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Surveillance of hoof disorders in Korean dairy cattle and the correlation of farm condition risk factors to their prevalence

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Abstract

Background This study investigated the prevalence of hoof disorders (HDs) in intensive dairy farms in Korea and their association with farm conditions. A total of 877 cattle from 15 farms were examined for infectious, noninfectious, and non-lesion HDs at the animal, foot, and farm levels. Risk factors such as bedding depth, floor wetness, floor elevation transitions, and aggressive hoof treatment were evaluated. Correlation and clustering analyses were used to assess the relationship between HDs and farm conditions and classify farms based on disease prevalence and management conditions.

Results Hoof disorders were identified in 31.5% of cattle, with hoof overgrowth (OG) (24.1%) being the most common. Infectious and noninfectious HDs were observed in 6.2% and 4.6% of cattle, respectively, with bovine digital dermatitis (BDD) (3.2%) and laminitis/corium damage (LCD) (3.1%) as the most prevalent. OG was more frequent in the front feet, while lesion HDs were more common in the rear feet. Correlation analysis showed that poor farm conditions, particularly aggressive hoof treatment and sharp floor elevation transitions, were linked to higher prevalence of BDD, LCD, and coronet swelling (CS). Hierarchical clustering classified farms into two main groups, distinguishing those with higher disease prevalence and poor conditions from those with lower prevalence and better management. This highlights differences in disease control across farms and the need for targeted interventions.

Conclusion This study provides an updated assessment of HD prevalence in intensive dairy farms in Korea, the first in nearly two decades. The reported prevalence of OG, BDD, LCD, and CS underscores the need for improved hoof care and farm management. Farms with better conditions had lower disease prevalence, serving as benchmarks for improvement, while farms with poor conditions require targeted interventions. Enhancing hoof care practices and farm management strategies could reduce HD incidence and improve dairy cattle welfare.

Keywords Dairy cattle, Lameness, Hoof disorders, Intensive dairy farming

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Background

The increasing worldwide demand for milk and other dairy products has prompted the intensification of dairy operations across the globe, resulting in a substantial increase in dairy yields and global economic benefits [1]. Despite the recognized profits of the expanding dairy industry, there has been a concurrent increase in doubts regarding the detrimental effects of dairy intensification on the environment, rural development, human well-being, and animal welfare [1]. Across numerous high-income nations, the trend toward intensifying indoor operations on dairy farms has had notable repercussions on animal well-being. This intensification aims to enhance productivity, yet often comes at the cost of compromising the welfare of the animals [2].

Cattle lameness poses a major welfare concern for the dairy farming sector, resulting in economic losses from reduced milk production, weight gain, reproductive performance, and the necessity to cull affected animals [3, 4]. Lameness is characterized by the irregularity of an animal's posture and gait, which is usually associated with underlying pathologies that cause pain in affected animals [5]. In a review about cattle welfare, approximately 90% of lameness cases in dairy cows stem from hoof disorders or diseases (HD) [6]. Lameness-related HDs in dairy cows can result from infectious diseases like foot rot (FR) and bovine digital dermatitis (BDD), as well as lesions caused by claw horn disruptions, such as sole ulcers (SU) and white line disease (WLD) [6]. Therefore, it is crucial to promptly identify and address impairments in animals at an early stage to prevent severe harm to their health and welfare [7]. Among the significant contributing factors to the increased occurrence of HDs on intensive dairy farms are management elements, including inadequate foot hygiene, utilization of concrete floors, limited grazing, and uncomfortable stalls [8]. Notably, restricted grazing emerges as a primary factor influencing HD development, leading to an elevated lameness incidence, particularly in intensively managed dairy farms, as indicated by a series of studies conducted over recent years [9].

In Korea, most dairy farms adopt intensive farm management practices, allowing them to efficiently utilize the limited land resources of the country [10]. Although indoor management boosts milk productivity and quality [11, 12], such intensive practices predispose the animals to welfare challenges, potentially leading to the development of lameness-causing HDs, consequently causing additional economic losses. Based on data from 1994 to 1999, the prevalence of HDs in Korea is estimated to be 11–21% [13]. Despite the ongoing intensification of dairy farms in Korea, a substantial concern has arisen from the absence of published data over the past two decades concerning the evaluation of lameness-causing HDs in cattle [14]. Given the widely recognized fact that HDs are the primary contributors to cattle lameness, this study conducted a surveillance of HD in intensive dairy cattle farms in Korea. This study also assessed specific risk factors associated with farm conditions to establish correlations between these conditions and the prevalence of HD.

