THE GLOBAL STANDARD
FOR LIVESTOCK DATA

Section 7- Guidelines for Lameness in Bovine

Section 7 – Bovine Functional Traits (Extract for the Guidelines on Lameness in Bovine)

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1 Lameness in Dairy Cattle

1.1 About this Guideline

The Guidelines for recording lameness in dairy cattle give an overview of the most common systems of lameness scoring and recording in dairy cows. They are important components of lameness control strategies on dairy farms. Lameness scoring, when applied on a regular basis, allows detection and treatment of lame individuals at an early stage of disease. Collected data can be used to evaluate the herd's lameness control strategy and provide information for further analyses and research. The guidelines include considerations and recommendations for improved lameness recording in the context of a herd health management program, animal welfare, benchmarking and genetic evaluation.

1.2 Terminology

Lameness scoring will be used in this document. Other terms such as locomotion scoring, mobility scoring, and gait behaviour or gait assessment are used for similar traits. These are distinct from locomotion scoring as referred to the «ICAR Guidelines for conformation recording» which are here on the ICAR website.

1.3 Recommendations of Lameness Recording Practices

SYSTEM: A five-scale system (1 to 5) which considers different aspects of posture and gait (arched back, head bob and signs of weight bearing on non-affected limbs) – Table 1.

USERS: Dairy farmers, veterinarians, hoof trimmers, dairy advisors and farm employees.

HOW MANY: If cows are housed in pens, the number of animals selected for assessment should be proportional to the number of cows in each pen. A strategic sampling would be to assess cows from the middle of the milking order; the number being associated to the size of the herd. On large pasture-based herds, it is recommended that the last 200 cows should be assessed as a screening test.

HOW: Score lameness on a flat, firm, and non-slippery surface on which the cows are expected to walk normally or familiar to. While cows are walking, the assessor should view the animals from the side. Cows must not be assessed when they are turning. Animals to be assessed should be randomly chosen.

WHEN: Assessing cows after milking is the best time for scoring lameness. The environmental conditions should be as calm as possible to allow cows to walk as they would normally.

HOW OFTEN:

For herd management:

- Optimally, every two weeks, at least once a month;
- For early detection of hoof health problems: weekly or every two weeks is recommended;
- If monthly assessment is not feasible and if no routine claw trimming is taking place: at dry-off and at the beginning of lactation.

For genetic evaluation:

- If possible, use of data collected for herd management (single or multiple records per cow and lactation).

KNOW-HOW: Short theoretical instructions on the description of the five lameness categories and practical basic training is needed. Annual training of assessors is highly recommended.

Table 1. Recommended standards for lameness recording[4]

Lameness scores		Description	Behavioural criteria
Standing	**Walking**		
1 - Normal		The cow stands and walks with a flat back posture. Smooth and fluid movement, the gait is normal.	• All legs bear weight equally • Joints flex freely • Head carriage remains steady as the animal moves
			
2 – Mildly lame		The cow stands with a level-back posture but develops an arched-back posture while walking. The ability to move freely not diminished.	• All legs bear weight equally Joints slightly stiff • Head carriage remains steady
			

3 – Moderately lame  	An arched-back posture is evident while both standing and walking. The gait is affected and is best described as short striding with one or more limbs. Capable of locomotion but ability to move freely is compromised.	• Slight limp can be discerned in one limb but the lameness is often bilateral • Joints show signs of stiffness but do not impede freedom of movement. Shorter strides • Head carriage remains steady
4 - Lame  	An arched-back posture is always evident and gait is best described as one deliberate step at a time. The cow favors one or more limbs/feet. Ability to move freely is obviously diminished.	• Reluctant to bear weight on at least one limb but still uses that limb in locomotion • Strides are hesitant and deliberate, and joints are stiff • Head bobs slightly as animal moves in accordance with the sore limb/hoof making contact with the ground

5 – Severely lame			
		The cow additionally demonstrates an inability or extreme reluctance to bear weight on one or more of her limbs/feet. Ability to move is severely restricted. Must be vigorously encouraged to stand and/or move.	• Extreme arched back when standing and walking • Obvious joint stiffness characterized by lack of joint flexion with very hesitant and deliberate strides • One or more strides obviously shortened • Head obviously bobs as sore limb/hoof makes contact with the ground

[4]:Ref.: Sprecher et al. 1997 / Source of the pictures: Zinpro First Step®: Dairy Lameness Assessment and Prevention Program.

