Holstein-Friesian (**HF**; n = 34) and cross-bred dairy cows (n = 36; primarily HF × Jersey) were included in this study (9 primiparous and 61 multiparous), approximately half of the total 144 cows used by Evers et al. (2021). All cows calved between January and April 2018 (mean calving date February 20, 2018, ± 22 d SD), and had an average DIM of 35 ± 16 d on the first day of data collection. Average BW and BCS in the first week of EG data collection was 493 ± 88.7 kg, and 3.0 ± 0.24 respectively, and 542 ± 71.9 kg and 2.9 ± 0.20, respectively, in the first week of LG data collection.

All cows were assigned to their respective treatments before calving, balanced by treatment according to expected calving date, breed, parity, BW, BCS, and economic breeding index. Upon the start of treatments, cows that had already calved were assigned directly to their treatment. Any cows that calved after this date were placed into their respective treatment after calving. Cows that calved more than 7 d after the first day of data collection (n = 5) were not included in the EG analyses.

Due to low rainfall and poor pasture growth during the 2018 grazing season, it was necessary to reduce the total number of grazing cows to maintain pasture availability levels. In mid-September 2018, before the start of the LG, the total number of cows was reduced by 7, distributed across treatments (3 from HI, 2 each from LO and MOD), to maintain consistent differences in stocking rates between treatments; thus only 63 cows remained on the trial during LG.

Feeding and Management

At pasture, cows grazed a sward of predominantly perennial ryegrass (*Lolium perenne* L.). Concentrate supplementation was based on pasture availability; cows were supplemented when pasture supply was insufficient to achieve target levels. Pasture was provided through a rotational grazing system, with access to fresh pasture provided every 24 to 36 h. Cows remained on pasture 24 h/d other than when traveling to and from the parlor for milking. Milking duration was approximately 1.5 h, twice per day. The distance from parlor to paddocks ranged from 90 to 865 m. During periods of inclement weather, grazing was managed by providing shortened periods at pasture (12 h), practicing on-off grazing (Kennedy et al., 2009), or housing cows during extreme rainfall. Cows were housed (indoor cubicle shed) for a cumulative total of either 15.5 (LO and MOD) or 17.5 d (HI) during EG, and 0 d for all treatment groups during LG. When housed during these periods, cows were supplied with ad libitum pasture silage. Cows were managed according to the same described protocols between the EG and LG periods.

Experimental Measurements

Details of complete scoring scales are available in Appendix Tables A1–A8 and Appendix Figure A1.

Clinical Health. Several aspects of clinical health were scored on a weekly basis. Two trained observers scored cows during EG (n = 5 inspections), yet only one of these observers (the primary author) remained to perform the scoring during LG (n = 7 inspections). Following the morning milking one day per week, each cow was successively restrained in a handling gate after exiting the parlor. The eyes and nose of each cow were scored for signs of ocular or nasal discharge on a 3-point scale adapted from Welfare Quality (0 = no discharge, to 2 = heavy discharge; Welfare Quality, 2009). The integument of the neck, along the back to the tail head was examined for any abrasions or alterations and scored on a 4-point scale (from 0 = no alterations, to 3 = major swelling with or without hair loss or lesions) adapted from Welfare Quality (2009) and Gibbons et al., (2012). The left side of the cow, just behind the last rib and below the short-ribs, was palpated and assigned a score for rumen fill according to a 5-point scale (from 1 = deep indentation, least fill, to 5 = no definition, most fill) adapted from the scale by the Agriculture and Horticulture Development Board (2019). During a subsequent afternoon milking, both rear hocks of each cow were scored while standing in the parlor for integument alterations on a 4-point scale (from 0 = no alterations, to 3 = major swelling with or without hair loss or lesions; Gibbons et al., 2012). For each health measure, the proportion of affected cows was summarized by trial week.

Lying Time. Total daily lying time was recorded using accelerometer leg-bands (IceTag; IceRobotics Ltd.) affixed above the rear fetlock on 10 focal cows per group. Focal cows were selected from within each treatment group, balancing for parity, DIM, body condition, and BW. Data were recorded for all 5 wk during EG and the final 6 wk of LG. The data were cleaned to include only days with complete records (24 h/d). Due to recording errors, data were eliminated from 5 cows during EG and 3 cows during LG resulting in 25 focal cows for EG (8 cows for HI and MOD, 9 cows for LO) and 27 focal cows for LG (8, 9, and 10 cows for MOD, HI, and LO groups, respectively). Average daily lying time was summarized by trial week for each focal cow.

Locomotion Scoring. Locomotion scoring of all cows was conducted by a single trained scorer throughout; the same primary scorer that performed clinical health scores. One day per week, after morning milking during both EG (n = 5 wk) and LG (n = 7 wk), each cow was released from the handling gate individually and their locomotion was scored as the cow walked past and away from the scorer. Five different components of the cow's locomotion (speed, spine curvature, head carriage, step tracking, and abduction or adduction) were each scored on a 5-point scale (from 1 = normal, to 5 = most severe deviation possible), according to the methods of O'Driscoll et al. (2010). Running cows were not scored. The 5 individual scores were then summed into a single overall locomotion score (minimum score 5, maximum score 25). According to O'Callaghan et al. (2003), a minimum of 2 components with a score of 3 or more would be considered a lame cow, thus we concluded that the minimum possible score for lameness was 9 (i.e., a cow with 2 categories scored 3, and the remaining 3 categories with a perfect score of 1, would have a minimum score of 9). The proportion of cows with a score of 9 or greater was summarized by treatment and week for each of EG and LG to determine the average prevalence of cows categorized as lame.

