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Lameness and Claw Lesions of the Norwegian Red Dairy Cattle Housed in Free Stalls in Relation to Environment, Parity and Stage of Lactation

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Sogstad ÅM, Fjeldaas T, Østerås O: Lameness and claw lesions of the Norwegian red dairy cattle housed in free stalls in relation to environment, parity and stage of lactation. Acta vet. scand. 2005, 46, 203-217. – Approximately 88% of Norwegian dairy cattle are housed in tie stalls. Free stall housing for all dairy cattle will be implemented within 20 years. This means that the majority of existing stalls will be rebuilt in the near future. Fifty-seven free stall herds of the Norwegian Red breed were randomly selected and 1547 cows and 403 heifers were trimmed by 13 claw trimmers during the late winter and spring of 2002. The claw trimmers had been taught diagnosing and recording of claw lesions. Environment, management- and feeding routines were also recorded. Fifty-three herds had concrete slatted alleys while 4 had solid concrete. Thirty-five herds had concrete as a stall base, while 17 had rubber mats, 2 had wood and 3 had deep litter straw beds. The prevalence of lameness was 1.6% in hind claws. Models for lameness and claw lesions were designed to estimate the influence of different risk factors and to account for the cluster effects within herd and claw trimmer. Detected risk factors for lameness were: parity three and above and narrow cubicles; for heel horn erosions: lactation stage around 5-7 months after calving and solid concrete alleys; for haemorrhages of the white line: lactation stage around 3-5 months after calving and solid concrete alleys; for haemorrhages of the sole: parity one, lactation stage around 5-7 months after calving and short cubicles, for white line fissures: slatted concrete alleys; for asymmetrical claws: parities two and above and for corkscrewed claws: solid concrete alleys. The prevalence of lameness in heifers was low, however 29% had one or more claw lesions. Heifers that were housed in pens or free stalls had more heel-horn erosions, haemorrhages of the sole and white-line fissures than heifers in tie stalls. As new free stalls are being built, it is important to optimise the conditions for claw health.

Claw lesions; free stalls; housing; environment; management; parity; stage of lactation.

Introduction

Claw disorders cause 90% of lameness in dairy cattle (*Murray et al.* 1996). Factors that have been associated with claw lesions are individual factors like stage of lactation, parity, weight and genetics (*Vermunt & Greenough* 1994). Herd factors involved are housing, environment, management and nutrition.

Infectious claw lesions like dermatitis and heel horn erosions are mainly influenced by the environment (*Manske et al*. 2002). Laminitis or claw horn disruption has largely been attributed to feeding regimens and especially rations high in rapidly fermentable carbohydrates have been focused on (*Logue et al.* 1993, *Vermunt & Gree-*

nough 1994). Lately, the effect of hormonal and metabolic changes on claw tissue around calving has received attention (*Lischer et al.* 2002, *Webster* 2002). Parity (*Enevoldsen et al.* 1991b, *Alban* 1995) and stage of lactation (*Huang et al.* 1995) has been shown to be risk factors for lameness and claw lesions as well as the possible exacerbation of disease by mechanical and nutritional influences (*Logue et al.* 1993).

Housing of dairy cattle has an unfavourable influence on claw health, but the negative influence of confined dairy systems may be reduced if they are well designed (*Bergsten* 2001). Most studies find that cattle housed in free stalls have more claw lesions than cattle in tie stalls (*Maton* 1987, *Thysen* 1987, *Faye & Lescourret* 1989, *Sogstad et al.,* in press). In tie stalls the lying-, standing-, milking- and feeding area is restricted to one station. In free stalls these areas, including the walking area is distributed on four stations which expose the claws to a much more complex environment. Approximately 88% of Norwegian dairy herds are housed in tie stalls (*Sogstad et al.* in press). Loose housing will be implemented for all dairy cattle within twenty years (*Royal Ministry of Agriculture* 2002) and from 2006 all cattle shall be supplied with soft flooring in their lying area. There will be challenges on how to make new and existing free stalls comfortable for animals and stockmen and at the same time cost effective. As part of a project on claw lesions in Norwegian Red dairy cattle, the present paper focuses on possible environmental risk factors in free stalls which may influence on claw health. Individual factors like parity and stage of lactation are included.