Methods

Ethical statement

This study on HDs in Korean dairy cattle farms prioritized the welfare of the animals. All procedures and examinations were conducted with utmost care to minimize any potential discomfort or harm. Qualified veterinarians and handlers ensured cattle well-being. Farm owners were informed and consented to the objectives of the study. Measures were taken to minimize harm during examinations, with data treated confidentially and results presented transparently for the advancement of cattle welfare.

Farm selection and information, and clinical inspection of hooves

Data on HD prevalence and farm condition scores were collected from various dairy farms. The selection process was through the requests from farm owners for the expertise of a specialized veterinarian for hoof care. The clinic regularly trims around 80 dairy farms annually. In this study, fifteen intensively managed dairy farms were randomly selected, with a total of 877 dairy cattle utilized for this study. The examination process and hoof trimming took place during single visit to each of the selected dairy farms only during the spring (March to June) and autumn (September to November) seasons from 2017 to 2019. The assessment of HDs in cattle and the scoring of farm condition risk factors were conducted based on the consensus by two expert veterinarians specialized in hoof care.

The prevalence of each HD was recorded, along with farm condition scores, for a comprehensive analysis. The dataset included information on infectious lesion HDs including BDD, FR, and coronet swelling (CS); noninfectious lesion HDs including laminitis/corium damage (LCD), SU, and WLD; and non-lesion HDs including hoof arthritis (HA) and Overgrowth (OG), detailed in Table 1. The veterinarians utilized a hydraulic lifting crush (depicted in Fig. 1A) to conduct the evaluation of all four feet, including the left front (LF), right front (FR), left rear (RL), and right rear (RR) hooves and perform the hoof trimming process. This stage allowed for the inspection of other HDs and underlying pathologies, which could be identified more clearly after the trimming of hooves (as shown in Fig. 1B). The clinical and pathological description of the HDs is presented in Table 1.

Table 1 List and description of surveyed hoof disorders

Categories	Name of foot disorder	Acronym	Description of clinical observation
Infectious hoof disorder	Bovine digital dermatitis	BDD	Observed red, wart-like lesions around the heel area and between the digits. Lesions varied in size, with some showing hairy projections. The affected areas emitted a foul smell
	Foot rot	FR	Lesion of the coronary band with spreading of the toes and/or necrosis of tissue between the toes.
	Coronet swelling	SC	Swelling on the tissue of the coronary band at the junction of the claw
Noninfectious hoof disorder	Laminitis/ Corium damage	LCD	Damage in the laminar corium leading to inflamed solar corium. Discoloration of the sole from yellow to red. Damage in corium characterized by defective horn growth were observed during hoof trimming.
	Sole ulcer	SU	Circumscribed lesion located in the sole horn, characterized by deteriorated sole tissue. Solar corium not affected. Hoof tester test was applied to assess the pain reaction of animals
	White line diseases	WLD	Collective term to lesions affecting the white line of the claw. This includes hemorrhage, fissure, and abscessation. Observed separation along the white line where the sole and wall meet. The space created by the separation contained debris.
Non-lesion deformities (NL)	Hoof arthritis	HA	Arthritis caused by trauma, sprain, or ligament injury in the foot, marked by swelling of the proximal or distal interphalangeal joint and a pain response to pressure.
	Overgrowth deformity	OG	Noted significant overgrowth of the hoof, leading to an abnormal hoof shape and angle. The overgrown hoof showed uneven wear and negatively impacted the animal's gait and posture.

Farm condition scoring

All farms included in this study were equipped with concrete flooring and used rice hulls or sawdust as the bedding material. Farm conditions were evaluated based on the following specific criteria: bedding depth, wetness level, number of floor elevation transition/threshold, and aggressive treatment (Supplementary file 1). These criteria were used to gauge the potential impact and initiation of HDs. The farm condition score is the average scores of multiple site observations within the farm including the feeding, drinking, milking, and laying area, where it is applicable. Total farm score ranged from 3 (minimum) to 12 (maximum). Farms in better condition received higher scores, indicating a lower likelihood of HD development. Information about each of the 15 selected farms is presented in Table 2 which included location (province) of each farm and relevant farm conditions score. The criteria were defined as follows:

Bedding depth

Scored based on depth of bedding with the following pointing measurement range: shallow (1 point; < 3 cm), moderate (2 points; 3–7 cm), and deep (3 points, > 7 cm).

Wetness level

Percentage moisture content of the floor bedding measured by oven dry method: very wet (1 point; ≥65%), moderate (2 points; 36–64%), and dry (3 points; ≤35%).

Floor elevation transition/threshold

Number of floor elevation transitions or thresholds with at least 15 cm height (sharp angle transition between floors of different heights) found along the common pathways in the farm where animals usually pass through to access the mentioned areas in the farm. Excessive (1 point; ≥3 transitions), rare (2 points; 1–2 transitions), and none (3 points: no transitions).