Hoof Health. Manual hoof inspections were performed on the rear hooves of each cow by the primary trained observer with the assistance of a professional hoof trimmer (Farm Relief Services, Derryvale, Roscrea, Tipperary, Ireland). Four inspections were performed for each cow. Depending on calving date, the first inspection occurred between approximately 3 wk before and one week following the start of treatments (mean ± SD; trial d −5 ± 11, DIM 24 ± 19). The next inspection took place after a minimum of 6 wk had elapsed since the start of treatments (mean ± SD; trial d 64 ± 14, DIM 92 ± 27). The final 2 inspections took place at the start and end of the LG; all cows were scored over 3 consecutive days at the beginning (mean ± SD; trial d 185 ± 1, DIM 212 ± 21) and on 4 separate days approximately 6 to 8 wk later (mean± SD; trial d 256 ± 7, DIM 282 ± 20).

During the inspections, cows were individually restrained within a hoof trimming crate and each rear leg was lifted in succession to provide access to the sole of the hoof. Water was used to remove any dirt and then a thin layer of the sole surface was pared away by the professional hoof trimmer to expose fresh, clean sole surface for inspection. Each hoof was scored for digital dermatitis on a 6-point scale (from 0 = none visible, to 5 = hyperkeratotic lesions; O'Driscoll et al., 2008), white line disease on a 5-point scale (from 9 = none apparent, to 4 = complete separation of the white line; O'Driscoll et al., 2008), sole hemorrhage or bruising on a 6-point scale (from 0 = none, to 5 = red and raw with possibly fresh blood; Leach et al., 1998; O'Driscoll et al., 2009b), and presence or absence of sole ulcers. Any hoof issues deemed to pose an immediate risk to the animal's hoof health and overall welfare were treated accordingly by the trained hoof professional at the time of the inspection.

Data Management

Several of the variables had few observations in the upper score levels indicative of the most severe levels of impairment (sum of incidences of third-level severity score or greater over both EG and LG for ocular discharge = 1, nasal discharge = 1, neck-back integument alterations = 29, hock integument alterations = 60, digital dermatitis = 22) and thus, these health scores were summarized into binary data and analyzed for the proportion of cows with the presence (score >0) or absence (score 0) of impairment. White line disease, which had a wider range of scores, was categorized into 3 levels, absent (score 0), mild (score 1), and visible separation (score ≥2). There were only 3 instances of sole bruising with a score ≥2 observed throughout the study, and because a mild bruise (score 1) has previously been categorized as similar in severity to no bruising by O'Driscoll et al. (2017), sole bruising was not analyzed further. Similarly, only a single instance of a sole ulcer was observed throughout the study, and therefore could not be analyzed. Rumen fill scores were categorized into a binary score of ≤2, indicative of insufficient feed intake, and >2, indicating sufficient intakes. In addition to analyzing the sum score for locomotion, the probability that each locomotion score component was impaired (score >1) was investigated for each of speed, spine curvature, step tracking and abduction or adduction. The probability of impaired head carriage was not analyzed as only 11 observations were >1.

Statistical Analyses

All data were analyzed using SAS 9.4 (SAS Institute Inc.). Significance was declared at $P < 0.05$, and marginal significance at $P \geq 0.05 < 0.1$. Clinical health and locomotion score component variables (ocular and nasal discharge, neck-back and hock integument alterations, rumen fill, speed, spine curvature, step tracking, abduction or adduction) were analyzed with a generalized linear mixed model, using the GLIMMIX procedure with a binomial distribution and logit link function. Total locomotion scores and lying time approached a normal distribution and were analyzed using a general linear mixed model using the MIXED procedure with all reported values as least squares means. Residuals were examined for continuous variables to ensure assumptions of normality were met. These models included the fixed effects of treatment, grazing period and the interaction between treatment and grazing

Table 1. Means (±SE) and effects of low (LO), moderate (MOD), and high (HI) grazing intensity treatments, during the early (EG) and late (LG) grazing periods, and their interaction on measures of clinical health[1]

	Treatment			*P*-value of odds ratio comparisons[2]		
Variable	LO	MOD	HI	Treatment	Period	Treatment × period
Ocular discharge				0.336	0.019	0.519
EG	23.9 (8.89)	22.1 (6.53)	16.1 (7.44)			
LG	12.5 (4.23)	6.7 (2.11)	11.9 (5.01)			
Nasal discharge				<0.001	<0.001	0.506
EG	20.1 (5.48)	40.0 (3.57)	37.7 (7.22)			
LG	12.5 (3.59)	25.0 (4.47)	16.4 (3.56)			
Neck-back alterations				0.046	<0.001	0.191
EG	53.1 (10.13)	63.2 (8.81)	53.5 (3.43)			
LG	0.8 (0.83)	10.0 (2.58)	4.3 (2.75)			
Hock alterations				0.199	<0.001	0.352
EG	68.4 (7.98)	67.4 (6.94)	60.0 (5.07)			
LG	23.3 (4.01)	26.7 (6.79)	19.3 (3.78)			
Rumen fill				0.889	<0.001	0.060
EG	74.9 (3.04)	88.4 (4.53)	86.7 (3.96)			
LG	96.7 (2.47)	93.3 (3.07)	94.9 (3.44)			

[1]Values presented for each treatment and grazing period are the average weekly proportion of cows scored 1 (variable present), except for rumen fill, which is presented as the average weekly proportion of cows scored ≤2.