1.4 Introduction

Locomotor diseases causing lameness are widely recognised as one of the most serious welfare issues for dairy cattle and they represent substantial costs for dairy farmers (von Keyserlingk *et al.*, 2009). Lameness indicates pain or discomfort during locomotion and is characterized by a change in gait or an irregularity of the walking pattern. Lameness is most often caused by claw and/or leg disorders reflecting the attempt of the animal to reduce the amount of weight bearing on the affected limb(s). Therefore, lameness is considered as an indicator of an underlying problem that often causes pain (Flower and Weary, 2009). Lameness is associated to lower dry matter intake, impaired milk production and reproduction, and can lead to early culling. Thus, by reducing a cow's mobility, overall health and welfare are impacted.

The majority of lameness cases in dairy cattle are related to lesions of the claws, infectious or non-infectious (Toussaint Raven, 1978), that induce pain. According to Green *et al.* (2002), 80-90% of causes of lameness in cattle are located in the distal limb. Claw diseases occur most frequently in the first 3-5 months post-partum. In North American dairy herds, the main causes of lameness are sole ulcers, white line disease, toe ulcers, digital dermatitis, foot rot, and thin soles (Bicalho *et al.*, 2007; Sanders *et al.*, 2009; DeFrain *et al.*, 2013).

In a field study done in 2013 and 2014 by University of Calgary, Canada, veterinarians looked at the relationship between claw lesions and lameness in 10 dairy farms (Douglas, Solano *et al.*, 2019). Results showed that on average, 20% of cows were lame. A lesion was present in 94% of all lame cows and in 84% of non-lame cows. A cow with a lesion was almost three times more likely to be lame than a cow without a lesion. Results suggest that a cow with a sole ulcer or a white-line lesion was 12 to 13 times more likely to be identified as lame, whereas a cow with digital dermatitis (DD) was three times more likely to be identified as lame. The fact that six to eight weeks pass before damage of the corium becomes visible at the sole horn explains the low correlation between lesion presence and lameness detection. In this study, 84% of non-lame cows showed a lesion, putting them at higher risk for becoming lame.

The type of lesion influences lameness prevalence differently; cows with a sole ulcer or white-line lesion having a greater chance of being identified as lame than those with DD. Then, recording claw lesions during trimming would be an optimal practice for monitoring and preventing more serious claw diseases or limb disorders.

Consequently, prevention methods such as frequent lameness scoring are effective for:

- Early detection of claw lesions and feet and leg disorders;
- Monitoring lameness prevalence;
- Comparing lameness incidence and severity between herds;
- Targeting individual cows that need hoof trimming.

Other potential underlying conditions causing lameness include joint disorders (e.g. arthritis, arthrosis, luxation), diseases of muscles and tendons (e.g. myositis, tendinitis), and neurological diseases (e.g. neuritis, paralysis). Genetics can play a role for occurrence of lameness through disposition to aforementioned disorders or malformations such as corkscrew claws or similar deformations.

The environment of the cows can increase the risk of lameness such as housing, including type of flooring, and herd management practices (Solano *et al.*, 2015). In Australia, New Zealand

and South America where the dairy industry is predominantly pasture-based, cows may often walk several kilometres and stand for several hours per day in a crowded concrete yard while they wait to be milked. The potential for lameness to negatively affect animal welfare is of ongoing concern (Beggs and al, 2019; Hund et al, 2019). Pressure applied when walking down to dairy and when in the yard from excessive/incorrect use of backing gate may induce lameness. Cows should be left to walk to and away from the dairy at their own pace and the backing gate should be used only to fill space in the yard - not to push cows up.

The risks factors most commonly associated with lameness are:

- Walking and standing on concrete, especially wet and rough;
- Walking long distance on poor walking surfaces;
- Lack or absence of appropriate bedding and bad hygiene;
- Poorly designed stalls;
- Overcrowded pens;
- Pressure applied when walking to and away from the dairy and incorrect use of backing gate;
- Overcrowded pens and poor cow traffic;
- Infrequent and/or incorrect claw trimming;
- Insufficient monitoring that results in late detection of cows requiring additional care;
- Poor management, particularly of transition cows;
- Insufficient body condition (<2; Randall *et al.*, 2015 / For reference, see the Section 5 ICAR Guidelines for conformation recording);
- Parity;
- Physical hazards.

Preventing lameness helps to optimize milk production, improves conception rates and animal welfare and reduces treatment costs and antibiotic use. Consequently, it lowers stress level in both, cows and dairy farmers. However, improving gait/locomotion requires detailed information on individual lameness cases and informative records helping to identify causative factors that need to be eliminated or corrected.