Aggressive treatment

Scored based on the proportion of cattle which received aggressive hoof trimming within each herd. Hoof trimming aggressiveness was evaluated based on the length of the hoof horn post-trimming from the soft tissues of the coronet to the claw horn tip, where ≤ 84 mm was considered aggressive. The classification was determined as follows: high aggressiveness (1 point; ≥11% of the herd), moderate aggressiveness (2 points; 6–10% of the herd), and least aggressive treatment (3 points; ≤5% of the herd).

Statistical analysis

The prevalence and frequency of HD per farm and affected foot were analyzed using cross-tabulations. To establish initial prevalence ranking and farm condition categories, the data from each farm was scaled based on the min and max observed prevalence and farm score.

Correlation analysis using Spearman's rank correlation was used to associate disease and farm conditions. To avoid producing disproportionate correlation calculation

Fig. 1 Cattle hoof assessment: (**A**) Cattle were guided through a hydraulic lifting chute for a comprehensive examination of all four feet; and (**B**) hoof trimming to enable a more thorough evaluation of potential underlying damage

due to small sample representation or presence of outliers, a proportional cut-off for HDs that has less than 5 cases was set. This excluded FR and SU in the correlation analysis. Correlation coefficients were visualized using a heatmap matrix and the variables with significant correlations ($p < 0.05$, $p < 0.001$) were depicted with an asterisk (*, **). Correlation analysis was done using IBM SPSS Statistics v.26.

Hierarchical clustering was performed to classify farms based on HD prevalence and farm condition scores. Since the dataset included both numerical (HD prevalence percentages) and ordinal (farm condition scores) variables, Gower's distance was used as the similarity measure to handle mixed data types. Numerical variables were normalized based on absolute differences, while ordinal variables were ranked to maintain their relative order. Clustering was performed using Ward's linkage method, which minimizes variance within clusters for well-separated groups. A dendrogram was generated to visualize the clustering structure, and a cut-off threshold of 0.5 was applied to define the final clusters. The clusters were then analyzed to compare HD prevalence and farm conditions, with data visualization techniques ensuring clarity and consistency. All analyses were conducted in R 4.3.2 using the cluster and factoextra packages.

Results

Prevalence and farm condition

Of the 877 dairy cattle examined, 310 HD cases were identified in 276 cattle with at least one HD case (31.5%). Non-lesion HDs were the most common (24.6%) mainly due to OG, followed by infectious HDs affecting 6.2% of the cattle, and noninfectious HD affecting 4.6% of the animals (Table 2). OG was the highly prevalent non-lesion HD (24.1%) while BDD was the most prevalent lesion HD affecting 3.2% of the animals, followed by LCD, CS, and WLD affecting 3.1%, 2.9%, and 1.4%, respectively. Moreover, some animals exhibited more than a one HD on the same or different feet (4.7%). On farms, BDD was present in 66.7% of farms, followed by WLD, SU and LCD (Table 2). Notably, the highest HD prevalence occurred in farms J (62.5%), A (55.1%), and G (48.8%), whereas farms H, D, E, B, K, F, and L had the lower prevalence (Table 2). Based on these, farm prevalence data were scaled and farms were categorized as high (46–62.5%), moderate (30–45%), or low prevalence (14–30%) (Table 3).

Regarding the distribution of HD among feet, 58.5% of HD affected the front feet, whereas 41.5% affected the rear feet (Fig. 2). OG constituted 93.6% and 63.6% of disorders in the front and rear feet, respectively. However, most HDs were generally more prevalent on the rear feet. Among the specific disorders, BDD, LCD, and CS demonstrated the same pattern of higher prevalence on the rear feet.

Based on the pattern of farm condition scores, we categorized the farms into groups (Table 3); Farms A, C, G and N were categorized as poor condition farms for having lower scores across most conditions; Farms B, H, I, J, K, L, and M were categorized as fair condition farms due to a mix of condition scores, possibly with higher scores in some conditions and lower in others; and Farms D, E, F, and O which were categorized as good condition farms with generally higher scores in most conditions.