Material and methods

Selection procedure

Herds were stratified on 3 regions and approximately 500 herds with more than 15 cow-years per herd were randomly sampled from each region by using the Norwegian Dairy Herd Recording System. In region 1, 91 herds had free stalls and every third was included. In region 2, only 25 had free stalls and all were included. In region 3, 84 herds had free stalls and every third of these were included. Herdsmen were enquired if they wanted to participate in the study. After negative responses, exclusions and dropouts, 57 free stalls were included. Cows and heifers more than 18 months of age and of the Norwegian Red cattle breed were claw trimmed. The study was part of a larger project on claw lesions in Norwegian Red dairy cattle and reference is made to *Sogstad et al.* (in press) for more information on material and methods.

Study population

The study population consisted of 57 herds with 1547 cows and 403 heifers. Heifers were animals more than 1.5 years of age and more than 30 days before first calving.

Environment, management and nutrition

Factors related to environment, management and nutrition are shown in Table 1 and 2. As a consequence of the large proportion of slatted alleys in Norway, only 4 herds were housed on

Table 1. Mean number of cow years, mean milk production per cow-year and mean % concentrate, silage and pasture in feeding units in the study population and the whole country (tie stalls and free stalls) in 2002 (SD).

Variable	Herds in study (n=57)	Herds in Norway (n=17 476)
Cow-years	28.0 (11.6)	15.1 (7.3)
Milk production/ cow-year (kg)	6359 (788)	6099 (107)
Concentrate (%)	37.3 (13.2)	41.4 (18.6)
Silage (%)	40.4 (12.6)	38.8 (14.3)
Pasture (%)	16.4 (11.7)	16.6 (10.4)

Table 2. Factors related to environment and management in the present study.

Variable	Class	Number of herds (n=57)
Alley	Slatted	53
	Solid concrete	4
Blind ending alleys	0	28
	>0	25
Automatic feeders[a]	0	6
	1	32
	≥2	19
Step (in front of manger)	Yes	15
	No	38
Stall base	Concrete	35
	Rubber mats	17
	Wood	2
	Deep litter	3
Bedding materiala	Saw dust	47
	Wooden shavings	3
	Straw	1
	None	4
Age of stall (years)	<2	9
	2-5	10
	6-10	13
	11-20	20
	>20	5
Pasture (weeks)	0	11
	1-8	5
	9-15	15
	>15	26
Claw trimming[a]	Twice per year	3
	Once per year	21
	Occasionally when needed	22
	Not at all	11
Cleanness of animals	Very good	20
	Good	28
	Average	8
	Bad	1
Scrapings/day	0 or 1	17
	>1	38
Manner of cleaning[a]	Manual	45
	Automatic	6

[a]Factor that was not analysed in the present study

solid concrete. Three stalls were only 1 year old. Of stalls less than 2 years old, 56% had rubber mats as a stall base and all had slatted alleys. Among older stalls, 25% had rubber mats and 90% had slatted alleys. The majority of the herds had mats of the hard type (1-2 cm). Seven of the herds had porous mats (2-4 cm). No herds had mattresses. Brisket boards are not common in Norway and were not recorded in any of the herds. The effect of claw trimming will be described in a later paper. Only heifers that were stalled either in pens, free stalls or tie stalls were included in the separate analyses on heifers.

Recruitment and training of claw trimmers

Thirteen professional claw trimmers attended two courses covering claw trimming procedures and diagnosis, recording and treatment of claw lesions. Individual, practical training was given to each claw trimmer in addition.

Data recording

The cows were trimmed once during the period from the 1st of January 2002 to summer let out. The last herd was visited on the 28th of June. Dermatitis, heel horn erosions, haemorrhages of the white line and the sole, sole ulcers and white line fissures were scored as not present (0), mild (1), moderate (2) or severe (3) as described by *Bergsten* (2000). In the statistical analyses of the present study the scores where scored as not present (0) or present (1). Asymmetric claws, corkscrewed claws and dorsal wall length were also recorded. Corkscrewed lateral hind claws included both mild cases where the abaxial wall was bent inwards with a curved dorsal border and serious cases of corkscrew claws where the abaxial wall was part of the weight-bearing surface. Precarpal and peritarsal swellings and wounds were recorded as not present (0) or present (1). Information on environment, management and nutrition was collected by the claw trimmer, the project leader or by the farmer. Missing data were collected by telephone or mail. Data on particular factors that were still missing after these procedures led to animals in these herds being excluded from the analyses for that particular factor. The recording of the hygiene of the animals was based on subjective assessments (Table 2). The adaptation period was defined as the length of time that the heifers were housed with older cows before calving.

