HOCK INJURIES IN FREESTALL HOUSED DAIRY COWS

by

Alejandra Karina Barrientos Araneda

D.V.M., Universidad Austral de Chile, 2008

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

in
THE FACULTY OF GRADUATE STUDIES
(Animal Science)

THE UNIVERSITY OF BRITISH COLUMBIA
(Vancouver)

December 2012

© Alejandra Karina Barrientos Araneda, 2012
Abstract

The objective of this thesis was to investigate housing and management risk factors associated with the prevalence of hock injuries in freestall herds (n = 76) in two areas of intensive dairy production, Northeastern US (NE-US) and California (CA). One group of high-production multiparous cows (n = 38) was monitored for hock injuries on each farm and data on management, facility and stall design were collected. Risk factors associated with the overall proportion of cows having injuries or severe injuries at the univariable level were submitted to multivariable general linear models. In NE-US, overall hock injuries increased with the percentage of stalls with fecal contamination (OR = 1.26; CI = 1.02 to 1.54, for a 10% increase), and with the use of sawdust bedding (OR = 3.47; CI = 1.14 to 10.62), and decreased with deep bedding (OR = 0.05; CI = 0.02 to 0.14), sand bedding (OR = 0.06; CI = 0.02 to 0.15), bedding DM ≥ 83.9% (OR = 0.08; CI = 0.03 to 0.20), and access to pasture during the dry period (OR = 0.17; CI = 0.05 to 0.53). In the multivariable model, only the presence of deep bedding remained significant. Severe hock injuries increased with the use of automatic scrapers (OR = 2.29; CI = 1.11 to 4.71) and the percentage of stalls with fecal contamination (OR = 1.14; CI = 1.00 to 1.31, for a 10% increase), and decreased with sand bedding (OR = 0.22; CI = 0.10 to 0.49), deep bedding (OR = 0.24; CI = 0.11 to 0.52), bedding DM ≥ 83.9% (OR = 0.28; CI = 0.14 to 0.58), and access to pasture during the dry period (OR = 0.42; CI = 0.18 to 0.97). The multivariable model included the use of automatic scrapers and deep bedding. In CA, stall stocking density (OR = 1.41; CI = 1.00 to 2.01, for a 10% increase) and bedding concavity (OR = 1.08; CI = 1.01 to 1.16, for a 2.5-cm decrease) were associated with an increase of hock injuries. In general, deep-bedded and well-maintained stalls significantly reduced the risk of hock injuries.
Preface

Alejandra Barrientos, Eduardo Galo, and Drs. Marina von Keyserlingk and Dan Weary designed this project collaboratively. Alejandra Barrientos conducted data collection, analysis, interpretation, and manuscript preparation under the supervision of Eduardo Galo (helped during data collection), Dr. Nuria Chapinal (helped with statistical analysis and manuscript preparation) and Drs. Marina von Keyserlingk and Dan Weary (both helped in the analysis, interpretation and manuscript preparation). A version of Chapter 2 has been submitted for publication and is currently under review. Barrientos A. K., N. Chapinal, D. M. Weary, E. Galo and M. A. G. von Keyserlingk. Hock injuries in freestall housed dairy cows in Northeastern US and California (submission number JDS-12-6389).

This research was conducted under the animal care protocol “Dairy cattle welfare: behaviour, lameness and disease” A10-0162 issued by the UBC Committee on Animal Care.
Table of Contents

Abstract.......................................................................................................................................... ii
Preface........................................................................................................................................... iii
Table of Contents ......................................................................................................................... iv
List of Tables ............................................................................................................................... vii
List of Figures............................................................................................................................. viii
List of Abbreviations ................................................................................................................... ix
Acknowledgements .................................................................................................................... x

Chapter  1: Introduction ...............................................................................................................1
  1.1 Linking freestall barn design and management with animal welfare ................................. 3
    1.1.1 Freestall design ............................................................................................................... 4
    1.1.1.1 Lying surface ........................................................................................................... 4
    1.1.1.2 Stall hardware/dimensions ................................................................................... 5
    1.1.2 Cow comfort assessment ............................................................................................. 6
  1.2 Skin lesions ........................................................................................................................ 9
    1.2.1 Hock injuries: prevalence, etiology and pathogenesis ................................................ 9
    1.2.2 Risk factors ................................................................................................................ 12
    1.2.3 Hock scoring assessment .......................................................................................... 13
  1.3 Thesis objectives.............................................................................................................. 15