[2]Significance was declared at $P < 0.05$, and marginal significance at $P \geq 0.05 < 0.1$.

period. The experimental unit was treatment group, with the individual cows considered the observational unit. Parity and calving date were included to control for potential differences across treatments arising throughout the study. These models also included the Kenward-Rogers adjustment for estimating degrees of freedom and an LSmeans statement with Tukey's adjustment for multiple comparisons. The SLICE option, which allows comparison of treatments at particular time points, was included to investigate treatment differences within EG and LG individually. Trial week was included as a repeated measure with cow as the subject. The autoregressive covariance structure was used for neck-back integument alterations and rumen fill, and heterogeneous autoregressive for all others.

The hoof health variables digital dermatitis and white line disease were also analyzed in a generalized linear mixed model, using the GLIMMIX procedure. The digital dermatitis model had a binomial distribution and logit link function, while the white line disease model had a multinomial distribution and cumulative logit link function. Fixed effects were treatment, inspection number within grazing period and their interaction. Cow was modeled as a random effect because PROC GLIMMIX does not model repeated measures for multinomial distributions. An LSmeans statement was included through the addition of the PLM procedure to the white line disease multinomial model to allow for inclusion of the Tukey's adjustment for multiple comparisons. As in previous models, parity and calving date were included to control for any variation across treatments, and the Kenward-Rogers adjustment for estimating degrees of freedom was included.

RESULTS

Clinical Health Scores

An overview of all clinical health scores is given in Table 1. No significant difference in ocular discharge was identified between treatments, nor was there a significant interaction between treatment and grazing period. However, regardless of treatment, cows were more likely to display ocular discharge in EG compared with LG (OR = 1.97, CI = 1.12–3.46, $P = 0.019$).

Cows on MOD were more likely to display nasal discharge compared with HPA-MI (OR = 3.11, CI = 1.81–5.32, $P < 0.001$). Cows on HI were also more likely to display nasal discharge than those on LO (OR = 1.95, CI = 1.12 − 3.38, $P = 0.047$), but no significant difference was detected between HI and MOD (OR = 0.63, CI = 0.39–1.00, $P = 0.120$). Nasal discharge for all treatments was more likely during EG than LG (OR = 2.41, CI = 1.58–3.67, $P < 0.001$). Evidence of a treatment effect was detected within both EG ($P = 0.006$) and LG ($P = 0.012$) when investigated individually.

There appeared to be an overall effect of treatment on the occurrence of neck-back alterations, yet after multiple comparison adjustment, the higher likelihood of neck-back alterations among cows on MOD than LO was only marginally significant (OR = 4.26, CI = 1.18–

Table 2. Least squared means (±SE) and effects of low, moderate, and high grazing intensity treatments (LO, MOD, HI), on hours spent lying per day overall, and during the early and late grazing periods (EG, LG), and their interactions

	Treatment				P-value[1]		
Daily lying time (h)	LO	MOD	HI	Grazing period	Treatment	Period	Treatment × period
Overall	10.4 (0.32)	9.5 (0.37)	9.1 (0.33)	—	0.020	<0.001	<0.001
EG	$10.6^{a,A}$ (0.39)	$8.7^{b,A}$ (0.43)	$8.4^{b,A}$ (0.41)	9.2 (0.25)			
LG	$10.2^{a,A}$ (0.31)	$10.4^{a,B}$ (0.37)	$9.7^{a,B}$ (0.32)	10.1 (0.21)			

[a,b]Lowercase superscripts indicate significant differences row-wise.

[A,B]Uppercase superscripts indicate significant differences column-wise.

[1]Significance was declared at $P < 0.05$, and marginal significance at $P \geq 0.05 < 0.1$.

15.34, P = 0.069). However, regardless of treatment, cows were considerably more likely to have neck-back alterations in EG compared with LG (OR = 32.32, CI = 13.14–79.48, P < 0.001).

No evidence of a significant difference in hock alterations was detected between treatments. During EG, cows were more likely to display hock alterations than during LG (OR = 7.57, CI = 4.86–11.80, P < 0.001).

Overall, cows were less likely to have a rumen fill score ≤2 in EG than in LG (OR = 0.27, CI = 0.15–0.48, P < 0.001). Further inspection of a marginally significant interaction suggests this may be driven by a difference between grazing periods for cows on LOW (P = 0.001), rather than MOD (P = 0.850) or HI (P = 0.245). Considering the grazing periods individually, the effect of treatment was detected during EG (P = 0.019), but not during LG (P = 0.452).

Lying Time

There was an interaction of lying time between treatment group and period (Table 2). Although LO cows spent a similar amount of time lying per day in both EG and LG, cows on both HI and MOD had shorter daily lying times during EG than during LG (P < 0.002). When grazing periods were examined individually, there was evidence for significant treatment differences within EG (P < 0.001) but not LG (0.295); during EG, cows on LO spent significantly more time lying per day than cows on either MOD or HI (P < 0.01).

Locomotion

The average prevalence of lame cows (locomotion score >9) for EG and LG respectively was 15.3 ± 3.12% and 39.2 ± 3.00% for LO, 20.0 ± 2.58% and 24.2 ± 5.69% for MOD, and 14.9 ± 4.79% and 17.0 ± 3.44% for HI. Total locomotion score was greater on LO compared with HI, yet no meaningful differences were detected between LO and MOD, nor MOD and HI (Table 3). Although there was no significant effect of grazing period overall, nor any interaction effect, when grazing periods were examined individually there was evidence for significant treatment differences within LG (P = 0.004) but not EG (P = 0.491); during LG, cows on LO displayed the highest locomotion scores and those on HI the lowest locomotion scores.