Data handling and statistical analyses

The information recorded at the farm was transferred to SAS version 8.0 for statistical analyses. As the front claws and the hind claws in free stalls are exposed to a quite similar environment and most lesions were found in hind claws, analyses were performed only in hind claws.

The variables were screened by simple univariate analyses. The significance level was set to $P \leq 0.05$. Peers of variables with a significant Pearson correlation coefficient higher than 0.20, were then assessed. The variables included in the model were those that most likely had an effect on the outcome according to the literature and the preliminary hypothesis. Generalized linear models were fit using "Proc Genmod" with logit link function, binomial distribution and herd as random variable. If the cluster effect of claw trimmer was significant, claw trimmer was used as random effect and herd nested within claw trimmer. The model was run as stepwise backward elimination and the variable with the highest P-value was excluded until all variables in the model had a P-value of ≤ 0.05.

Parity was grouped into first lactation (1), second lactation (2) and third lactation and above (3). The estimate for cubicle length- and width was calculated for every 10 cm. There were no stalls with solid concrete alleys that had rubber

Table 3. Dimensions of the cubicles and alleys in the study and recommended measures in Norway (*Ruud* 2003).

Variable		Dimensions (cm)	Herds (n)	Norwegian recommendations
Cubicle length	Open front	180-200	0	
		201-219	3	220-240
		220-225	1	
	Closed front	180-200	3	
		201-219	5	240-250
		220-230	13	
	Half open,	180-200	0	
	half closed	201-219	6	
		220-225	12	
	Other	180-200	0	
	combinations	201-219	4	
	/unknown	220-240	9	
Cubicle width		90-119	14	120
		120-125	43	
Kerb height		5-19	40	20-30
		20-30	15	
		31-35	1	
Neck rail height		94-100	10	
		101-109	26	100-110
		110-119	12	
Kerb to neck rail		108-159	23	
		160-169	23	170
		170-200	7	
Elevation of manger		0-19	28	
		20-24	18	20
		25-33	6	
Slot width		3.5-4	45	3.5-4
		4-5	2	
Slat width		12-15	50	12-15
		16-17	3	

mats in the cubicles, consequently stall base and alley had to be run in two separate models. Cows on solid concrete alleys were dirtier than cows on slatted floors, hence cleanliness of the animal and alley were also run in separate models as well as adaptation period and days at pasture.

Results

Lameness, claw lesions, carpal and tarsal remarks

Front limb lameness was recorded in 0.3% and hind claw lameness in 1.6% of the cows. The following prevalence was recorded for lesions in hind claws; 6.7% had dermatitis, 39.6% had

Table 4. Estimated ß (CI) for significant risk factors in the final model for each claw lesion (n=1540).

		L	E	HWL	HS	WLD	Y	Z
Intercept		2.65 (-1.52/6.82)	-0.78 (-1.42/-0.14)	-2.27 (-2.76/-1.79)	-85.34 (-136.94/-33.75)	-2.22 (-2.39/-2.04)	-1.85 (-2.58/-1.13)	-3.02 (-3.26/-2.77)
Parity	1	-1.21 (-2.52/0.10)			0.54 (0.25/0.83)		-0.76 (-1.00/-0.51)	
	2	-1.90 (-3.73/-0.07)			0.04 (-0.19/0.27)		-0.54 (-0.90/-0.17)	
	3	0.00			0.00		0.00	
Months in milk			0.17 (0.07/0.28)	0.36 (0.18/0.54)	0.53 (0.34/0.73)			
Months in milk^2			-0.01 (-0.02/-0.004)	-0.04 (-0.06/-0.02)	-0.06 (-0.07/-0.04)			
Alley	Solid concrete		0.32 (0.02/0.62)	0.94 (0.43/1.46)		-0.77 (-1.32/-0.23)		1.30 (0.54/2.06)
	Slatted concrete		0.000	0.000		0.000		0.00
Cubicle length					8.00 (3.12/12.87)			
Cubicle length^2					-0.19 (-0.31/-0.08)			
Cubicle width		-0.53 (-0.90/-0.15)						

L=Lameness
E=Heel horn erosion
HWL=Haemorrhage of the white line
HS=Haemorrhage of the sole
WLD=White line fissure
Y=Asymmetric claws
Z=Corcscrewed claws

heel horn erosions, 13.6% had haemorrhages of the white line, 20.0% had haemorrhages of the sole, 3.0% had sole ulcers and 9.4% had white line fissures. Most lesions were mild and heel horn erosions had the highest prevalence of moderate and severe scores (5%). Remarks to the carpus and tarsus were 5.2% and 4.0%, respectively.