The use of detailed information from veterinarians (for more severe lameness cases) and hoof trimmers (screening data and less severe cases) may allow deeper insight into improvement options. As various disorders are demonstrated to be related to certain risk factors, recordings obtained at routine claw trimming and treatment of lame cows allows for targeting on-farm risk assessment enabling farmers to alleviate or even eliminate potential risk factors.

1.5 Lameness Scoring Methods

Subjective methods are currently used for assessing cows on farms, and the results are described as numerical rating scores. It rates individual cows for the presence or absence of certain behaviours and postures related to gait. These scoring systems focus mainly on locomotion or gait associated with the degree of reluctance of bearing weight on the affected limb(s) with five, four or even only two categories (Brenninkmeyer *et al.*, 2007).

Over time, results from different studies show that subjective scoring can be applied consistently within and among observers, especially if the scoring system provides a detailed definition of each category and if the observers/assessors have been trained (Flower and Weary, 2009). Despite lack of precision, simple recording of lame animals by dairy farmers, advisors or veterinarians may be the easiest system for recording lameness on a routine basis. However, it is most reliable for cows that are either moderately lame, lame or severely lame (Sogstad *et al.*, 2012). Lameness scoring should be seen as a complement to the recording of claw health information during routine claw trimming for early detection of individual cows with problems in between trimmings.

Recording lameness may be performed on different levels of specificity and for different purposes. According to the objectives, some systems refer as being either a lameness scoring system or a mobility scoring system. A specific system is used for scoring lameness in tie-stall barns.

1.6 The Sprecher system: Scale of 1 to 5

The most popular systems for scoring lameness rely on the Sprecher system. This is a five-point scale system widely recognised and used worldwide due to its simplicity and the observation of the presence of behaviors such as an arched back when standing and walking (Sprecher *et al.*, 1997). This scoring system, where 1 is «normal» and 5 is «severely lame», is non-invasive and easily applied under farm conditions with short theoretical instructions and subsequent practical training. It allows more individuals to perform this assessment such as dairy farmers and their employees, veterinarians, hoof trimmers and advisors. Then, this scoring information can be used for herd management and early detection of lameness.

A similar approach uses behavioral variables or production variables as indicators for impaired gait (Schlageter-Tello *et al.*, 2014). The «Zinpro First Step®: Dairy Lameness Assessment and Prevention Program» uses that 1 to 5 scale to assess the severity of dairy cattle lameness. It is based on the observation of cows standing and walking (gait), with a special emphasis on their back posture. A combination of the Sprecher system and the «Zinpro First Step®» is presented in Table 1 and is the reference standard proposed for the current Guidelines.

However, in large herds such in Australia and New Zealand, a similar system is used where 0 means «Walks evenly» and 3, «Very lame». This system called «mobility scoring system» is also used in the UK and the US and is summarized at APPENDIX 1. A correspondence can be made between the mobility scoring system and the one presented on Table 26 where:

Mobility Scoring System	**Table 26**
Score 0: Walks evenly	Score 1: Normal
Score 1: Walks unevenly	Score 2: Mildly lame
Score 2: Lame	Score 3: Moderately lame
Score 3: Very lame	Score 5: Severely Lame

There are other scoring or assessment systems used in different countries and for different purposes and they are described in 1.12 (Appendix 1):

- «Welfare Quality Network» with a scale of 0 to 2;
- «Gait behaviours for non-lame and lame cows»;
- «König-Garcia mobility score»;
- «Stall lameness score system (SLS): 0 for non-lame cow and 2 for lame cows.

1.7 Some considerations for recording lameness

1.7.1 Training of the observers

Training is the main factor assuring proper performance of the observers at lameness scoring. Improved agreement across observers is obtained as more cows are assessed (March *et al.*, 2007). In this study, the authors suggested that 200 to 300 cows are sufficient numbers to score for reaching the acceptance threshold for agreement and reliability when using a five-scale system. Even after obtaining the acceptance threshold, observers should receive periodic training to avoid any "drift" which refers to the tendency of observers to change over time how they apply the definition of a measurement. A periodic training would be defined by once or twice a year alternating between practical exercise and online training for example.

Generally, training is crucial for achieving high agreement levels. It should be designed depending on the level of precision that is required. For example, the integration of a 5-scale gait scoring system into on-farm welfare assessment protocols is seen as justified, if adequate practical learning phase is assured (March *et al.*, 2007). However, Garcia *et al.* (2015) demonstrated that contrary to the current belief, the highest level of experience was not necessarily associated with a higher chance of perfect agreement.

1.7.2 How many animals should be assessed?

It is important to recognise that the ideal approach to assess the levels of lameness within a milking herd is to assess all cows. This approach highlights the potential animal welfare benefits of formal and systematic lameness scoring of dairy herds for improving identification and treatment of lame cows (Main *et al.* 2010; Beggs *et al.* 2019).