Chapter  2: Hock injuries in freestall housed dairy cows in Northeastern US and California
........................................................................................................................................................18
2.1 Introduction .......................................................................................................................... 18

2.2 Methods ............................................................................................................................. 19

2.2.1 Farm selection and visits ............................................................................................ 19

2.2.2 Hock assessment ........................................................................................................... 20

2.2.3 Management and facility design measures ................................................................. 21

2.2.3.1 General management ............................................................................................ 21

2.2.3.2 Pen management ................................................................................................... 22

2.2.3.3 Stall design .......................................................................................................... 22

2.2.3.4 Bedding ............................................................................................................... 23

2.2.4 Data analysis ................................................................................................................ 24

2.3 Results ............................................................................................................................... 26

2.3.1 Northeastern United States ......................................................................................... 26

2.3.2 California .................................................................................................................... 27

2.4 Discussion ........................................................................................................................ 27

2.4.1 Northeastern United States ......................................................................................... 28

2.4.2 California .................................................................................................................... 30

2.5 Conclusion ....................................................................................................................... 31

Chapter 3: General Discussion ..................................................................................................35

3.1 Relevance of hock injury assessment ............................................................................... 35

3.2 Developing a reliable hock scoring protocol ................................................................. 37

3.3 Lying surface as a risk factor for hock injuries ............................................................... 38

3.4 Future directions ............................................................................................................. 40
References.....................................................................................................................................42

Appendices....................................................................................................................................50

Appendix A. Example of benchmarking provided to producers for hock injuries....................... 50
List of Tables

Table 2.1. Management and facility design variables of interest considered in the univariable analysis for each region. Units and categories are shown for continuous and categorical variables, respectively.................................................................33

Table 2.2. Univariable associations of the logit-transformed proportion of all hock injuries and only severe hock injuries with management and facility design factors in the NE-US and CA. Management and facility design factors are sorted by \( R^2 \). Parameter estimates were back-transformed and results are presented as OR and 95% CI.................................................................34
List of Figures

Figure 1.1. Lying stall dimensions typically considered when looking for comfortable lying behaviour: A) Stall length to the brisket locator; B) Total stall length, as distance from the external side of the curb to the front barrier or wall; C) Neck rail position, distance from the vertical plane above the rear curb to the internal side of the rail; D) Neck rail height, distance from the bedding surface to the bottom of the rail; E) Rear curb height; and F) Rear curb width. ........................................................................................................................................................................................................................................................................................................ 16

Figure 1.2. Hock assessment scale used in recent studies in North America. Adapted from Hock Assessment Chart for Cattle, Cornell Cooperative Extension, Cornell University. ......................... 17
List of Abbreviations

BCS = body condition score
CCAC = Canadian Council on Animal Care
CI = confidence interval
DIM = days in milk
DM = dry matter
NAHMS = National Animal Health Monitoring System
OR = odds ratio
TMR = total mixed ration
US = United States
USDA = United States Department of Agriculture
Acknowledgements

I would like to express deep gratitude to my supervisors Dr. Nina von Keyserlingk and Dr. Dan Weary, who believed in my ability to complete a Masters degree in a foreign language, even before I believed that I could. Nina gave me constant emotional support and encouragement during the course of my work. I am thankful for all of Dan’s thoughtful comments and helpful contributions to all aspects of this research. You are both inspiring professors and I feel proud to have been one of your students.

To all students and staff in the Animal Welfare Program, thank you for all your friendship and help. I feel especially thankful for Nuria Chapinal’s patience while mentoring me in my statistical analysis.

A very special thanks goes to Kiyomi Ito for her friendship and for her invaluable assistance during the collection of data and in the daily management of this project.

This thesis would not have been possible without the support and advise of Ed Galo. Thank you for trusting me with such an important project. I am honored to have worked with you.

Finally, I owe a big thanks to my family, for their love and for giving me the freedom to choose my own path. I am fortunate to have had Carlos Riquelme by my side, providing me with unconditional love and emotional support throughout this process.
Chapter 1: Introduction

In recent decades, the dairy sector has shown a global tendency toward intensification driven by pressures of low cash margins per unit of milk sold (Alvarez et al., 2008). This trend has shifted the farm structure in the United States (US) towards fewer and larger dairies with the greatest declines seen in farms with < 200 cows. In contrast the number of very large operations with $\geq$ 2,000 cows has doubled between 2000 and 2006 (Macdonald et al., 2007). Based on USDA (2007) census data, the three states with the largest number of dairy operations were Wisconsin (14,900), Pennsylvania (8,700) and New York (6,400). California reported only 2,300 operations, but was the state with the largest number of dairy cows (1.8 million) and had large herds where 91.2% of cows were housed in herds $\geq$ 500 cows. In an attempt to improve efficiency, producers are investing in modern housing systems able to house the increasing numbers of cows. These structural changes combined with dramatic improvements in management have led to increased milk production. Accordingly, milk production per cow has increased 32.7% from 1991 to 2006 (USDA, 2007).