Cubicle design

The design and dimensions of the cubicles in the study are given in Table 3 and the estimates for the different risk factors are given in Table 4. The cubicle length was within the recommendations in only one of the herds with open fronted cubicles. No herds with only closed fronted cubicles had lengths within the recommendations. All were too short. The majority of the cows were housed in cubicles that were longer than 200 cm. When the cubicle size increased from 200 cm, there were fewer haemorrhages of the sole and a tendency towards less heel horn erosions (P=0.06).

Fourteen herds had cubicles that were too narrow, but the majority of the cubicles were within the recommendations. Narrow cubicles were related to more lameness. There was a tendency towards more heel horn erosions in cubicles against a wall (closed front). The model became unstable when the type of front was

included and type of front was not included in the final model.
Fifteen of the herds had kerb heights within the Norwegian recommendations. Most kerbs were too low. No significant effect of kerb height was found on lameness or any claw lesion.

Stall base
The odds for haemorrhages of the sole were significant higher when there was concrete or rubber mats as stall base versus wooden or straw bed stall bases. There was no significant difference in the odds of having any claw lesion in cows on concrete or rubber mats. The type of stall base was strongly correlated with type of alley and was not entered into the final model. There were more remarks as to the carpus (OR=6.4 (2.0-20.0)) and the tarsus (OR=6.4 (2.1-19.3)) in cows on concrete versus cows on rubber mats.

Alley
There were more heel horn erosions (OR=1.4 (1.0-1.9)) and haemorrhages of the white line (OR=2.6 (1.5-4.3)) in hind claws of cows housed on solid concrete versus cows housed on slatted concrete floors (estimates are given in Table 4). There were more white line fissures (OR=2.2 (1.3-3.7)) in cows stalled on slatted floors. There were more corkscrewed claws (OR=3.7 (1.7-7.8)) on solid concrete versus slatted concrete floors. The width of the slots in slatted alleys was within the Norwegian recommendations in 45 of the herds, whereas the width of the slats was within the recommendations in 50 of the herds.

Hygiene of the animal
Cows with the scores average or bad tended to have more heel horn erosions than cows with the scores good or very good. The variable was strongly correlated with type of alley and was not included in the final model.

Adaptation period
There was a tendency towards less heel horn erosions, haemorrhages of the white line and the sole and white line fissures when the adaptation period was less than 3 weeks long.

Parity
The estimates given in Table 4 shows that there was more lameness among cows in third lactation or above than in cows in second lactation (OR=6.7 (1.1-41.7)). First lactation cows had more haemorrhages of the sole than cows in third lactation or above (OR=1.7 (1.3-2.3)). Cows in third lactation or above had more asymmetric claws than cows in first lactation (OR=2.1 (1.7-2.7)).

Months in lactation
The number of months since calving was significant for heel horn erosions and haemorrhages of the white line and the sole in the model (Table 4). Cows that had calved 5-7 months ago had most heel horn erosions. Cows that had calved 3-5 months ago had most haemorrhages of the white line and cows that had calved 4-6 months ago had most haemorrhages of the sole.

Other risk factors
The age of the stall was correlated with several of the factors that were analysed and were not included in the model. The variables that were most correlated with age of stall were type of alley, stall base, cubicle length and whether or not there was a step in front of the manger. There were no clear associations between lameness or any of the claw lesions and herd size, time spent at pasture, number of blind ending alleys, height from alley base to manger, step in front of the manger or feeding intensity (% feeding units of concentrate). Eighteen herds had mangers where the height was within the Norwegian recommendations. Most were too

Table 5. Housing of the heifers and adaptation period in weeks for first lactation heifers.