Locomotion component effects are presented in Table 4. Cows on HI were less likely to have an impaired walking speed than either LO (OR = 0.24, CI = 0.09–0.63, P = 0.010) or MOD (OR = 0.29, CI = 0.11–0.77, P = 0.035). Overall, walking speed was more likely to be impaired in EG than LG (OR = 4.23, CI = 2.16–8.58, P < 0.001). Examining the grazing periods individually, there was no significant effect of treatment in EG (P = 0.131), and only marginal significance in LG (P = 0.057).

Table 3. Least squared means (±SE) and effects of low, moderate, and high grazing intensity treatments (LO, MOD, HI), early or late grazing period (EG, LG), and their interactions on total locomotion scores

	Treatment				P-value[1]		
Variable	LO	MOD	HI	Grazing period	Treatment	Period	Treatment × period
Total locomotion score	7.1^{a} (0.20)	6.8^{ab} (0.20)	6.5^{b} (0.19)	—	0.033	0.123	0.553
EG	6.9 (0.28)	6.6 (0.29)	6.5 (0.26)	6.7 (0.18)			
LG	7.4 (0.20)	6.9 (0.20)	6.5 (0.19)	6.9 (0.14)			

[a,b]Differing superscripts denote significantly different comparisons.

[1]Significance was declared at $P < 0.05$, and marginal significance at $P \geq 0.05 < 0.1$.

Table 4. Means (±SE) and effects of low, moderate, and high grazing intensity treatments (LO, MOD, HI), early or late grazing period (EG, LG), and their interactions on locomotion score components[1]

	Treatment			*P*-value of odds ratio comparison[2]		
Locomotion score component	LO	MOD	HI	Treatment	Period	Treatment × period
Speed				0.014	<0.001	0.39
EG	26.9 (1.83)	31.6 (7.81)	19.3 (5.04)			
LG	20.8 (3.00)	15.0 (3.87)	9.7 (4.23)			
Spine curvature				0.951	0.124	0.007
EG	25.8 (5.71)	26.3 (2.88)	24.1 (6.49)			
LG	33.3 (4.94)	16.7 (2.47)	34.2 (2.59)			
Step tracking				0.013	<0.001	<0.001
EG	64.2 (7.30)	47.4 (4.40)	62.7 (7.04)			
LG	86.7 (1.67)	90.0 (1.83)	67.5 (5.16)			
Abduction or adduction				0.001	0.15	0.135
EG	74.1 (2.30)	57.9 (6.86)	64.1 (6.86)			
LG	83.3 (4.41)	68.3 (3.33)	60.7 (2.66)			

[1]All values for locomotion score components are the average weekly proportion of cows scored as impaired (score ≥1) within each treatment and period.

[2]Significance was declared at $P < 0.05$, and marginal significance at $P \geq 0.05 < 0.1$.

Although there was an interaction between treatment and grazing period for spine curvature, after adjustment for multiple comparisons, cows on HI were only marginally less likely to display an arched spine during EG than LG (OR = 0.29, CI = 0.13–0.68, $P = 0.053$), with no meaningful difference in LO ($P = 0.653$) or MOD ($P = 0.619$).

There was an interaction between treatment and grazing period on step tracking, with a greater change in the mean score experienced by cows on MOD and LO than those on HI between EG and LG. Indeed, it was noted that within grazing periods individually, there was a significant effect of treatment during LG ($P < 0.001$), yet not during EG ($P = 0.141$). During LG, cows on HI were less likely to display impaired tracking than both those on LO (OR = 0.20, CI = 0.09–0.47, $P = 0.003$) and MOD (OR = 0.13, CI = 0.05–0.33, $P < 0.001$). However, no meaningful difference was detected between LO and MOD during LG ($P = 0.955$).

Cows on both HI (OR = 0.36, CI = 0.21–0.61, $P = 0.001$) and MOD (OR = 0.40, CI = 0.23–0.69, $P = 0.003$) were less likely to display impaired abduction or adduction compared with those on LO. Within grazing periods individually, there was a significant effect of treatment in LG ($P < 0.001$), yet not during EG ($P = 0.20$).

Hoof Health

There was no significant effect of treatment, nor any interaction between treatment and inspection number, within grazing period on digital dermatitis (Table 5). However, there was an effect of inspection number within grazing period. At the end of EG cows were

Table 5. Means (±SE) and effects of low, moderate, and high grazing intensity treatments (LO, MOD, HI), early or late grazing period (EG, LG), and their interactions on measures of hoof health[1]

	Treatment			*P*-value of odds ratio comparison[2]		
Variable	LO	MOD	HI	Treatment	INSP (period)	Treatment × INSP (period)
Digital dermatitis				0.974	0.006	0.483
Score ≥1						
EG	23.8 (14.29)	28.9 (13.16)	24.0 (0.0)			
LG	23.5 (7.73)	19.3 (4.26)	18.4 (5.38)			
White line disease				0.795	0.001	0.527
Score 1						
EG	45.2 (7.14)	31.6 (0.0)	36.0 (12.0)			
LG	23.5 (7.73)	17.9 (12.06)	18.0 (3.73)			
Score ≥2						
EG	21.4 (2.38)	29.0 (2.63)	30.0 (6.0)			
LG	19.4 (6.91)	21.3 (3.68)	9.1 (0.41)			

[1]Values presented for digital dermatitis are the average weekly proportion of cows scored 1 (signs of dermatitis present), and, for white line damage, the average weekly proportion of cows scored 1 (mild) and score ≥2 (visible separation). INSP = inspection number.