Studies have shown that random sampling during milking conveys limited practical benefits and oblige the assessor to be present throughout the milking (Main *et al.* 2010). Farm size may be a barrier to farmers participating in lameness scoring of the whole herd. A simpler alternative sampling strategy would be an incentive to do it more frequently.

Main *et al.* (2010) suggested a sampling based on getting within 5% of the true prevalence (Table 27). This study suggested that sampling herds from the middle of the milking order on most farms would seem most appropriate.

Table 2. Sampling based on the quadratic equation that best explained the sample size needed to get within 5% of the true prevalence based on sampling cows from the middle of the milking order.

Herd size	Sample size*
25	20
50	30
75	40
100	49
125	57
150	64
200	75
225	79
250	82
275	84
300	85

* *Sample size = −0.001n2 + 0.498n + 6.785, where n = number of cows in milking herd.*

In large pasture-based herds, Beggs *et al.* (2019) indicate that lameness scoring at least 200 cows at the end of the milking order would give some confidence that the overall lameness prevalence is correct. This number is useful as a screening test, identifying herds that were likely to have lameness prevalence above a given threshold. Presence of severely lame cows at the end of milking order may also be useful for identifying those farms likely to benefit from further support. But on a practical point of view, this recommendation would require dedicating resources on that specific task. Farmers are taught to look for lame cows every time they come into milking, at milking and when walking out.

1.7.3 Walking surface and location

Several studies indicate that the surface conditions in the walking area (soil and flooring) can have profound effects on gait. In a study, gait of cows walking on sand was compared to gait on slatted and solid concrete flooring. On slatted concrete floor, cows walked more slowly with considerably shortened strides and with the rear feet placed at greater distance behind the front ones. On the solid concrete floor, cows took shorter strides and steps than on the sand surface, but the speed did not differ significantly. Rubber mats on concrete floor increased the length of strides and steps and had a positive effect on locomotion in both, lame and non-lame cows (Telezhenko and Bergsten, 2005).

Concrete is not an ideal surface for dairy cows to walk on despite it being the most common surface found on farms. It could lack sufficient grip for cows to move around comfortably without fear of slipping. Grooving is therefore essential for a good traction, but a compromise has to be struck between sufficient grooves for allowing traction and too many grooves that would cause excessive wear (Cook, 2005).

Rubber flooring provides a more secure footing and is softer and more comfortable to walk on, especially for lame cattle (Flower *et al.*, 2007).

Consequently, lameness scoring should be performed with cows walking on a flat, firm, and non-slippery surface. To gain consistency and reliability of scores on subsequent visits on the same farm ideally the same way, the same location and same walking surface should be used for scoring. For example, when the parlour exiting routine becomes disrupted, cows will often not show their normal behaviour and are more likely to conceal lameness (Groenevelt *et al.*, 2014).

1.7.4 How often and when

To correctly identify new cases of lameness and for early detection of claw health problems, it is preferable if monitoring of lameness is performed every two weeks (Eriksson *et al.* 2020 – In press). Several studies concluded that lameness and locomotion scores may be useful indicator traits for claw health (Laursen *et al.*, 2009; Weber *et al.*, 2013; Egger-Danner *et al.*, 2017). Decreased assessment frequency can make it more difficult to adequately identify new lame animals (Eriksson *et al.* 2020 – In press). In addition to lameness assessment every two weeks, immediate treatment of lame cows will lead to reduced lameness prevalence. Early treatment of lame dairy cows results in the development of less severe claw lesions, increasing the chance of full recovery and decreased the amount of time an animal was lame (Groenevelt *et al.*, 2014).

In the near future, new technical advances (e.g. sensors. pedometers or accelerometers) could make it possible to monitor the gait of dairy cows in real time such that lame cows could be treated immediately (Haladjian *et al.*, 2018). Examples of behaviours that may be associated with lameness include walking speed, lying time, etc.

It is especially important to assess lameness at dry off and at the beginning of lactation if no routine claw trimming is taking place in the herd. If there are lesions, it is important that these can heal during the dry period such that the animal does not enter a new lactation with existing foot health problems. As not all claw disorders are correlated to lameness, claw trimming is recommended when cows enter the dry period and at approximately two months post-partum (Kofler, 2015). In a study, Ahlén & Fjeldaas (2019) showed that locomotion scoring was insufficient to detect and control digital dermatitis in Norwegian free stall herds and that inspection in trimming chutes was necessary to detect the disease.