Variable	Class	Number of herds (n)
Floor for heifers	Concrete	6
	Slatted floor	45
	Other	4
Housing from insemination to calving	Tie stall	9
	Pen	35
	Free stall	5
	Other	9
Adaptation period	≤3	15
	>3	42

low. No risk factors were significant for sole ulcers and dermatitis.

Heifers

Details on housing for heifers and adaptation period is given in Table 5, whereas the prevalence of lameness, remarks to the carpus and the tarsus and different claw lesions is given in Table 6. Twenty nine percent of the heifers had one or more remarks to the hind claws. The prevalence of asymmetric claws was 3% in front claws and 5.7% in hind claws. The prevalence of corkscrewed hind claws was 0.7%.

The prevalence of heel horn erosions, haemorrhages of the sole and white line fissures was higher when heifers were stalled in pens or in free stalls versus heifers that were stalled in tie stalls from insemination to calving. Slightly more heel horn erosions and haemorrhages of the sole were found in heifers stalled in free stalls versus pens.

Discussion

Representativity

This study was part of a project where the main aim was to compare equal numbers of tie stalls and free stalls (*Sogstad et al.,* in press) and we got an imbalance in the distribution of solid concrete versus slatted alleys. The herds in the present study are, however, assumed to be representative for free stall herds in Norway.

The cluster effects within herd and claw trimmer were the same as was found by *Sogstad et al.* (in press). The cluster effect within herd was significant for all claw lesions, but most marked for heel horn erosions. The cluster effect within claw trimmer was only significant for heel horn erosions. This shows that the inclusion of different risk factors in the analyses does not influence the cluster effects.

The uncertainty around interrelationships, confounding and causal mechanisms is certainly present in all epidemiological studies, and the risk factors detected in the study can only be indicative of associations to help generate hypotheses. The low number of recorded cases of dermatitis and sole ulcers made the detection of risk factors for these lesions unlikely.

Cubicle design

Many cubicles in the present study did not satisfy the Norwegian recommendations for cubi-

Table 6. Prevalence (%) of heifers with lameness and claw lesions (n=403).

	L	C/T	D	E	HWL	HS	U	WLD
Front claws	0	3.5	1.2	8.9	3.2	3.3	0.3	3.0
Hind claws	0.5	2.0	1.7	11.4	2.7	6.7	0.5	3.5

L=Lameness
C/T=Remarks to the carpus/tarsus
D=Dermatitis
E=Heel horn erosion
HWL=Haemorrhage of the white line
HS=Haemorrhage of the sole
U=Sole ulcer
WLD=White line fissure

cle dimensions. Short cubicles seemed to be a risk factor for haemorrhages of the sole and probably for heel horn erosions. Narrow cubicles seemed to have a negative influence on lameness. More haemorrhages of the sole and a tendency towards more heel horn erosions in cubicles against a wall might be a consequence of cows spending too much time in the alleys. A cow needs 3 m for rising and lying down (*Bergsten* 2001) and lack of borrowing space have been found to be a risk factor for lameness incidence (*Faull et al.* 1996). Different types of cubicles in free stalls have been shown to influence both lying time and claw health (*Leonard et al.* 1994, *Leonard et al.* 1996). Unsatisfactory cubicle design is likely to cause considerable discomfort, and particularly the length of the bed (*Faull et al.* 1996). Narrow, uncomfortable cubicles (*Philipot et al.* 1993) have been suggested to be important influencing factors on lameness incidence. In the study by *Faull et al.* (1996) only 12% of the cubicles permitted real freedom of movement. Cubicles against a wall in the present study were not longer than open fronted cubicles leading to a reduced borrowing space. Cubicle dimensions should be adjusted to the largest animals in the herd.

While recommended measures for kerb height in Norway are 20-30 cm (*Ruud* 2003), most kerbs were less than 15 cm high in the present study. *Faull et al.* (1996) suggested that the height of the kerb should be no more than 15 cm. Variations in floor level have been suggested as a possible risk factor for claw horn lesions (*Philipot et al.* 1993). Even though no significant effects were revealed in the present study, high kerbs, steps in the alley area or in front of the manger cause weight being transferred to the hind claws and hence may contribute to the development of claw lesions.