[2]Significance was declared at $P < 0.05$, and marginal significance at $P \geq 0.05 < 0.1$.

less likely to display signs of digital dermatitis than at the first inspection (OR = 0.22, CI = 0.07–0.66, $P = 0.035$). Likewise, at the start of LG cows were also less likely to display signs of digital dermatitis than at the first inspection (OR = 0.17, CI = 0.06–0.52, $P = 0.012$). No significant difference was detected between inspections at the start and end of LG ($P = 0.350$).

There was no meaningful effect of treatment on white line disease, nor any interaction between treatment and inspection number within grazing period (Table 5). However, there was an effect of inspection number, with incidence decreasing over time. White line disease was less likely at the end of LG compared with both the start (OR = 0.25, CI = 0.11–0.56, $P = 0.005$), or end of EG (OR = 0.21, CI = 0.10–0.48, $P = 0.001$). There was also marginally less white line disease at the start of LG compared with the end of EG (OR = 0.40, CI = 0.19–0.82, $P = 0.064$). No meaningful difference in white line disease was detected between the start and end of either EG or LG.

DISCUSSION

All 3 treatments investigated in this study represent some degree of intensification, with the lowest examined stocking rate still above the 2018 Irish national average of 2.06 livestock units/ha (Dillon et al., 2019). Stocking rates in Ireland are predicted to continue to rise (Dillon et al., 2021) because increasing stocking rate is considered one of the main drivers of productivity in pasture-based dairy systems (Hoden et al., 1991; Macdonald et al., 2008; Baudracco et al., 2010). In New Zealand, where pasture-based dairy production also predominates, stocking rates are already higher than those in Ireland. Based on national data, the average stocking rate in New Zealand between 2005 and 2014 was 2.96 cows/ha (Ma et al., 2019), whereas experimental studies in New Zealand utilized stocking rates up to 4.3 cows/ha (Macdonald et al., 2008; Beukes et al., 2019). With pasture-based dairy production continuing this trajectory toward more intensive production, investigating how varying levels of intensification affect dairy cow welfare is vital to ensure the sustainability of pasture-based production.

Of the welfare indicators investigated, nasal discharge, neck-back integument alterations, locomotion and lying time differed between the tested levels of increased grazing intensity. Additionally, no single treatment consistently demonstrated greater impairment than others. Indeed, the greatest effects observed in this study were differences between grazing periods. Both nasal and ocular discharge, integument alterations to the hocks and neck-back region, and the speed component of locomotion score all demonstrated improvement later in the grazing season. Additionally, incidence of both digital dermatitis and white line disease was reduced at the end of the grazing season compared with the beginning. Although we cannot assume this was a continuous, linear improvement, this does support our hypothesis that differences between the EG and LG would be apparent, as they are characterized by differences in grass growth, weather patterns, and cow physiology, and therefore management practices as well. This may be noted in Figure 1, for example, which illustrates that mean daily herbage allowance during LG was higher than in EG, and differences between treatments varied within grazing period.

The EG and LG were also preceded by drastically different environments. In EG, cows had recently regained access to pasture after a prolonged period of indoor housing of 2 to 3 mo (November to January), which is albeit lower than the average of approximately 4 mo (Creighton et al., 2011; Crossley et al., 2021). Additionally, the unseasonably poor weather experienced during the EG in 2018 resulted in practicing on-off grazing, where cows spent short periods of time indoors (e.g., overnight; Kennedy et al., 2009). Cows are exposed to a different variety of risk factors during housing than on pasture, and carry-over effects of the housing period have been observed to persist into the grazing period and improve after time on pasture, such as lameness (Wagner et al., 2018; Armbrecht et al., 2019) and integument alteration (Rutherford et al., 2008; Potterton et al., 2011; Burow et al., 2013b). In contrast, the LG followed a prolonged time on pasture, which provides time to recover from any lingering effects of housing, yet exposes cows to a new set of challenges such as long daily walking distances on potentially rough surfaces (Doherty et al., 2014).

Integument Alterations

Although only a minor effect of treatment was detected on the occurrence of integument alterations, there was a large effect of grazing period, particularly for integument of the neck and back. At over 30 times greater risk of integument alterations to the neck and back and 8 times greater for the hocks in EG than LG, this indicates a strong carry-over effect from the housing environment. Due to the previously described uncharacteristic spring weather during the study, cows were also practicing on-off grazing and spending partial days or nights indoors during this period. Protruding areas of the body are vulnerable to injury at this time due to contact with housing elements (Weary and Taszkun, 2000; Brenninkmeyer et al., 2016). The average of 53 to 63% of cows displaying neck and back integument alterations in EG is similar or higher than levels observed previously during housing periods on Irish farms (66% to the head-neck-back region and 32% to the hindquarters; Crossley et al., 2021), in the UK (median of 20–50% to the neck, back, or tailbone; Huxley et al., 2004), and in Norway (22% to the neck; Kielland et al., 2010). Integument alterations to the hocks, which is typically the most affected region of the body (Brenninkmeyer et al., 2016), were present during EG at comparable or higher levels to previous studies of hybrid pasture-based farms recorded during the housing period in Norway (35–61%; Kielland et al., 2009) and Denmark (47%; Burow et al., 2013b). Studies of hock injuries have shown that integument alterations are more likely with longer housing periods and can improve with greater time on pasture (Rutherford et al., 2008; Potterton et al., 2011; Burow et al., 2013b) where lying surfaces are softer and there is less risk of contact with infrastructure. This supports the observed improvement between the EG and LG for both neck-back and hock integument alterations in our study. Similarly, de Graaf et al. (2017) found that integument alterations were less common at the start of housing, following prolonged periods on pasture, than at the end of a housing period.