The most suitable time to assess lameness is right after milking because it is more compatible with normal farm work routines. The assessment should not disrupt cows outflow routine to be sure they keep a normal behavior. To support that practice, results reported by Flower and Weary (2006) showed that for cows with and without sole ulcer, the differences in gait before and after milking were evident. After milking, all cows had a significant improved gait. This change was probably due to udder distention and/or motivation to return to the home pen.

Finally, the use of detailed information from veterinarians (for more severe cases) and hoof trimmers (screening data and less severe cases) may allow deeper insight into improvement options. As various disorders seem to be related to certain risk factors, information obtained

during routine claw trimming and treatment of lame cows allow for targeting on-farm risk assessment in order to alleviate or even eliminate potential risk factors.

1.8 How to Score Lameness

Including lameness scoring in routine herd management is the most practical way for detecting lameness in dairy cattle on farms. This method or practice can be used in free-stall or other types of loose-housing systems and in tie-stall systems where cattle are routinely exercised, if practical. The lameness scores are ideally entered into a herd management software or can be recorded using a board and a paper recording sheet. Appendix 2 presents two examples of data recording sheets.

1.8.1 Instructions for a free-stall barn

Identify a suitable location

Often the easiest location on the farm is the passage between the milking parlor and the pens. The criteria for choosing an adequate location are:

- Distance allows observation of cattle walking for four strides (minimum of two strides);
- Surface is smooth/flat and allows long confident strides without slippage;
- Avoid slatted concrete surfaces if possible;
- Avoid sloped flooring (downward or upward) or alleys with steps.

If cattle have been released from tie-stalls for allowing the scoring, habituate them to walking by walking up and down a passageway in a calm manner until the cattle walk in a straight line at a steady pace.

Identification of the animal

Record the identification of the cow to be assessed in the data-recording sheet:

- Ear tag number;
- Neck number.

Lameness score the cow

Observe at least four strides for each animal and record the degree of limping/reluctance of bearing weight on the affected limb(s) of the cow. Score and record information on the data-scoring sheet. Appendix 2 presents examples of recording sheets.

1.8.2 Instructions for a tie-stall barn

- Assess standing cows
- Encourage all cows to be assessed to stand for at least 3 minutes before their assessment begins. Do not score if the cow urinates or defecates during the assessment.
- Identification of the animal
- Record the identification of the cow to be assessed in the data-recording sheet.
- Observe
- Observe the cow for lameness. The assessment consists of two parts:

A. Assessment of foot placement – Standing Pose

1. Observe the foot position and placement of the cow for a full 10 seconds in each of the following three positions:
   - Directly behind the cow such that both legs are visible (about 0,5-1m behind the stall)
   - Left of the cow for a side-view of both legs
   - Right of the cow.
2. Record the presence of EDGE, SHIFT and REST indicators for each position (Ref.: Table 4).

B. Shifting of the cow from side to side

1. Position yourself behind the cow with a view of both front and hind feet.
2. Ask the producer to shift the cows from side to side:
   - First walk from the right to the left behind the cow and then back to the right
   - If the cow does not respond to your movement, repeat this while tapping her hip bone, with your hand, on the side opposite to where you want her to move (i.e. If you want her to move left, tap her right hip bone)
   - If this still does not work, poking gently with the tip of a pen may replace a tap.
3. Pay attention to how the cow shifts weight from foot to foot
   - Observe if the UNEVEN indicator is present. This can be identified as a reluctance to bear weight on a particular foot*[1]
   - Observe the foot position and placement and the presence of EDGE, SHIFT and REST indicators resumed after movement.
4. Record presence of behavioral indicators in the Data Recording Sheets.

1.8.3 Score cows

A cow will be scored as obviously/severely lame (unacceptable) if 2 or more indicators are recorded. Record either «Lame» or «Not lame» on the recording data-sheet.

[1] Cows with sole ulcers or white line lesions on the lateral hind claw often try to relieve pain by putting more weight on the medial claw.

1.9 Use of Lameness Data

A precondition for use of lameness records for benchmarking, herd management and genetic evaluation is the storage of the information collected on farms into a central data base.

1.9.1 Herd Management

Lameness records are valuable information for early detection of claw problems. Claw trimming data are essential for the identification of the specific problem(s) and for targeting corrective measures (Fjeldaas *et al.*, 2011; Kofler, 2013). According to Green *et al.* (2002), lameness prevalence is highest in early lactation cows. In Austria, a study related to the «Efficient Cow Project» (Egger-Danner *et al.*, 2017) involving about 7,000 cows with lameness records assessed according to the Sprecher system at each milk recording test across a lactation, revealed rather stable incidences across the lactation.