Stall base

No significant differences in the effects of concrete stall bases versus rubber mats on any of the claw lesions were revealed in the present study. This is partly in contrast to the findings of *Bergsten & Frank* (1996a) where cows on rubber mats in tie stalls had less haemorrhages than cows on concrete stall bases. When two types of cubicles were compared (*Leonard et al.* 1994), and one type was larger and bedded with rubber mats, heifers spent significantly longer time lying down in the cubicles with rubber mats. Analyses on the type and amount of bedding were not performed in the present study, but it has been shown that lack of bedding is a risk factor (*Faull et al.* 1996). No positive influence of rubber mats in the present study might be due to the majority of the mats being of the hard type or that mats were not provided with sufficient bedding material. The difference in lying time between cows on concrete and cows on rubber mats may be too small to influence claw health significantly, as there are so many other factors involved in free stalls. Rubber mats might in addition act as a reservoir for microorganisms if they are not well fit or if they are not properly cleaned.

No herds had mattresses in this study. Mattresses are thought to lead to a more restful behaviour than mats, suggesting that mattresses improve cow comfort (*Chaplin et al.* 2000). Mattresses are softer and easier to keep clean, and the use of mattresses should be encouraged in free stalls. More remarks to the carpus and the tarsus on concrete were expected due to the abrasive nature of concrete. In one study hock lesion scores were higher in cows on concrete stall bases than in cows on sand (*Vokey et al.* 2004). It has also been shown that replacing mats with mattresses may reduce the risk of hock damage (*Livesey et al.* 2002).

Alley

The imbalance in the distribution of alley types in the present study must be kept in mind when the results are interpreted. The higher prevalence of heel horn erosions on solid concrete with automatic scrapers versus slatted alleys is in agreement with *Thysen* (1987), but in contrast to a Dutch study (*Somers et al.* 2003). *Philipot et al.* (1993) found that the risk factors for heel horn erosion were associated with poor hygiene, and manure has been shown to have detrimental effects on horn (*Mülling & Budras* 1998). In free stalls feet are continuously exposed to manure in the alleys and faeces and urine might accumulate to a greater degree on solid floors. However this depends on the scraping frequency (*Somers et al.* 2003) found that cows on slatted floors with manure scrapers had less digital dermatitis, interdigital dermatitis and heel horn erosions than cows on slatted floors without scrapers.

There were more white line haemorrhages, but not sole haemorrhages in cows on solid concrete alleys in the present study. *Kujala* (2003) did not find associations between either the flooring nor the housing system and haemorrhages. The higher prevalence of white line haemorrhages on solid concrete alleys versus slatted alleys might be due to the impaired quality of the horn resulting from heel horn erosions, but there is no obvious explanation to why this would not count for haemorrhages of the sole as well.

The higher prevalence of white line fissures on slatted floors may be the result of uneven pressure exerted by the slats which has been suggested to influence particularly the white line (*David* 1989). Haemorrhages of the white line have been suggested to predispose to white line fissures. However, fissures might also be caused directly by mechanical influences in the environment (*Mülling* 2002). The result in the present study indicates that direct mechanical influences may be more important for the development of white line fissures than white line haemorrhages. Walking on slatted floors leads to uneven forces on the claw and mechanical influences probably are important in the pathogenesis of white line fissures. Fiedler (2000) found more white line disease in free stalls than in tie stalls and explained this by overcrowding, uncomfortable cubicles and narrow passageways. Bad slats, increased competition and bulling activity have also been suggested as influencing factors (*David* 1989). A Swedish study in pigs showed that sows on slatted concrete had more white line fissures and heel horn erosions than both sows on solid concrete floors and deep straw beds. The difference was partly explained by the uneven point pressure of the slats or possibly that the slats had too sharp edges (*Ehlorsson et al.* 2002). The result in the pig study might be biased by more bedding material being provided to solid concrete floors than to slatted floors.

More corkscrewed claws were found on solid concrete than on slatted alleys in the present study. More corkscrew claws have been found in free stalls than in tie stalls (*Kujala* 2003), but in contrast to the present study, there were no differences between solid floors with scrapers and slatted floors.

Straw yards seem to provide the best surface for the prevention of claw lesions (*Somers et al.* 2003) with the exception of heel horn erosions (*Livesey et al.* 1998). Straw yards are uncommon in Norway.

Hygiene of the animal

More heel horn erosions in dirty cows is in agreement with *Manske et al.* (2002). Poor housing hygiene acts as a risk factor for heel horn erosions (*Philipot et al.* 1993), and this is probably explained by the infectious nature of heel horn erosion.