Correlation analysis

The correlation analysis between HDs as shown in Fig. 3A indicated that majority of the HDs are negatively correlated with certain farm conditions. This is specifically substantial for BDD, CS, and LCD as these HDs have shown significantly strong negative correlation ($p < 0.001$) with the total farm score. BDD, SC, and LCD showed a strong negative correlation with the floor transition

Table 2 Frequency distribution and prevalence of hoof disorders of Korean dairy cattle in each farm

Farm (*n*)	A	B	C	D	E	F	G	H	I	J	K	L	M	*N*	O	Total	% AP	%FP
HD	**69**	**48**	**63**	**50**	**75**	**74**	**41**	**57**	**36**	**40**	**65**	**105**	**35**	**83**	**36**	**877**		
Infectious																		
BDD	8	0	7	0	2	2	3	0	1	2	0	1	0	1	1	28	3.2	66.7
FR	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0.1	6.7
CS	11	0	0	0	0	0	3	0	0	5	0	4	0	2	0	25	2.9	33.3
Total	19	0	8	0	2	2	6	0	1	7	0	5	0	3	1	54	6.2	
Noninfectious																		
WLD	0	0	0	0	2	1	1	1	0	1	1	1	0	1	3	12	1.4	60.00
SU	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.1	60.00
LCD	8	1	7	0	0	0	3	1	0	0	0	5	1	1	0	27	3.1	53.3
Total	8	1	7	0	2	1	4	2	1	1	1	6	1	2	3	40	4.56	
Non-lesion																		
OG	23	7	19	8	10	14	12	7	9	18	13	13	13	30	15	211	24.1	100.0
HA	0	2	0	0	0	0	0	0	0	0	1	1	0	1	0	5	0.6	26.7
Total	23	9	19	8	10	14	12	7	9	18	14	14	13	31	15	216	24.6	
Total cases	50	10	34	8	14	17	22	9	11	26	15	25	14	36	19	310		
N affected	38	10	27	8	13	16	20	8	12	25	14	23	13	33	16	276		
% affected	55.1	20.8	42.9	16.0	17.3	21.6	48.8	14.0	33.3	62.5	21.5	21.9	37.1	39.8	44.4	31.5		

%AP: Percentage prevalence of hoof disorders among animals

%FP: Farms with HD

Total case: Number of observed HD cases

N affected: Number of animals with at least one HD case

Table 3 Information and scoring of the condition of the farm

Farm	Province	Bedding level	Floor Wetness	Floor Transition	Trimming Aggressiveness	Farm Score	Farm Cond'*n*	Prev. Rank	Cluster
D	JN	3	3	3	3	12	Good	Low	1 A
E	JN	3	3	3	3	12	Good	Low	1 A
B	CN	3	2	3	3	11	Good	Low	1 A
F	CN	3	2	3	3	11	Good	Low	1 A
H	CN	2	3	3	3	11	Good	Low	1 A
O	GG	3	2	3	3	11	Good	Moderate	1 A
I	GB	1	2	3	3	9	Fair	Moderate	1B
K	CN	2	1	3	3	9	Fair	Low	1B
L	CN	2	2	2	3	9	Fair	Low	1B
M	GG	2	2	3	3	10	Fair	Moderate	1B
N	JJ	1	1	3	3	8	Fair	Moderate	1B
A	CN	1	2	1	1	5	Poor	High	2
C	JN	1	2	2	1	6	Poor	Moderate	2
G	CN	2	2	1	2	7	Poor	High	2
J	CN	2	1	2	3	8	Fair	High	2

CN: Chungnam; JN: Jeonnam; GB: Gyeongbuk; GG: Gyeonggi; JJ: Jeju

Farm condition: Poor: ≤ 7; Fair: 8–10, Good: ≥ 11

Prevalence (%): Low: 14.0–30.02; Moderate: 30.2–46.4; High: 46.4–62.5

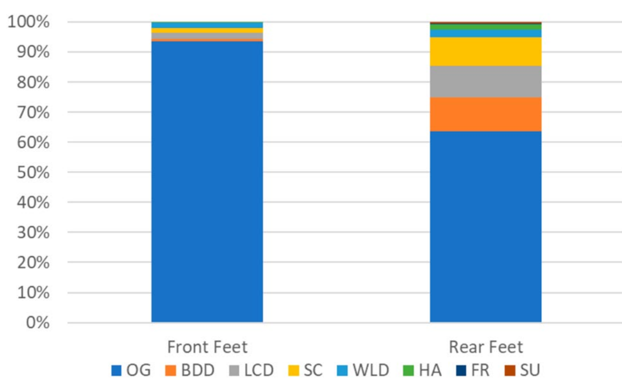

Fig. 2 Precentage distribution of hoof disorders between front and rear hooves

score, indicating that a higher number of floor transitions (lower score) was associated with an increased prevalence of these diseases. BDD and LCD showed a strong negative correlation with the aggressive treatment score ($p < 0.001$), indicating that a higher proportion of animals undergoing aggressive hoof trimming (lower score) was associated with an increased prevalence of these diseases. LCD showed a significant negative correlation with bedding depth ($p < 0.05$), indicating that shallower bedding was associated with a higher prevalence of these diseases. OG showed a significant negative correlation with floor wetness, indicating that wetter floors were associated with a higher prevalence of OG. WLD and HA did not show any significant correlations among the farm conditions. We observed significant correlations among HDs, with a strong positive correlation between BDD and LCD, while BDD and CS showed significant negative correlations.

