Lameness and Free stall Design – Research at the University of Wisconsin, School of Veterinary Medicine

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Introduction

Farmers are faced with many choices when building a free stall barn. How many rows of stalls per pen, what kind of divider loop, what type of stall surface, what grooving pattern for concrete is best, how high should the side walls be, what type of cooling system should be installed? It is fair to say that recommendations made 4-5 years ago were based more on ease of building and reducing cost per stall than what was best for our dairy cows.

No more! We now realize that many of the standards used that are published in free stall planning literature are totally inadequate for the care of our dairy cows. Forward thinking farmers have made changes and reaped the rewards. Related to stall and barn design, there has been unprecedented enlightenment in the last two years driven by workers in Ontario, British Columbia, Kansas State and here in Wisconsin.

In this paper, I will share some of the research and field experiences at the UW School of Veterinary Medicine over the past three years, related to cow comfort and lameness.

Lameness in Dairy Cows

Lameness prevalence reported in a number of studies throughout the world has documented a wide range of prevalence from 0 to 55% of the herd affected. This variation may be due to a combination of many factors, including breed types surveyed, genetic selection, conformation characteristics, nutrition and feeding practices, amount of milk production, manure handling systems, presence or absence of certain types of infectious disease, and factors related to the environment in which we keep dairy cows.

In the last major survey in North America, which involved 17 dairy herds in the Midwest, the prevalence of lameness was 13.7% during the summer and 16.7% during the spring. Mean herd size was 50 cows, and 14 of the 17 herds used stanchion or tie-stall housing. It was our impression that the situation had worsened – particularly in the free stall barns that we were visiting when herd troubleshooting.

We have recently completed a lameness survey of 30 Wisconsin dairy herds, half tie stall and half free stall housed. Lameness was determined using a 4 point system of locomotion scoring and all the cows on each farm were scored once in the winter and once in the summer. The system of scoring used is given in Table 1.

Table 1. Locomotion scoring system used to determine prevalence of lameness in herds of dairy cows

Locomotion score	Criteria
1 (no gait abnormality)	Walks rapidly and confidently, making long strides with a level back.
2 (slight lameness)	Walk more slowly making shorter strides with an arched back. Stand with a level back and do not favor a leg. Difficult to detect any weight transfer from affected limb.
3 (moderate lameness)	Often thin, walk slowly making deliberate short steps with an arched back, and frequent stops. Weight transfer will cause sinking of the dew-claws of the unaffected hind limb. Encounter some difficulty turning. Stand with an arched back and frequently rest lame foot.
4 (severe lameness)	Usually very thin, move very slowly making frequent stops to rest affected limb, which is only partially weight bearing. Frequently salivate due to grinding of teeth. Extreme difficulty turning. Stand and walk with an arched back.

We determine 'clinically lame' as all cows scoring 3 and 4 using this system. Score 2 cows are not included, but are cows with developing or healing lesions that walk with a slightly abnormal gait. On average, about 22% of the cows in a herd are clinically lame. Table 2 outlines targets for use when making comparison of scores between herds. The top 25th percentile of herds achieved less than 15% clinically lame in summer and winter. This therefore is our target lameness prevalence. Interestingly, these top herds did not have any score 4 severely lame cows. Thus, the finding of one or two severely lame cows in a herd is a good predictor that lameness is a problem.