Ocular and Nasal Discharge

Poor ventilation or air quality experienced during housing can predispose cows to illness or irritants resulting in ocular or nasal discharge (Callan and Garry, 2002). Thus, the reduction in ocular and nasal discharge from EG to LG may be due to exposure to fresh air at pasture. Nasal discharge may be an indicator of impaired health such as respiratory infection (Love et al., 2014), and increased stress and reduced plane of nutrition may increase the risk of illness (Gorden and Plummer, 2010), which could play a role in the observed effect of treatment on nasal discharge as well. Indeed, nasal discharge was one of only 2 welfare indicators to support our hypothesis that cows experiencing greater grazing intensity would display more indicators of poor welfare; nasal discharge was more commonly observed among cows under the moderate and high levels of grazing intensity than those on the low level. The principal difference between cows on LO versus MOD is pasture availability, as they both represent the same farm system intensity. Cows on LO versus HI, however, differ in both pasture availability and farm system intensity. At the higher stocking rate and lower pasture availability, there could be greater competition for access to pasture, perhaps leading to more nutritional and social stress, and thus a greater risk of illness. Higher animal densities at increased stocking rate could also have contributed to increased disease transmission between animals as seen in continuously housed systems (Callan and Garry, 2002). However, as the relationship between nasal discharge and physiological or environmental stress and immune function were not examined in this study, such an interpretation cannot be confirmed. Further study is needed to investigate the potential connection between nutritional or environmental stress and increased nasal discharge due to illness.

Rumen Fill

Although rumen fill scoring is considered more subjective than other, more widely practiced assessment methods such as BCS, it has been shown to support changes or differences in feed intakes at a herd level (Schneider et al., 2022). Unlike the majority of indicators, which improved across the grazing season, rumen fill declined between EG and LG, which was counter to expectations. Due to the increasing energy demands of cows in early lactation (Jorritsma et al., 2003) which exceed grass growth rates until late spring (Hurtado-Uria et al., 2013), one would expect cows to display more signs of insufficient intakes during EG rather than LG. However, the unseasonably cold and wet weather during the early grazing season required that cows on-off grazed and thus were housed for a portion of the EG (e.g., individual full days or only overnight), with a cumulative total of 15.5 d for both LO and MOD, and 17.5 d for HI. Consequently, in addition to treatment diets, cows were provided with ad libitum grass silage during these periods. This allowed them the opportunity for greater feed intakes than would be provided under typical grazing conditions for the same period, and likely resulted in greater rumen fill.

Lying Time

As predicted, cows under the greatest grazing intensity (HI) in EG displayed the shortest average daily lying time. This is potentially the result of a greater amount of time required for grazing due to increased competition to obtain sufficient grass. This supports previous findings of O'Driscoll et al. (2019) who reported that a restricted feed allowance resulted in shorter lying times. However, the shorter lying time of cows on HI were still within the expected range in lying time for grazing dairy cows of approximately 7.5 to 10.5 h/d (O'Driscoll et al., 2009a, 2010, 2019; Sepúlveda-Varas et al., 2014). Such a difference in treatment groups was not detected during LG. This may reflect reductions in daily DMI in late lactation (National Research Council, 2001) such that all cows require less grazing time to meet their nutritional demands, leaving more time to perform other behaviors such as resting. The greater lying times in LG experienced by cows on HI and MOD also support previous findings that lying time increases with greater DIM (Ito et al., 2014; O'Driscoll et al., 2019). Cows on the LO treatment may not have been affected because increasing their already elevated lying times would be restricted by the time required for performing other important behaviors such as grazing.

Locomotion

Overall locomotion score was one factor that did not show an effect of grazing period, although there was a small yet significant improvement in locomotion score as grazing intensity increased. This was counter to our hypothesis that more intensive grazing management would result in more negative effects on welfare indicators. Although the average score was low for all treatments, the average prevalence of lameness within the herd, using a minimum threshold score of 9 derived from O'Callaghan et al. (2003), ranged from 15 to 39% depending on treatment and grazing period. This is higher than some previously reported levels of clinical lameness on Irish farms during the grazing season of 6 to 11%, (O'Connor et al., 2020) and 10% (Crossley et al., 2021). However, the scale used in our study makes no distinction between cows presenting with mild rather than severe lameness, and may be more similar to cows scored as having suboptimal mobility rather than clinical lameness. Suboptimal mobility describes any cows whose quality of locomotion deviates from the normal optimal gait (O'Connor et al., 2019). Previous research of suboptimal mobility on Irish dairy farms reported a prevalence of 38% of cows scored with suboptimal mobility, and found it was associated with low BCS and the presence of claw disorders (O'Connor et al., 2019). For comparison, studies reported the prevalence of clinical or severe lameness on pasture-based systems to be 31 to 35% in Brazil (Bran et al., 2018), and 32% in the UK (Griffiths et al., 2018), as well as 28, 31, and 55% for continuous housing systems in British Columbia, California, and the northeastern United States, respectively, in North America (von Keyserlingk et al., 2012).