Farm clustering analysis

The hierarchical clustering analysis based on HD prevalence and farm condition scores grouped the farms into two main clusters, with Cluster 1 further divided into two subgroups, as shown in Fig. 3B. Cluster 1 included farms O, B, F, H, D, E, I, L, M, K, and N, with higher farm scores and lower disease prevalence compared to Cluster 2. Within this cluster, Subgroup 1 A (O, B, F, H, D, E) had an average disease prevalence of 27.4% and a farm score of 10.8, while Subgroup 1B (I, L, M, K, N) had an average disease prevalence of 22.1% and a farm score of 9.5. Cluster 2, which included farms A, C, G, and J, had the highest disease prevalence (48.0%) and the lowest farm scores (6.6). Farms in this cluster exhibited poorer farm conditions and higher HD prevalence compared to those in Cluster 1. These results highlight distinct groupings of farms based on HD prevalence and farm conditions, reflecting variations in disease occurrence across different farm environments.

Discussion

This study examined the prevalence and distribution of HD in intensively managed dairy cattle and assessed their correlation with farm management conditions in Korea. The results indicate that infectious HD prevalence (6.2%) in this study is comparable to the 7.8% reported by Lee et al. (2001) [14], suggesting that infectious disease rates have remained stable over the past two decades. In contrast, a 2007 report summarizing data from the 1990s estimated HD prevalence at 11–21%, including overgrowth, ulcers, laminitis, and infections. While the current study found an overall HD prevalence of 31.5%, differences in classification methods and sampling may account for variations across studies. However, the high