During the last 50 years, types of housing on US dairies have changed from predominantly stanchion and tie-stall operations to freestalls and dry lots (USDA, 2010). The National Animal Health Monitoring System (NAHMS) 2007 survey, that included farms in 17 states representing 80% of dairy operations in the United States, reported that 60% of cows were housed in freestall barns (USDA, 2010).

This shift towards intensification has raised public concerns about the welfare of the animals. Concerns have focused on three main questions: 1) is the animal functioning well
(biological functioning); 2) is the animal feeling well (affective state); and 3) is the animal able to live a natural life (natural living) (Fraser et al., 1997). In some cases, improvements in one aspect of animal welfare may result in improvements in other aspects (e.g. reduced physiological signs of hyperthermia will likely reduce feelings of discomfort) (von Keyserlingk et al., 2009). However, sometimes addressing one of these concerns might conflict with another. For example, a lactating dairy cow on pasture (e.g. improved natural living) may be unable to seek shade on a hot day and thus may feel uncomfortably hot (reduce affective state), showing signs of hyperthermia, and ultimately reduced milk production (poor biological functioning) (von Keyserlingk et al., 2009). Traditionally, producers believed that welfare could be assessed simply from a high level of productivity (Fraser, 2008), but over the last decade there has been a greater interest in more directly assessing aspects of cow comfort. Although the term cow comfort is now widely used throughout the dairy industry there appears to be a lack of consensus within the literature as to what it means (Weary and Tucker, 2003). The majority of producer oriented reports (e.g., Krawczel, 2010; Osborne, 2011; Grant, 2012) use this term to describe how well cows cope with their environment with the assumption that the better she is able to cope the greater likelihood she will improve her milk production.

Interest in on-farm assessment of welfare has grown in the past decade, in response to consumer demands for higher welfare standards (Fraser, 2003). Welfare assessment research considers two broad approaches: environment-based measures and animal-based measures. Environmental parameters describe the physical features of housing and the management of the farm, such as feeding facilities, air quality, and space allowance. Animal-based parameters record animals’ reactions to their specific environments and include behaviour, health and
physiology (Johnsen et al., 2001). The advantage of using environmental parameters is that they are easy to record, tend to remain constant, can be measured objectively (making them highly reliable), and also can serve as a basis for problem solving. However, environmental parameters are at best indirectly related to welfare (Whay et al., 2003a). Animal-based parameters are more directly associated with animal welfare (Whay et al., 2003b). Recording animal-based parameters can be difficult and time-consuming (Johnsen et al., 2001), but new technologies have replaced labour intensive techniques such as continuous observation with electronic devices that can accurately measure behaviour in a group of animals (Ito et al., 2009).

Achieving genuine improvements in housing and management requires methodologies that accurately reflect their impact on the animal. Thus, animal-based measurements such as behavior, and evaluation of health and injuries have become common methods of welfare assessments on commercial farms (Whay et al., 2003b; Haskell et al., 2006).

1.1 Linking freestall barn design and management with animal welfare

Freestall housing for dairy cattle was invented in the United Kingdom in the 1950’s (Rural Design and Building Association, 2009) and quickly began to replace the predominant tie stall systems. Freestall housing was seen as being advantageous in that cows had more space to perform natural movements compared to the highly restrictive tie stall systems. The freestall system quickly found favor in many parts of the world with the first introduction in North America occurring in Washington State, in the 1960’s (Albright, 1964).
1.1.1 Freestall design

Freestall housed cows are usually grouped according to stage of lactation, provided free access to a lying area divided into individual cubicles referred to as stalls and are fed a high-energy diet formulated to meet their nutritional requirements along a common feeding area (Albright, 1964). In essence the free stall system was designed to provide a comfortable area that allows sufficient rest, protect the animals from weather extremes, allows free access to an appropriate diet, and minimizes the risk of injury and disease. Despite these laudable aims, current freestall barns sometimes fail to achieve these goals and can expose cows to undesirable conditions such as hard concrete walkways with slurry (Cook and Nordlund, 2009). Inadequate freestall features have been associated with a high prevalence of lameness and leg injuries (Haskell et al., 2006; Fulwider et al., 2007; Rutherford et al., 2008; Lombard et al., 2010).