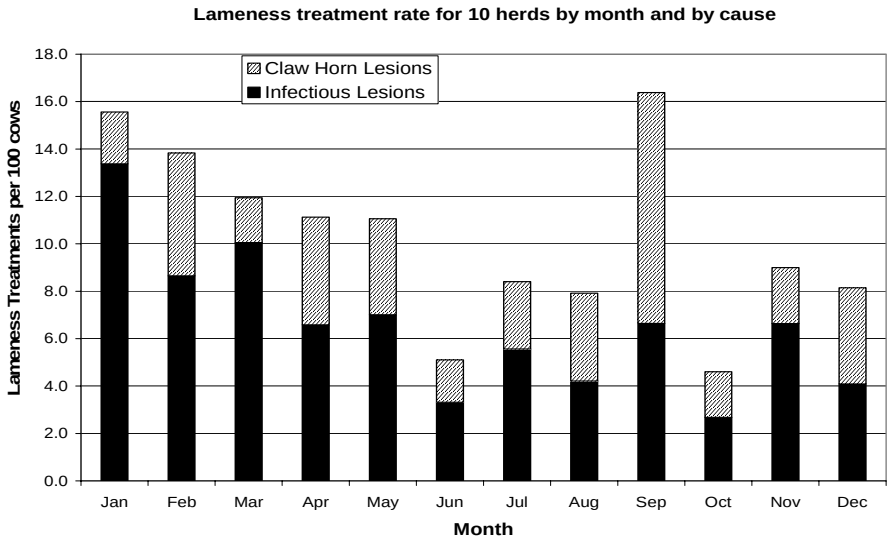
Table 2. Distribution of locomotion scores during summer and winter for dairy cows in 30 herds in Wisconsin

	Locomotion score							
	Summer				Winter			
Score	1	2	3	4	1	2	3	4
Minimum	18.5	6.7	7.3	0.0	27.2	8.8	9.6	0.0
25th percentile	46.0	19.4	11.2	0.2	46.8	16.9	14.0	0.0
Mean	54.9	23.3	18.0	3.0	55.9	19.0	20.7	3.2
75th percentile	66.6	27.8	24.7	4.7	63.9	21.9	28.0	5.0
Maximum	80.0	31.9	35.2	16.7	79.3	29.4	35.1	12.3

Lameness prevalence averaged 19.6% in tie stall barns in both summer and winter – a little higher than had been previously reported. Prevalence was higher still in free stall barns at 22.8% in the summer and 27.8% in the winter, confirming our suspicion that lameness in free stall barns was worse than had previously been documented.

From a subset of the 30 herds, we collected lameness treatment records to determine incidence rate from 10 herds, which averaged 22.2% lameness prevalence. A total of 1155 lameness treatments were recorded and the mean lameness treatment rate was 69.1 limb cases per 100 cows per year. The ratio of incidence to prevalence was 3.1:1, suggesting that in the absence of accurate treatment records, an estimate of incidence may be made from a prevalence determination using locomotion scoring, by using a multiplier of 3. Heel warts were the most common lesion found, accounting for 56.8% of all treatments. Sole hemorrhage (6.4%), sole ulcer (18.4%) and white line disease (10.4%) were the most common claw horn lesions identified.

Figure 1. Lameness treatment rate (Limb cases per 100 cows) by month for 10 herds.



We looked at lameness treatment rate by month. The rate was higher at the end of winter – probably when herds were not using footbaths and experiencing manure handling problems in cold weather conditions, but the rate was also markedly higher in September – two months after the period of heat stress in Wisconsin. We suspect that heat stress triggers a change in cow behavior, and/or triggers sub-acute ruminal acidosis (SARA) which leads to claw horn lesions some 2 months later. These are chronic long-term lesions which cows may well carry for much of the winter if left untreated.

Examining the lameness prevalence dataset for risk factors, we noted that stall base type appeared to be significant – in both tie stalls and free stalls. Herds using sand appeared to have much lower lameness prevalence than herds using other types of stall base – including mats and mattresses. In particular, free stall herds with mattress stall bases appeared to be at particular risk of a higher rate of lameness – especially during the winter (Table 3).

Table 3. Mean prevalence of lameness during summer and winter among lactating cows on 29[†] dairy herds in Wisconsin classified as to housing type (free stalls vs tie stalls) and stall surface (sand vs mat or mattress [non-sand]). From Cook (2003).