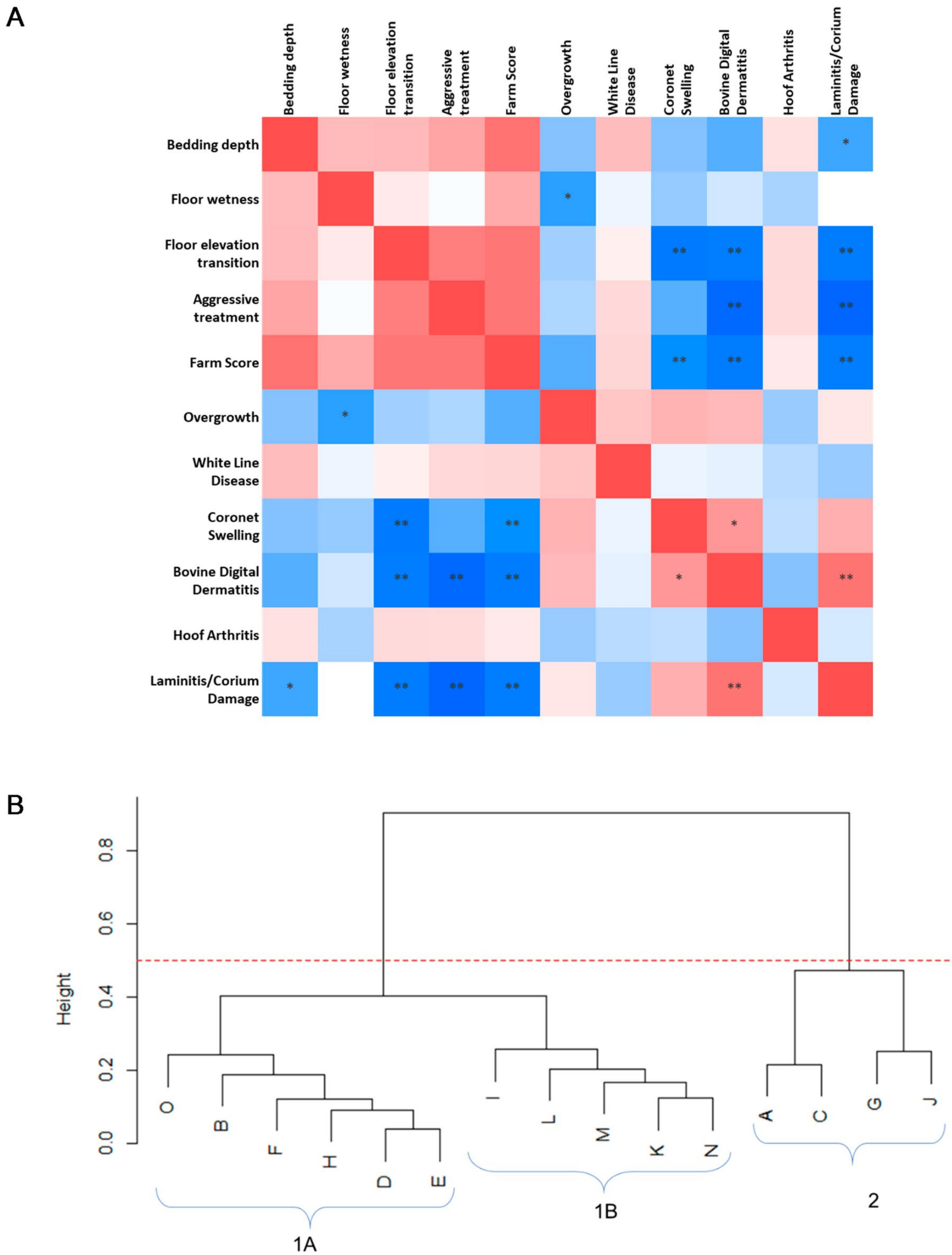

Fig. 3 Spearman's rank correlation coefficient matrix (**A**). Red signifies positive correlation and blue for negative correlation between variables. Correlations with "*" denotes significance at 5% level, while "**" denotes significance at 1% level; and Hierarchical clustering of farms based on hoof disease prevalence and farm condition scores, using Gower's distance and Ward's linkage method to group farms by management conditions and disease prevalence (**B**)

prevalence of OG in both studies suggests that the overall HD prevalence is largely driven by OG rather than an increase in other HDs. In this 2007 report, OG was the most frequently observed condition, with 49.3% prevalence in 1994–1996 and 27.5% in1997–1999 [13] while this study found a 24.1% prevalence. These findings reinforce the continued significance of OG as a management challenge, emphasizing the need for improved hoof care practices among intensive cattle farms in the country.

OG accounted for 76.5% of non-lesion HD cases, making it the primary contributor to overall HD prevalence. Neglecting OG can lead to severe health issues in cattle, as it primarily results from inadequate hoof wear and trimming practices in intensive farming setups [15, 16]. Poor hoof wear affects animal welfare, increasing the likelihood of mechanical injuries and raising the risk of secondary infections [17]. OG causes imbalanced digits and altered weight distribution, which can result in sole and heel ulcers [18]. Additionally, OG can lead to medial toe rotation, predisposing cattle to lameness and other infectious hoof conditions [19]. Addressing OG through routine trimming and improved hoof care remains crucial to reducing its long-term impact on dairy cattle.

Among infectious HDs, BDD was the most prevalent (3.2%), followed by CS (2.9%) and a solitary case of FR (0.1%). This diverges from the report from 2001 which described a higher FR prevalence than BDD [14]. Contrarywise, more recent Canadian and Brazilian studies have shown an elevated prevalence of BDD compared with FR [20, 21]. BDD persists in the UK as a leading cause of lameness in British dairy cattle [22]. This could indicate that the trend of HD prevalence in Korea have shifted over the years, which may have followed the global trend due to dairy farm intensification. On the other hand, CS remains relatively underexplored. In a previous study in Malaysia, a similar disorder termed as swelling of the coronet was found to be highly prevalent [16]. CS is an indicative marker for the onset of BDD and FR, offering a clinical sign for initial diagnostic purposes [23, 24]. The CS cases in this study may indicate early-stage infections that could progress into other HDs, given their significant positive correlations with BDD. The single FR case was identified on a farm with poor conditions and moderate prevalence; however, this does not establish a direct causal link. Its occurrence may be influenced by multiple factors, including individual animal susceptibility, environmental conditions, and bacterial exposure. Additionally, some CS cases may have been early-stage FR, emphasizing the need for further investigation to clarify potential diagnostic overlap.

Noninfectious HDs such as LCD and WLD have also been notably observed. While laminitis primarily impacts the laminar corium, severe cases can lead to contusion of the sole corium, potentially giving rise to secondary lesions in the sole region [25, 26]. One of the initial surveys in Korea on laminitis in cattle reported that 1.6% of the animals were affected, accounting for 21% of all HD cases [14]. In comparison, this study found LCD in 3.1% of cattle with HD, indicating a higher occurrence than previously reported. On the other hand, reports on the prevalence of WLD in cattle varies from country to country. In this study, a low percentage of cattle has WLD, affecting 4.4% among animals with HD. Compared to the study conducted in 1995 which reported that WLD affected 2.4% of cattle with HD in Korea [27], the current data was higher, indicating that the prevalence of WLD in the country have increased. Laminitis and corium damage in cattle are closely related conditions that affect the feet, specifically the structures supporting the hoof. Therefore, precise techniques must be implemented for the diagnosis of these HDs.