According to Randall *et al.* (2018), between 79 and 83% of lameness events were estimated to be attributable to all previous lameness events and between 9 and 21% attributable to exposure to lameness events that occurred at least 16 weeks previously. Then, preventing the first case of lameness could potentially be important in avoiding an escalation of repeated lameness events. In addition, findings from this study highlight that early and effective treatment of lameness reducing the likelihood of recurrence or cases becoming chronic may also be crucial to lameness control at a herd level.

1.9.2 Benchmarking

A precondition for the use of lameness records for benchmarking, herd management and genetic evaluation is the storage of the information collected on farms into a central data base.

Benchmarking is important for herd management as it ranks the farm amongst its peers and it helps identifying where improvement is needed. However, to be able to compare herds, the frequency of assessment, the stage of lactation and the recording scheme itself need to be considered. Animals at risk need to be defined based on the strategy of data recording. If assessment of lameness is done every month or even more often, the frequency will most likely be higher compared to an assessment that is done once in lactation, or once a year at herd level. Therefore, the interpretation of results needs to take into account the circumstances of recording. The reference population will need to be defined and the criteria for claw health considered.

1.9.3 Welfare

It is well recognised that lameness is a painful experience for the cow (Whay *et al.*, 1997), causing loss of milk yield, poor fertility and body condition. The presence of lame and ill cattle in the milk-producing herd erodes consumer confidence in dairy farmers and farming practices. Despite increased awareness of lameness in relation to welfare and lost productivity, no studies reported a reduction in the prevalence of lameness over the last 20 years (Heringstad and Egger-Danner *et al.*, 2018). There are a number of barriers to improvement in the prevalence of lameness. Firstly, dairy farmers must recognise lameness. Studies have shown that without training, farmers will detect mainly the severely lame cows (Whay *et al.*, 2003; Leach *et al.*, 2010). Secondly, dairy farmers must find the time to observe the locomotion of all their cattle at frequent intervals. For them, shortage of time is a major obstacle to the use of visual lameness scoring as a tool for reducing lameness (Leach *et al.*, 2012). However, providing dairy farmers

with training to detect all states of lameness, and the use of incentives for reducing lameness would improve the situation.

To encourage dairy farmers to carry out lameness assessments, a number of organisations included lameness assessments within a welfare assessment scheme. Among those organisations are increasing numbers of retailers, milk processors and other food groups that now include aspects of animal welfare in their assessment schemes. The schemes are designed to provide assurance to the consumers about the standards of animal welfare. Lameness is one of the most commonly used welfare indicators in these schemes. Recording lameness as an indicator of welfare is a very valuable method to raise awareness and its negative impact for the dairy farmers and the public. However, there is a variation between schemes in the scale used for scoring animals, some only score a limited proportion of the herd and some do not record the identity of the animal, which are aspects that require improvement for allowing wider use of the data.

1.9.4 Genetics

Lameness records are valuable auxiliary traits for genetic improvement and should, if possible, be combined with claw trimming records, veterinary diagnoses and other existing information (e.g., culling for claw health, linear scoring) as lameness information itself does not give an indication of the causative disorder. Ring *et al.* (2018) and Egger-Danner *et al.* (2017) showed positive genetic correlations between lameness and direct claw health traits.

Animals at risk need to be identified and checked whether there is variation in the type of scoring scale used. The frequency of scoring has to be considered for the choice of the model. If repeated lameness scores are available per cow and lactations, trait definitions and models need to be optimised.

Trait definitions depend on the scale used. Several studies (Berry *et al.*, 2010; Parker Gaddis *et al.*, 2014; Koeck *et al.*, 2016) used lameness observations, coded «0» (not lame) or «1» (lame), in a comparable manner to certain health disorders recorded by farmers. In other cases, lameness can be grouped into three different scores (non-lame, lame and severely lame cows). Definitions might take into account the frequency of the occurrence of different scores as well as the frequency of recording (Koeck *et al.*, 2018). If the lameness data recorded will be used for herd management purposes, then data quality has to be especially verified (https://www.icar.org/Guidelines/07-Bovine-Functional-Traits.pdf). An important question is the definition of the contemporary group:

- Is lameness recorded from all animals or only for the lame cows?
- Is the trait definition across farms comparable?
- Are the same standards used?

The severity of lameness may also be described using a clinical gait score (Sprecher *et al.*, 1997; Flower and Weary, 2006; Koeck *et al.*, 2016; Egger-Danner *et al.*, 2017), which quantifies lameness on a scale from absent to very severe. For analysis, the severely lame cows (scored 3 or higher) may be analysed jointly (e.g. Rouha-Muelleder *et al.*, 2009; Weber *et al.*, 2013).