	Free stalls		Tie stalls	
Stall Base	Sand	Non-Sand	Sand	Non-Sand
Number of herds	9[†]	7	4	10[†]
Lameness Prevalence				
Summer	18.4	26.8*,[a]	12.2[b]	22.1
Winter	21.2[a]	33.7*,[b]	12.1[a]	21.7[a]

*Values were significantly ($P = 0.007$) different.
[a,b] In each row, values with different letter superscripts were significantly ($P < 0.05$) different.
[†] Includes cow data from one herd with segregated sand free stalls and non-sand tie stalls.

These data raised our awareness of the issues related to stall design in free stall barns and at the same time, Dr Neil Anderson was challenging the dairy scientists and engineers to take a look at the stalls they were advising farmers to build and watch how our dairy cows were using them. Drs Dan Weary and Cassandra Tucker at the University of British Columbia was also performing welfare based research into stall design providing some much needed scientific information on the needs and behavior of the cow in the different stall designs that were commonplace.

Free stall Usage and Stall Design

In his efforts to teach veterinary students how to assess a free stall, Dr Ken Nordlund developed and subsequently, along with myself, refined a system of approaching the stall from a cow's perspective – getting into, lying down, rising and leaving the stall. We produced a flowchart to lead the investigator through the important points to look out for, stressing that these points need to be considered as a unit (Nordlund and Cook, 2003). The five points are:

1. **Surface cushion**

We were already aware of the benefits of sand as a stall surface, but we were beginning to ask questions about the suitability of mattresses containing air, water, rubber crumbs or foam. Preference tests performed by Dr Roger Palmer at the UW Dairy Science facility at Arlington had shown that cows prefer the most cushioned surfaces – such as Pasture Mat Plus, Foam mat and Ulti-mat, but we had also found less than satisfactory lameness prevalence in facilities using these and similar products. Data from the UBC confirmed that lying times increase and stall standing activity decreases in mattress stalls with more bedding (7.5Kg v 1Kg). Loose bedded sand stalls remain the ideal bedding surface.

2. **Adequate defined resting area**

We had developed regression equations using body weight as a crude marker of size to develop target measurements for width between the dividers, mounted on center, and

length from rear curb to brisket board. The commonly quoted measurements of 45” wide and 66-68” curb to brisket are barely adequate for a first lactation animal. Mature cows required stalls 50” wide and a platform 72” from curb to brisket. Pre-fresh cows required stalls 54” wide to accommodate their girth.

More recently we have placed more emphasis on the design of the brisket locator. The normal rising motion of the cow requires that she throw her front leg forward over the locator to transfer weight. Brisket locators greater than 4” high and concrete fills prevent these cows from performing this important part of the rising motion. For that reason, we have recommended using a smooth plastic brisket locator or smoothed section of wood – set so that only 4” protrudes above the stall surface.

3. **Room to lunge and bob**

Larger cows require a stall 10’ long against a side wall to front lunge. Not only that, but we must avoid putting obstructions in the bob zone – the area at full lunge between the stall surface and a space about 40” above it. Horizontal mounting rails, concrete, bedding and wires are all common bob zone violations. If a deterrent bar is used in head to head stalls to stop cows passing through the middle, it should be located 40” above the stall surface.

In head to head stalls there is a common misunderstanding. Engineers and builders believed that if we have an open front on a 15’ platform, the cows will lunge forward into it. Wrong. We must think not only in terms of mechanical obstructions, but also in terms of social obstructions. If a cow is occupying the stall in front, it is uncommon for the adjacent cow to lunge into that area – it has become obstructed by the presence of the cow. To improve head to head stalls, we must either make the platform 18’ long and/or provide for side lunging and tolerate cows lying diagonally across the stall.

To provide for side lunging, the top edge of the lower divider rail must be no higher than 11” above the stall surface. All loops must therefore by wide-loops and we currently favor the designs where the upper divider rail slopes downward at the rear, which allows the cow to pivot easily out of the stall. In order to prevent cows walking along the rear of the stall, the divider rail must extend to within 9” of the rear curb.