Adaptation period

The tendency towards a benefit of an adaptation period of less than three weeks is partly in agreement with *Manske et al.* (2002), but in contrast to what has been found by others (*Bergsten* 2001). There was no effect of pre-calving housing on claw lesion development in one study where heifers were housed either in straw yards or in cubicles and then transferred to concrete cubicle yards after calving (*Laven & Livesey* 2002). In another study, the severity of sole haemorrhages and sole ulcers was significantly reduced when heifers were housed in a straw yard until 8 weeks after calving instead of moving the heifers to a cubicle yard 4 weeks before calving (*Webster* 2002). Heifers might refuse to use the cubicles and the concentrate dispenser for several days after inclusion into the milking herd (*Kjæstad* 2001). The optimal length of the adaptation period may therefore depend on the type of floor in the heifer section versus the type of floor in the lactating cow section and also on which period is the most vulnerable when it comes to different risk factors and their influence on claw health.

Parity

More lameness with increasing age is in agreement with several studies (*Wells et al.* 1993, *Ward* 1999, *Offer et al.* 2000, *Manske et al.* 2002), but partly in contrast to (*Alban* 1995) who found most lameness in lactation 1 and 4. The prevalence of lameness and its relation to parity is influenced by culling practises, but the increasing prevalence with age as seen in the present study might be the result of aging and cumulative damages to claw tissue. Repeated scarring of the corium may lead to irreversible damage (*Lischer et al.* 2002). The highest odds for haemorrhages of the sole in primiparous cows are in agreement with other studies (*Bergsten* 1994, *Manske et al.* 2002). Heifers are experiencing major changes in the housing conditions, social environment, nutrition and physiologic demands. Researchers have also suggested that tissues of the claw like the digital cushion may not be fully developed in heifers (*Lischer et al.* 2002).

Months in lactation

The prevalence of haemorrhages has been found to be highest around 3-5 months after calving also in other studies (*Huang et al*. 1995, *Leach et al.* 1997, *Offer et al.* 2000, *Manske et al.* 2002). The study by *Leach et al.* (1997) showed that haemorrhages of the white line peaked earlier than haemorrhages of the sole which is also in agreement with the present study. The greatest risk for claw horn disruption may be 1-2 months after peak lactation. The horn of the sole grows at a rate of approximately 3-4 mm per month (*Shearer & Van Amstel* 2001) and with a sole thickness of 5-10 mm, it can take up to 3 months before any visible signs of haemorrhage. The higher prevalence of heel horn erosions at 5-7 months in lactation, cannot be explained by changes in the environment. *Enevoldsen et al.* (1991a) also showed that the risk for heel horn erosions increased with the stage of lactation. Heel horn erosions and haemorrhages have been found to be correlated lesions (*Sogstad et al.,* in press). Claw horn disruption might contribute to heel horn erosion as a result of impaired horn production or heel horn erosion might contribute to claw horn disruption as a result of the altered weight bearing of the sole or a combination of the two (*Greenough & Vermunt* 1991). The recordings were done at the end of the housing season, which might have influenced the result.

Other factors

The mean herd size in the present study was relatively small and as expected, significant differences in the prevalence of lameness and claw lesions between small and large herds were not found. More lameness has been found in large herds (*Alban et al.* 1996) and has been thought to be part of the intensification of the dairy industry (*Faye & Lescourret* 1989). In very large herds however, cows with locomotion problems are more difficult to spot and the herdsmen may also be more likely to cull lame cows. The space allowance per cow may be more important than the size of the herd.

Positive effects of spending time at pasture were not revealed in the present study. Cows at pasture have longer lying times than when they are housed (*Singh et al.* 1993) and the pasture provides a more yielding walking surface than most free stall designs. The incidence of lameness and the prevalence of claw lesions is lower in the summer than in the winter (*Clarkson et al.* 1996, *Murray et al.* 1996) and cows calving at pasture are less lame than cows calving during the housing period (*Alban et al.* 1996). The negative influence of poorly designed housing on the incidence of lameness can be reduced when turned out on grass (*Kerr* 1998). In the present study all herds had been housed more than 3 months, probably masking any positive effect of pasture on the prevalence of lameness and claw lesions.