In a review, Heringstad and Egger-Danner *et al.*, (2018) reported heritability estimates of lameness varying between 0.02 and 0.16 based on linear models and from 0.02 to 0.15 based on threshold models. Berry *et al.* (2011) reports heritabilities for lameness varying from 0.03 to

0.096 when scored by farmers or by trained assessors. The genetic correlations between lameness and claw health were between 0.60 and 0.95 (Heringstad and Egger-Danner *et al.*, 2018; Ring *et al.*, 2018). Most genetic correlations between production and lameness are unfavourable. The relationship of lameness and claw health with milk production is complex as it is difficult to distinguish causes from effects (Heringstad and Egger-Danner *et al.*, 2018).

Koeck *et al.* (2019) showed that selecting for a better lameness score has the potential to reduce claw diseases, especially the frequency of severe claw diseases that lead to culling. As recording systems include lameness data as integral parts of routine welfare assessments on farms, and more and more farmers use lameness scoring for herd management purposes, increased availability of data may be expected in the future.

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1.12 Appendix 1

1.12.1 Alternative Scoring Systems for Lameness

1.12.1.1 Mobility scoring system: Scale of 0 to 3

A mobility scoring system is used in the UK (AHDB Dairy), in New Zealand (DairyNZ) and in Australia (Dairy Australia) where herds are large and cows are grazing most of the year. It is also promoted in the FARM Program in the US. It was designed so that anyone with experience of working with dairy cattle is able to perform mobility scoring effectively. The mobility scoring system is a four-point scale ranging from 0 «Walks evenly» to 3 «Severely or very lame». It simply assesses the cow's ability to move easily. By simplifying the scoring system, the aim is that dairy farmers are able to easily assess cow mobility on farm without the need for professional help.

1.12.1.2 The Welfare Quality Network: Scale of 0 to 2

This European organisation focuses on scientific exchange and activities to contribute to the development of the Welfare Quality® animal welfare assessment systems. A Welfare Quality® assessment protocol for cattle was developed for scoring lameness and proposes a 3-point scale program where 0 is «Not lame» and 2 is «severely lame». No specific target is proposed for each point.

1.12.1.3 Gait behaviours for non-lame and lame cows

Table 3 presents the general description for a two-scale program for scoring lameness: Lame or non-lame. This program is based only on gait behaviors and assessors must rely on evident signs of body language for determining the status of lameness of animals.

Table 3. General description of gait behaviours for non-lame and lame cows.

Behaviors	**Non-Lame Cows**	**Lame Cows**
Head bob	Up and down head movement when walking. The head moves evenly as an animal walks.	Jerky or exaggerated up and down head movements when walking. Obvious when foot makes contact with ground
Asymmetric steps	Animal places her feet in an even “1, 2, 3, 4” fashion	Animal has uneven rhythm of foot placement “1, 2.....3, 4”. Foot placement is not equal on both sides
Limping	Animal bears weight evenly over the four limbs	Walk with an uneven, irregular, jerky or awkward step as if favoring one leg

www.dairyresearch.ca/pdf/3-Animal%20Based%20Protocols-Dairy%20Research%20Cluster-eng.pdf

1.12.1.4 König-Garcia mobility score

König-Garcia *et al* (2015) developed a five-scale scoring system named: the König-Garcia mobility score. This system was specifically developed to enable scoring while walking only because it is difficult to get an opportunity to see cows standing and walking under practical conditions. This mobility scoring achieves relatively high within-observer agreement and seems feasible for on-farm implementation as a tool for monitoring mobility for benchmarking of lameness prevalence.

1.12.1.5 Stall lameness score system (SLS): 0 for non-lame cow and 2 for lame cows

In tie-stall barns, scoring lameness can be challenging because cows may not be used to walking and there may not be a suitable area in which to walk cows. If walking and observation of cows is not possible, a stall lameness score system should be used.

This system represents an easier approach for scoring dry cows and young stock. SLS can be conducted in automated milking systems when cows are fixed during milking time to detect lame or affected cows. The SLS is based on a number of behaviours that cow shows while standing in the tie-stall (Winckler and Willen, 2001; Leach et al., 2009; Gibbons et al., 2014 -

Table 4).

The most common behaviours recorded are:

- Weight shifting;
- Standing on the edge of the stall;
- Uneven weight bearing while standing, and;
- Uneven weight bearing while moving from side to side.

The SLS method provides an estimate of the prevalence of lameness in tie-stall herds comparable with traditional gait scoring, but does not require that the cows be untied. It could be used to improve lameness detection on tie-stall farms and obtain estimates of lameness prevalence without the need to walk the cows (Gibbons *et al.*, 2014).