4. **Room to rise below and behind the neck rail**

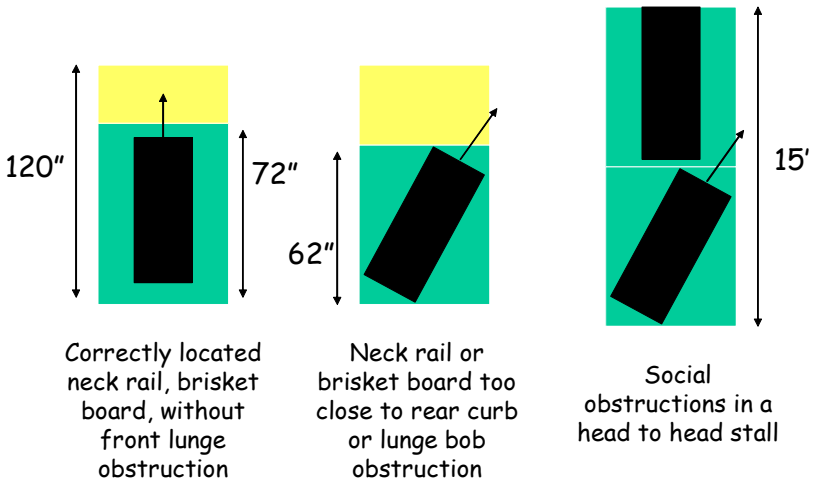
Neck rail location is the most common fault we currently find with stall designs. Much has been made of the vertical height below the neck rail – we now recommend 48-50” for a mattress stall and 44-50” for a sand stall. However, we see this as very much a secondary problem to the horizontal distance from the rear curb to the neck rail. Neck rails are often pulled closer to the rear curb in response to diagonal lying. Unfortunately, diagonal lying is a complex issue caused by several factors which include – too short a stall, head to head stalls on a 15’ platform, too small an area behind the brisket locator, lunge and bob zone obstructions, and locating neck rails too near the rear curb can actually make matters worse not better (figure 2).

The commonest stall blueprint used over the last few years has this measurement at 62". It is located at this point to 'keep cows and stalls clean'. Unfortunately it may do this in some stalls by reducing stall use, which may trigger lameness problems. When located at 62", the only way the cow can get all four feet on the stall is if she stands diagonally across it. If she passes manure at this point it will land in the rear corner of the stall. To lie down from this position, she must lunge to the side, which means that she lies diagonally across the stall – depositing manure in the rear corner of the stall again. To stand, she must try to avoid the neck rail – forcing her to hit it and step back – leaving her perching in the stall, with the rear feet in the alley. This is unacceptable from an animal well-being point of view.

Neck rails in mattress stalls should be 66-68" from the rear curb for first lactation heifers and 70-72" for mature cows. Be prepared to move them to allow cows to stand square in the stall. From this position, they will front lunge and lie straight in the stall if other obstructions are cleared.

In sand stalls, the width of the rear curb takes away lying and standing space – as cows will not stand on the sloped or rounded curb. We also know that cows do not spend prolonged periods of time standing in sand stalls. As a rule of thumb we locate the neck rail above the brisket locator and pull it toward the rear curb a distance equivalent to the width of the rear curb.

Figure 2. Diagonal lying problems in free stalls – mechanical and social obstructions



5. **Curb height**

The effective curb height from the alley surface to the top of the stall surface should be no more than 8". Higher curbs will accentuate the stresses on the rear feet when cows perch in the stall, and lead to heifer stall acceptance problems – they will be fearful of stepping off a high curb.

It is clear using this system of stall evaluation that fixing one component and leaving behind two or three problems unchanged will not improve stall use. The components of the stall act as a unit. We must consider each component just as important as the next and improve all of the serious deficiencies at the same time. Frequently this involves purchasing new dividers and remounting them. The expense at $100 per stall is minimal compared to the problems you will be solving.