Detecting nutritional risk factors is hard in epidemiological studies and no clear relationships between feeding intensity/routines and lameness and claw lesions were detected in the present study. Diets with a high concentrate to roughage ratio have traditionally been seen as one of the major risk factors for lameness (*Logue et al.* 1993, *Vermunt & Greenough* 1994). In both first lactation heifers and multiparous cows high starch diets have been reported to lead to an increase in hoof lesions (*Livesey et al.* 1998, *Blowey et al.* 2000). However, a good housing environment and good management might reduce the negative influence of high starch diets (*Livesey et al.* 2003, *Offer et al.* 2004). This is in agreement with *Bergsten & Frank* (1996b) who indicated that the type of floor is more important than the diet if the diet is fed in an appropriate way.

Heifers

The lameness prevalence in heifers was relatively low. Lameness is hard to detect when driving the animal to the trimming chute. Heel horn erosions and haemorrhages of the sole had the highest prevalence. Seventy-seven percent of heifers had haemorrhages at 13 months of age in one study (*Vermunt & Greenough* 1996). In another study, heifers had more severe haemorrhages than older animals 4 months before calving (*Greenough & Vermunt* 1991). The presence of claw lesions in the heifers suggests that claw assessments should be performed in all heifers well before calving. A higher prevalence of claw lesions in heifers stalled in free stalls and in pens versus heifers stalled in tie stalls is in agreement with what has been found in lactating cows (*Sogstad et al.,* in press).

Conclusion

The complexity of causal mechanisms behind lameness and claw lesions makes risk factors hard to define. The present study indicated the following risk factors for lameness: parity three and above and narrow cubicles; for heel horn erosions: lactation stage around 5-7 months after calving and solid concrete alleys; for haemorrhages of the white line: lactation stage around 3-5 months after calving and solid concrete alleys; for haemorrhages of the sole: parity one, lactation stage around 5-7 months after calving and short cubicles, for white line fissures: slatted concrete alleys; for asymmetric claws: parities two and above and for corkscrewed claws: solid concrete alleys. The results suggest that the type of alley may be more important than the stall base.

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Sammendrag

Rundt 88% av norske mjølkekyr står oppstallet i båsfjøs. Det er vedtatt at alt storfe innen 20 år skal være oppstallet i løsdrift. Det betyr at de fleste eksisterende båsfjøs må bygges om eller at det må bygges nytt i nær framtid. Femtisju tilfeldig utvalgte løsdriftbesetninger med 1547 kyr og 403 kviger ble besøkt av 13 klauvskjærere på senvinteren og våren 2002. Klauvskjærerne hadde fått opplæring i praktisk klauvskjæring, diagnostisering og registrering av klauvlidelser. Informasjon om oppstallingsforhold, miljø, stell- og fôrings rutiner ble i tillegg registrert. Femtitre besetninger hadde betongsviller i gangarealet, mens 4 hadde heldekkende betong. Trettifem besetninger hadde betong i liggebåsen, mens 17 hadde gummimatter, 2 hadde tregolv og 3 hadde strøseng. Modeller for halthet og klauvlidelser ble laget for å estimere viktigheten av forskjellige risikofaktorer og for å ta hensyn til cluster-effekter innen besetning og innen klauvskjærer. De påviste risikofaktorene for halthet var: laktasjonsnummer 3 og over og smale liggebåser; for hornforråtnelse: laktasjonsstadium omkring 5-7 mnd etter kalving og heldekkende betong i gangarealet; for blødning i den hvite linje: laktasjonsstadium 3-5 mnd etter kalving og heldekkende betong i gangarealet; for blødning i sålen: laktasjonsnummer 1, laktasjonsstadium 4-6 mnd etter kalving og korte båser; for løsning i den hvite linje: spaltegolv i gangarealet; for skjeve klauver: laktasjonsnummer 2 og over og for korketrekkerklauv/ombøyd vegg: heldekkende betong i gangarealet. Få kviger var halte, men 29% hadde én eller flere merknader til klauvhelsa på bakbein. Forekomsten av hornforråtnelse, blødninger i sålen og løsning i den hvite linjen var høyere hos kviger oppstallet i binge og i løsdrift enn hos kviger oppstallet på båsfjøs. Vi står overfor store utfordringer når det gjelder å gi best mulig betingelser for kyrs bein i nybygg og i eksisterende løsdriftfjøs.

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