Examining individual locomotion score components revealed that no single treatment consistently demonstrated greater impairment, although, the study intervention of regularly examining the cows' hooves may have contributed to this outcome. Cows on HI displayed the least impaired walking speed and lower impairment of step tracking than other treatments. These cows may have experienced more motivation to return to pasture to feed as they received the lowest pasture availability and were under a greater level of competition for feed access due to increased stocking rate. Motivation to access fresh feed has been associated with changes in gait (Flower et al., 2006), and the use of a feed reward has been shown to result in increased walking speed and stride length, even in lame cows (Mokhtarnazif et al., 2020). Later in the grazing season, cows on all treatments displayed less impaired walking speed. This may be due to increased exercise experienced throughout the grazing season. Walking from paddocks to parlor daily on less hard and slippery surfaces than concrete flooring has been suggested to alleviate stiffness and promote limb flexibility (Hernandez-Mendo et al., 2007; O'Driscoll et al., 2009b). In contrast, cows generally demonstrated greater impairment for the components of step tracking, and spine curvature, and a similar level of impaired ab/adduction during the later grazing period. These opposing changes in gait components could explain why the overall locomotion score did not vary by grazing period, despite the increase in the prevalence of lame cows across all treatments.

The observed treatment differences in locomotion components, even though there was little effect on overall locomotion score, also supports the presence of largely mild hoof disorders. Although these can influence the cows' gait, they are less likely to result in impaired locomotion or lameness than more severe disorders (O'Connor et al., 2019). Of the initial 4 types of hoof lesions assessed, both sole bruising and sole ulcers were present at such low levels that comparison between treatments or grazing periods was not possible. For those lesions that were present at greater levels (white line disease and digital dermatitis) the proportion of affected cows was not influenced by the levels of grazing intensity investigated in this study; however, they too demonstrated improvement from the EG to LG. This was evident over a shorter term for digital dermatitis, between the 2 EG inspections, and over a longer period for white line disease, between the start of EG and end of LG.

Hoof Health

Digital dermatitis is the result of infectious agents, and multiple reported risk factors are associated with housing, including solid grooved flooring (Barker et al., 2009) and exposure of hooves to slurry (Cook et al., 2004). Thus, this would explain the greater occurrence of digital dermatitis in the EG as a period of time is required for lesions to resolve following a decrease in infectious agents, and cows were still occasionally housed for partial days due to variable weather. Laven and Lawrence (2006) similarly identified effects of grazing season, with fewer cases of digital dermatitis reported in the months of June to October compared with February. Wet grazing conditions during EG may have resulted in some softening of the hoof, potentially putting them at greater risk of more severe claw lesions (Borderas et al., 2004). However, this was not analyzed in this study and therefore cannot be determined. Although, in general, access to pasture has a positive impact on reduction of claw lesions associated with moist conditions (Armbrecht et al., 2018).

In contrast, white line disease is the result of mechanical damage to the hoof. During the EG, cows have been more recently exposed to the hard indoor flooring surfaces, which is commonly associated with white line disease (Barker et al., 2009; Shearer and van Amstel, 2017). Cows are also more recently calved at this time in a spring-calving system, and may therefore be at greater risk of white line disease due to weakening of the connective tissues in the hoof which occurs around parturition, leaving hooves susceptible to physical stress (Tarlton et al., 2002; Knott et al., 2007). Exposure to these factors would explain the greater incidence of white line disease observed in our study during EG compared with LG periods. Although white line disease sometimes occurs more often in the later grazing season (Laven and Lawrence, 2006), it is likely after experiencing greater walking distances to pasture as poorly maintained roadways are a commonly reported risk factor (Chesterton et al., 1989; Doherty et al., 2014). In contrast, the farm used in the current study has extremely well-constructed and maintained roadways, which could explain the lack of development of the disorder later in the grazing season.

Study Limitations

One limitation of this study is that grazing season and stage of lactation were unavoidably linked. However, this is true for all seasonal-calving systems and therefore accurately reflects the conditions experienced by cows on Irish spring-calving dairy farms. Second, while every effort was made to control for differences between treatment groups, this data were collected from a single year of a system-level study. Therefore, treatment groups were not replicated and variability between individual cows within groups may have influenced the outcomes. As such, this analysis could be considered a case study of a spring-calving pasture-based production system, and statistical inferences considered with caution. Nevertheless, clear differences were identified between both treatments and grazing periods, providing valuable information about the impact of grazing intensity on indicators of dairy welfare, and warranting further study to confirm these findings.

CONCLUSIONS

Elevated levels of grazing intensity in this study, resulting from modifications of pasture availability and farm system intensity, affected some but not all indicators of welfare, particularly during the EG period. Greater grazing intensity was associated with more signs of nasal discharge, minor increases in integument damage to the neck and back, shorter lying times during EG and reduced impairment of locomotion score and some associated components. The greatest effects were instead observed between the EG and LG periods, which saw the improvement of all welfare indicators, except for rumen fill and locomotion score. However, uncharacteristic weather throughout the experimental grazing season influenced grazing management, and thus may have also had an effect on the results to some degree. Further study of the impact of increased grazing intensity in commercial settings and under more typical weather conditions may provide additional support for these findings.