Table 4. Description of the behaviour indicators of the stall lameness score system[2].

Behaviour indicator	Description
Standing Pose (Voluntary movements)	
Stand on Edge (EDGE)	Placement of one or more feet on the edge of the stall while standing stationary. Standing on the edge of a step when stationary, typically to relieve pressure on one part of the claw. This does not refer to when both hind feet are in the gutter or when cow briefly places her foot on the edge during a movement/step.
Weight shift (SHIFT)	Regular, **repeated** shifting of weight from one foot to another. Repeated shifting is defined as lifting each hind foot at least twice off the ground (L-R-L- R or vice versa). The foot must be lifted and returned to the same location and does not include stepping forward or backward
Uneven weight (REST)	Repeated resting of one foot more than the other as indicated by the cow **raising** a part or the entire foot off the ground. This does NOT include raising of the foot to lick or during kicking.
Cow moved from side to side	
Uneven movement	Uneven weight bearing between feet when the cow was encouraged to move from side to side. This is demonstrated by a greater **rapid movement** of one foot of relative to the other, or by an evident **reluctance to bear weight** on a particular foot.

1.12.2 5.11.2 Future Measures of Lameness

Development of gait assessment or automatic lameness detection systems could provide more accurate and reliable data in the near future. Currently, these technologies are mostly used in research and they require sophisticated equipment or installation that limits their large-scale use on farms. Some examples of such technologies include 3D images-based systems, thermal imaging cameras, 4-scale weighing platform, or wearable activity sensors (Alsaaod *et al.* 2015; Beer *et al.* 2016; Nechanitzky *et al.* 2016, Barker *et al.* 2018).

[2] *Ref.: Gibbons, et al. 2014.*

Using an activity sensor to measure, inter alia, lying time, tools for automatic lameness detection can estimate the risk of lameness by employing special models that take milking and feeding times into account (De Mol *et al.* 2013). Beer *et al.* (2016) reported that compared to healthy, non-lame cows, the behaviour of lame cows or cows with foot pathologies was characterized by longer lying bouts, more time spent lying down, shorter strides, slower walking speed, lower bite rate while grazing, and lower feeding time or faster eating. Models based on only two 3D accelerometer variables (walking speed, standing bouts) automatically identified slightly lame cows with both a sensitivity and specificity exceeding 90% (Beer *et al.* 2016).

Giuliana *et al.* (2014) showed that lameness leads to behavioural changes in automatic milking systems. A recent study showed that a 4-scale weighing platform allowed the detection of cows with sole ulcers or white line disease with a sensitivity of 97% and a specificity of 80% (Nechanitzky *et al* 2016). Recently, infrared thermography (IRT) has been used in bovine medicine to identify thermal skin abnormalities by characterizing a temperature increase or decrease in affected areas. The variation in superficial thermal patterns resulting from changes in blood flow, in particular, can be used to detect inflammation or injury associated with conditions such as foot lesions (Alsaaod and Büscher 2012; Stokes *et al.* 2012; Alsaaod *et al.* 2014; Wilhelm *et al.* 2015).

These technologies are still costly and still under development for increasing accuracy and precision for detecting abnormalities in cow gait or posture.

1.13 Appendix 2

1.13.1 Data Recording Sheets

A greater understanding of the dynamics of lameness in dairy herds can be obtained from improved record keeping systems and a comprehension of how lame cows interact with the environment (Cook, 2005). The dairy farmers or herd manager needs to determine the extent of the lameness problem on his herd:

The predominant causes;

Their trigger factors, the risk factors, and,

To understand the role of cow comfort and adequate hoof care.

Figure 1[3] and Figure 2 present proposed templates for recording lameness in free- and tie-stall barns respectively.

Figure 1. Example of a data-recording sheet – Free-stall.

	Cow ID	**1 Normal**	**2 Mildly lame**	**3 Moderately lame**	**4 Lame**	**5 Severely lame**
1						
2						
3						
4						
5						
6						
…						

Note: 90% cows = score 1 / <10% cows = scores 2 + 3

[3] *Both adapted from the Dairy Research Cluster (www.dairyresearch.ca/cow-comfort.php#self).*

Figure 2. Example of a data-recording sheet – Tie-stall.

	Cow ID	Stand on edge	Weight shift	Uneven weight	Uneven movement	Severely lame
1						
2						
3						
4						
5						
6						
…						

Note: A cow will be scored as obviously/severely lame (unacceptable) if 2 or more indicators are recorded.