SU and HA presented lower prevalence compared to other HDs which is most likely due to optimal flooring of farms in this study. Additionally, cases of animals with no reaction to pain during the hoof tester examination were excluded. Since studies suggest that like most other HDs, SU is linked to many other risk including the presence of other HDs [28, 29], further studies such as longitudinal surveillance of HDs on dairy farms are warranted.

Hoof deformity due to OG of the claws was observed to be generally more prevalent in front hooves. Front claws grow much slower than the claws of the rear hooves; however, the wear and tear rates of the front hooves were noted to be lower [30]. On the other hand, rear feet are more predisposed to lesion HDs as 80% of cases of lesion HDs occurred on the rear feet. This is consistent with reports from other countries, ranging from 73.4 to 90% of the cases [16, 20, 31]. The potential overloading of the lateral claw is a major contributing factor to the elevated occurrence of lesion HD in the rear feet. This overload may result from mechanical conditions linked to OG, resulting in an imbalance in claw shape that disrupts the weight distribution between the claws. This imbalance is particularly pronounced in the lateral claws of the rear feet, where pressure is mainly concentrated at the heel-sole junction [32]. As previously noted, the rear claws have a faster growth rate, potentially leading to more frequent claw trimming than the front claws. This contributes to the elevated OG levels observed in the front feet in this study. Another plausible reason for the increased prevalence of HDs in the rear foot could be attributed to the fact that, during lactation, a significant portion of the milk's weight is primarily supported by the hind legs [33].

This study also established the relationship between specific HDs and farm conditions using Spearman's rank correlation. The assessed conditions represent farm-level risk factors linked to HD development. The results highlight the negative correlation between certain HDs and farm conditions indicating farms in better condition could experience a lower incidence of HD. The negative correlation between floor elevation transition score and HD prevalence suggests that farms with more floor transitions (lower score) had a higher occurrence of HD, specifically BDD and LCD. Although this factor has not yet been investigated previously, cattle may sustain injuries from uneven floor level, particularly if they are lame or have other mobility problems. Cattle may suffer from falls or injuries that strain their muscles, ligaments, tendons, or both when they must climb steps that are excessively high or steep. Furthermore, persistent strain from frequently navigating challenging floor elevation transitions might aggravate pre-existing diseases or disabilities. Additionally, these elevations or thresholds have been observed to have sharp edges which may attribute to increase the chance of causing open wounds and traumas on cattle hooves once they pass through these. Preventing injuries and enhancing the welfare of cattle can be achieved by avoiding steep steps and installing suitable and even flooring. Farms with a higher proportion of cattle undergoing aggressive hoof trimming had a higher prevalence of BDD and LCD, as shown by the negative correlation with the aggressive treatment score. This confirms that farms with higher proportion of aggressive trimming (lower aggressive treatment scores), had more cases of BDD and LCD. Routine hoof trimming is important in enhancing the locomotion of animals, hence help prevent lameness, as it keeps the balance of weight distribution on hooves [34–36]. However, some hoof trimmers tend to aggressively trim the claws to treat deep lesions, resulting to permanent damage to the corium leading to poor hoof conformation. There is a recommended claw trimming protocol in dairy cows; however, over trimming even without drawing blood, could cut through sensitive tissues, or even worse, could lead to thin soles which could result to open wounds, imbalanced load bearing, compression of the corium that would hence induce sole hemorrhage and other claw horn lesions [37–39]. Another possible reason for the observed correlation, particularly with BDD, is that over-trimming not only creates microabrasions but also increases the risk of infection when combined with contaminated trimming tools [40]. These open wounds and abrasions serve as direct entry points for pathogens associated with BDD. Additionally, improper trimming can cause imbalanced weight distribution and increased mechanical stress, further predisposing cattle to lesions and infection.

Bedding depth score showed negative correlations with LCD. Recent research has demonstrated that ample bedding enhances animal condition, fosters growth and behavioral improvements, and reduces serum biomarkers associated with subclinical joint damage including cross linked C-peptide of type II collagen (CTX-II), procollagen IIA N-terminal peptide and cartilage oligomeric matrix protein [41, 42]. This is because flooring with ample bedding, as opposed to bare concrete, offers greater welfare and comfort, reducing hoof injuries [42]. Hoof injuries frequently stem from sharp objects or abrasive surfaces, particularly from bare floors and shallow beds. Injuries in the hoof could serve as entry point for the diverse microorganisms on the bedding and floor, leading to diseases like BDD and FR [36]. These HDs are driven by shifts in the microbial community or dysbiosis on the hoof skin [37, 38]. In a previous study, applying BDD lesion materials and bacteria to unabraded feet in BDD induction experiments did not cause lesions, indicating that open wounds are required for invasive bacteria to penetrate tissues [43].