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Table A1. Ocular discharge scoring scale[1]

Score	Description
0	No visible discharge from either eye
1	Small amount of clear discharge/tears around either eye (not larger than the diameter of the eye)
2	Heavy amount of clear or other discharge around either eye

[1]Adapted from Welfare Quality (2009).

Table A2. Nasal discharge scoring scale[1]

Score	Description
0	Nose is either dry or moist but with no visible discharge from either nostril
1	Nose is moist with a small amount of clear or opaque discharge from either nostril
2	Nose is moist with heavy, opaque discharge from either nostril

[1]Adapted from Welfare Quality (2009).

Table A3. Integument damage/alteration scoring scale for the neck and back region[1]

Score	Description
0	No swelling. No missing, thinning or broken hair.
1	Bald area on neck or back. No swelling, or mild swelling (<1 cm).
2	Medium swelling (1–2.5 cm) or lesion on bald area.
3	Major swelling (>2.5 cm) with or without bald area/lesion.

[1]Adapted from Welfare Quality (2009) and Gibbons et al. (2012).

APPENDIX

Table A4. Rumen fill scoring scale[1]

Score	Description
1	Deep indentation (full hand's width) below short-ribs and behind last rib. Muscle band extends down from hooks, creating pronounced rectangular shape between short-ribs, last rib, and muscle band. Rumen felt within triangle is soft and easily depressed.
2	Distinct triangle visible between short-ribs, last rib, and muscle band. Fairly deep indentation (half to full hand's width) below short-ribs and behind last rib. Firm feeling to rumen within triangle.
3	Triangle visible. Skin extends down, near-vertically, from short-ribs about 3 fingers width. Some definition behind last rib. Muscle band slightly visible and at 45-degree angle. Solid-feeling rumen within triangle.
4	Triangle barely visible. Slight indentation below short-ribs, with skin extending down about 1–2 fingers' width. Skin continues straight across from last rib to below hook.
5	No triangle visible. No definition below short-ribs. Skin extends out from short-ribs to meet belly.

[1]Adapted from AHDB (2019).

Table A5. Locomotion scoring scale[1]

Gait component	Score	Description
Spine curvature	1	Flat back always. Spine flat during locomotion.
	2	Back flat or slightly arched while walking. Slight departure from the horizontal plane, only obvious intermittently as cows walks.
	3	Slight arch, even when standing. Increases when walking. Slight departure from horizontal but constant.
	4	Spine obviously curved/arched.
	5	Spine fully/extremely arched.
Head carriage	1	Normal vertical movement during locomotion.
	2	Head "nods" slightly during locomotion.
	3	Marked vertical head movement during locomotion.
	4	Severe vertical movement during locomotion.
	5	Head lowered almost to ground level with each step.
Speed/symmetry	1	Symmetrical rhythmic steps; even weight on all feet. Normal locomotion at a comfortable pace.
	2	Slight asymmetry to gait. All legs not moving at same pace. Locomotion slower than normal.
	3	Asymmetrical gate identifiable in one or more legs. Slight limp evident. Slow, slightly hesitant walk or slight reluctance to bear weight.
	4	Stiff, asymmetric gait. Obvious limp but still able to walk. Very slow, hesitant walk or reluctance to bear weight.
	5	Obvious joint stiffness. Unable to bear weight on one or more limbs. Cow unwilling/unable to walk.
Tracking	1	Hind footprint fully traces or is more forward than front footprint.
	2	Hind footprint partly traces (slightly behind) front footprint.
	3	Toe of hind footprint reaches heel of front footprint.
	4	Hind footprint approx. 30 cm behind front footprint.
	5	Hind footprint more than 30 cm "behind" front footprint; shuffling.
Abduction or adduction	1	Hind limbs move forward parallel to vertical midline of animal.
	2	Slight deviation from midline of animal.
	3	Hooves form a C-shape in the air as they move forward in either direction.
	4	C-shape so defined as to be almost circular.
	5	Hooves circle completely in the air between each step.

[1]Adapted from O'Driscoll et al. (2010).

Table A6. Dermatitis scoring scale[1]

Score	Description
0	No appearance
1	Slight irritation of the skin (roughened appearance)
2	Irritation of the skin with rough, thickened appearance (may be evidence of grayish exudates)
3	Irritation of the skin with rough, thickened, moist appearance and swelling
4	Swelling of the skin with grayish exudates and signs of hyperkeratosis
5	Dermis no longer intact, moist eczema and hyperkeratotic lesions

[1]Adapted from O'Driscoll et al. (2008).

Table A7. White line disease scoring scale[1]

Score	Description
0	No appearance of white line
1	Striated appearance of white line
2	Slight separation
3	Moderate separation
4	Complete separation of the white line

[1]Adapted from O'Driscoll et al. (2008).

Table A8. Sole hemorrhage/bruise scoring scale[1]

Score	Description
0	No bruising
1	Diffuse red or yellow in horn
2	Stronger red coloration
3	Deep dense red
4	Port coloration
5	Red raw, possibly fresh blood

[1]Adapted from Leach et al. (1998) and O'Driscoll et al. (2009b).

Figure A1. Integument damage or alteration scoring scale for tarsal joint injury in dairy cattle. A score of 0 = no swelling; no hair missing, thinning, or broken. 1 = no swelling or mild swelling (<1 cm); bald area on hock. 2 = medium swelling (1–2.5 cm) or lesion on bald area. 3 = major swelling (>2.5 cm) with or without bald area or lesion (Gibbons et al., 2012).