Free stall Behavior and Lame Cows

Our most recent research has investigated possible differences in cow behavior in free stall barns with sand and mattress free stall bases, with relevance to lameness. We have visited 12 expanded dairy herds, averaging 300 cows per herd, six using sand and six using a rubber crumb mattress stall surface. Each herd was locomotion scored and for one 24 hour period the high group mature cow pen was video filmed. 10 cows per farm were color marked and tracked for the entire period recording location (alley, stall or milking parlor), activity (standing, lying, feeding, drinking) and time spent performing each activity. The mean lameness prevalence in the sand herds in this study was 11%, and in the mattress herds it was 24% - confirming the trend we had previously identified. Surely we would find a difference in lying time and total standing time on concrete? Actually, we did not – both groups of herds were similar for these two variables. Of the 120 cows followed, 73 were normal sound locomotion score 1, 37 were slightly lame locomotion score 2 and 10 were moderately lame locomotion score 3. We did not include severely lame cows.

We have found that normal and lame cows behave similarly in sand stall herds. Typically they lie down for 12h/d, milk for 3h/d, feed for 4.5h/d, socialize and drink in the alley for 2.5h/d and stand in the stall (including perching) for 2h/d.

The behavior of normal cows in mattress herds is also very similar – the only significant difference is that they stand in the stall for 44 min longer per day ($P=0.048$). However, there is a marked difference in behavior in lame cows in mattress free stalls. Slightly lame cows stood for 4.4h/d and moderately lame cows stood for 6.1h/d – significantly different from equivalent cows in sand stalls ($P<0.001$). This increase in stall standing has effects on the daily time budget – with a compression of other activities, notably standing in the alley, feeding and in moderately lame cows, lying time – which was reduced to 10h/d (Table 4).

Table 4. Effect of Locomotion Score and Stall Base type (Mattress or Sand) on Daily Activity Time Budget

Activity h/d	Locomotion Score					
	1		2		3	
Stall base	Mat	Sand	Mat	Sand	Mat	Sand
Lying time	12.0	12.0	11.7	12.0	10.0	12.8
Standing in Stall	2.4	1.7	4.4	2.1	6.1	1.8
Time standing in alley (including drinking)	2.8	2.3	1.6	2.2	1.4	1.8
Time Up Feeding	4.3	4.7	3.8	4.6	3.5	5.1
Time Up Milking	2.5	3.3	2.6	3.2	3.0	2.7

Cows appear to strive to maintain a relatively fixed amount of lying time per day – approx 12h/d in this study. However, the desire to lie down is limited by the pain associated with the actual process of rising and lying and the fear of slipping. Lame cows in sand stalls suffer less fear of slipping because of the traction provided by the bedding material when rising and probably less pain, consequently they lie down more promptly. Lame cows on a mattress surface suffer more pain and fear of slipping when rising and must wait longer for the pain to subside, or be reluctant to lie back down again for fear of slipping on the smooth mattress cover. The stall standing is not in place of standing in the alley – it is enforced during a stall use session while she prepares to lie down again. Stall designs which fail to allow for adequate lunge and bob increase weight bearing and stress on the rear feet and potentially worsen the situation. Cows on sand appear to compensate for these design faults, cows on mattresses do not.

Extended time spent standing in the stall in lame cows may be detrimental to claw health, increasing the duration of lameness and explaining the higher prevalence observed in mattress herds.

Indices of Cow Comfort

Several indices of cow comfort are used on dairy farms including the Cow Comfort Index (CCI) and the Proportion Eligible Lying (PEL) or Stall Usage Index. Targets of >85% for the CCI and >75% for the PEL taken at 1h after return of the cows from the morning milking have been suggested (Overton et al., 2003), but these benchmarks have been derived from very few herds.