Only OG showed a negative correlation with the wetness score, indicating that as wetness scores decreased (indicating higher moisture levels), OG prevalence increased, confirming a positive association between excessive moisture and OG occurrence. Although the direct mechanism remains unclear, prolonged exposure to moisture around the hooves may contribute to increased hoof growth or structural changes, potentially influencing OG development. Overall, the negative correlation with the total farm score suggests that farms with higher scores, likely reflecting better overall conditions and management practices, tend to have lower occurrences of these disorders.

The clustering analysis grouped farms based on HD prevalence and farm conditions, highlighting key differences in disease management. Cluster 1 generally had lower disease prevalence, but variations within its subgroups suggest that good farm conditions alone do not fully explain disease control. While some farms maintained consistently low disease levels, others showed more variation, suggesting that factors beyond farm conditions, such as biosecurity measures, herd management, and environmental influences, may contribute to disease occurrence. Cluster 2, with lower farm scores, had the highest disease prevalence, reinforcing the link between suboptimal farm conditions and increased disease risk. Farms in this group had higher floor wetness, shallow bedding, and reduced treatment interventions, which may have contributed to disease persistence. These results suggest that certain environmental and management factors act as risk enhancers, making disease control more challenging in poorly managed farms. While improving farm conditions is critical for reducing HD, additional targeted disease control strategies are needed to achieve consistent and effective management. Identifying farms based on their disease risk profiles allows for more precise interventions, ensuring that control measures are tailored to specific farm needs rather than relying on general management improvements.

This study provides valuable insights into HD prevalence and farm conditions, though some factors should be considered when comparing results with other studies. Differences in farm management practices, biosecurity measures, and classification methods may influence prevalence comparisons, as variations in scoring criteria and data collection approaches could lead to inconsistencies across studies. Environmental variability, including humidity, temperature, and seasonal changes, along with management differences across years, may also affect disease occurrence. Since data collection was conducted in spring and autumn, which are transitional seasons, the effects of extreme conditions in summer and winter were not captured. Including these seasons in future studies would provide a more comprehensive understanding of how temperature extremes, humidity fluctuations, and seasonal management adjustments influence HD prevalence. While the findings clearly differentiate farm groups based on disease prevalence and management conditions, variability within groups suggests that localized environmental conditions, stocking density, or genetic resistance may also contribute to disease patterns. To improve comparability and strengthen disease risk assessments, future research should incorporate longitudinal data, multi-seasonal observations, and standardized classification criteria across different farm systems.

Conclusion

This study provides key insights into HD prevalence in intensively managed dairy cattle and its relationship with farm conditions. Overgrown hooves (OG) were the most prevalent HD, highlighting the need for better hoof care. While infectious HD rates remained stable, BDD emerged as the most prevalent infectious HD. Farm conditions played a significant role in HD occurrence, with factors like floor elevation transitions, aggressive trimming, shallow bedding, and wet flooring being strongly linked to higher disease prevalence. Farms with better management practices had lower HD incidence, reinforcing the importance of proper environmental and hoof care strategies. Clustering analysis revealed that farms with poorer conditions had higher HD prevalence, but variability within farm groups suggests that other factors, like herd management and biosecurity, also contribute to disease risks. These findings emphasize the need for targeted interventions, improved farm management, and standardized hoof care protocols to minimize HD risks. Future research should incorporate multi-seasonal and long-term studies to better understand disease patterns and develop effective, farm-specific management strategies.

Abbreviations

HD	Hoof disorders
FR	Foot rot
BDD	Bovine digital dermatitis
SU	Sole ulcer
WLD	White line disease
NL	non-lesion hoof deformity
LF	left front
FR	right front
RL	left rear
RR	right rear
OG	Hoof overgrowth
LCD	laminitis/corium damage
CS	Coronet swelling
HA	Hoof arthritis

Supplementary Information

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Supplementary Material 1

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Author contributions

HE, SKK carried out the experiment. HE wrote the manuscript with support SSL, and YIC. YIC helped supervise the project. YIC and SKK conceived the original idea.

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Data availability

The datasets supporting the conclusions of this article are included within the article. Any further inquiry about the dataset can be directly answered by the corresponding author upon request.

Declarations

Ethics approval and consent to participate

The authors confirm that the conduct of this research was carried out in compliance with the Animal Research Reporting In Vivo Experiments (ARRIVE) guidelines and complied with institutional, national, and international regulations for the ethical handling of animals. All experimental protocols conducted in this study were reviewed and approved by the Sunchon National University ethics committee.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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