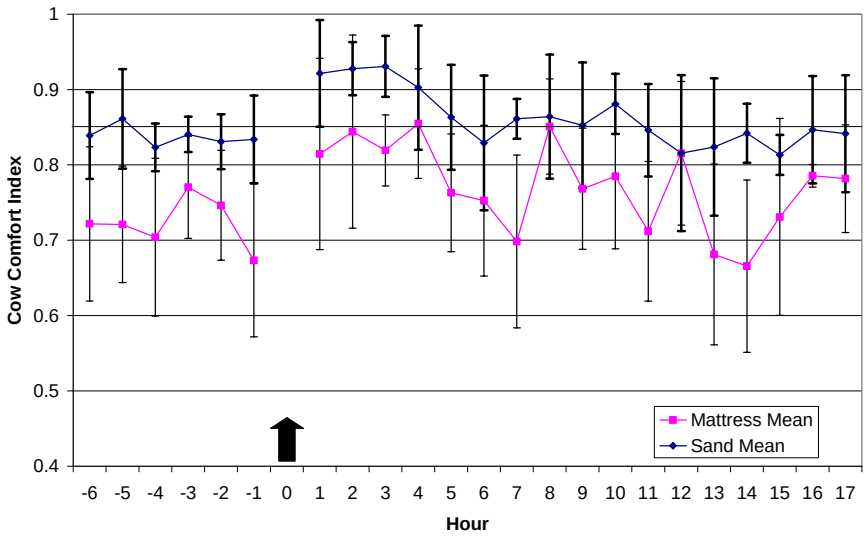
We derived several indices at hourly intervals for 12 herds (six sand herds and six mattress herds). Data from each herd was aligned by the time of AM milking. Figure 3 shows the diurnal variation in CCI by stall base type. There was a significant effect of base on CCI (P=0.002) and time was also significant. More variability was observed in the CCI in mattress herds compared to sand herds, and the average over the 24h period was 14% lower.

All of the indices were poor predictors of mean daily lying time at all hours of the day. There was a significant relationship between CCI and mean daily standing time in the

stall at 5h and 2h before the morning milking, with the reading at 2h having the higher adjusted R^2 (0.83) and P value (0.0003) combination. At 2h before the morning milking, there was a significant relationship between CCI and lameness prevalence in the pen (R^2 0.89, P=0.0005), but there was also a significant effect of base (P=0.0008), which complicated the relationship. CCI less than 76% was uniformly associated with pen lameness prevalence rates greater than 20%.

The CCI therefore does not reflect lying time, but reflects standing behavior in lame cows. A CCI >85% 1 h after return from AM milking means virtually nothing. Comfort of lame cows should be assessed later in the stall use session, preferably early AM before milking. As the index predicts standing rather than lying behavior, we prefer to use the term Stall Standing Index (SSI), which is basically 100-CCI or the number of cows in a stall that are standing.

Figure 3. Mean (with one-standard deviation error bars) Cow Comfort Index (%) by Hour for Sand and Mattress herds. The bold arrow represents the time of departure for the morning milking.



The Future – changes we can make tomorrow

In order to improve the welfare and care of lame cows in mattress herds, we can do three things to help:

1. Redesign the stalls to current standards; improve surface cushion, remove lunge and bob obstructions, remove concrete and high brisket boards from the front of the stall, allow for side lunging and move neck rails forward.

These changes will mean that cows can rise more normally, reducing stresses on the rear feet.

2. Reduce the trigger factors for lameness ….. avoid SARA by improving feed management, ensure that the transition into the herd for heifers does not involve dramatic group changes, and diet and housing changes, operate an effective foot bath program to control heel warts and ensure that your hoof-trimmer is doing a good job and not over-trimming.

3. Take lame cows out of the mattress free stall barn and allow them to recover on a dedicated straw bedded pack.

Here they can rise and lie down free from negotiating obstructions to movement. Start with severely lame cows, then move to moderately lame cows if space allows.

In the last twelve months there has been a remarkable improvement in our knowledge of what dairy cows' require of their housing. Veterinarians and ethologists are working with engineers and builders so that new barn constructions do not make the mistakes of old. With better facilities, we have seen associated improvements in cow comfort, health and productivity. There are many other issues requiring more research – the effects of overstocking, group changes, the role of rubber flooring surfaces … the list is almost endless. Our research has led us to the conclusion that LAME is a four letter word we cannot afford to ignore!

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