1.1.1.1 Lying surface

Cows prevented from lying down comfortably show behavioral and physiological stress responses that can affect their health and production (Munksgaard and Simonsen, 1996). Hence, the majority of research to date has focused on designing the most suitable lying surface (Andreasen and Forkman, 2012). The lying stall (see Figure 1.1) consists of three main parts: the stall base, the bedding material placed on top of the stall base and the associated hardware used to index the cow within the stall (lateral partitions, neck rail, and brisket locator on the stall base). The most common stall bases are concrete, rubber mats, mattresses, and deep bedding (Lombard et al., 2010). Research investigating the stall base has shown that cows spend more time lying down, and do so more frequently, on mattresses compared with a concrete stall base (Haley et al., 2001), and on deep-bedded surfaces compared with inadequately bedded mattresses.
Bedding materials vary greatly with the most common in North America being sawdust, straw, dry or compost manure and sand (Lombard et al., 2010). Ideally each of these materials should provide thermal comfort and cushioning, be durable and have sufficient friction to allow rising and lying down without slipping, as well as ensuring cleanliness and health (Van Gastelen et al., 2011). However, some bedding materials are associated with poor health outcomes. For example, udder infections are more common in organic bedding resources – such as sawdust and straw – due to a greater proliferation of pathogens (Hogan et al. 1989; Zdanowicz et al., 2004). In contrast, because of the relatively dry and inorganic nature of sand, low prevalence of skin lesions are associated with sand-bedded stalls (Weary and Taszkun, 2000).

1.1.1.2 Stall hardware/dimensions

Stall features such as the length of the lying area, width between partitions, and presence and position of restrictive barriers such as neck rail and brisket locator also vary broadly within and between regions (Lombard et al., 2010; von Keyserlingk et al. 2012). This variability may be due to the rapid shift to intensive housing accompanied by insufficient research resulting in a lack of clarity regarding recommendations. For instance, recommendations for overall stall length range from 200 to 274 cm, and for lateral head lunge range between 40 and 60 cm (Faull et al., 1996; Bickert, 2000). Fortunately, research has begun to provide data that can improve our understanding of what comfortable lying behaviour means (Ceballos et al., 2004), closing the gap between on-farm recommendations and design features. Some favorable stall features for lying and standing fully in the stall have been reported: cows lie down longer and stand on
concrete less time when offered wider stalls (Tucker et al., 2004), stalls without brisket locator (Tucker et al., 2006), stalls with the neck rail positioned higher above the stall surface (Tucker et al., 2005), and further from the rear curb (Fregonesi et al., 2009). At the same time, extended times standing on concrete due to uncomfortable stall management, have been associated to higher risk of lameness (Bernardi et al., 2009), especially for transition cows (Proudfoot et al., 2010; Dippel et al., 2011).

Collectively this evidence shows how different aspects of freestall housing and management can affect the cows’ behavior, changing the way cows use these important resources and exposing them to health risks.

1.1.2 Cow comfort assessment

Considering the many animal behavior and health implications of poor housing design and management described above, experimental approaches used to evaluate how well cows cope in their environment have shifted their emphasis from resource-based measures to animal-based measures (Haskell et al., 2006), and typically involve one of three methods: 1) preference testing, 2) analysis of behaviour, and 3) assessment of injuries and diseases.

Environmental preference testing, a technique that allows animals to choose between alternative options, has been used for over 30 years to identify housing features that are of greater importance for the animals (Fraser and Matthews, 1997). Preferences sometimes correspond with other measures of biological functioning such as injury; for instance, dairy cattle prefer heavily vs. lightly bedded mattress stalls (Tucker and Weary, 2004) and deep-bedded vs. mattress stalls (Tucker et al., 2003), which also minimize hock injuries (Weary and Taszkun, 2000). However, this methodology has limitations as it only allows animals to choose between
alternatives provided, which might not represent necessarily what is most beneficial (Fraser, 2008). Preferences of individual animals may also not be independent: other factors such as dominance among individuals, familiarity or previous experience can affect the preference (Dawkins, 1977). In addition, the extent of the preference is hard to evaluate and difficult to interpret (Kirkden and Pajor, 2006). Finally, a known preference will not be enough to draw inferences about animal welfare, unless we also investigate the strength of the animal’s motivation and the benefit to the individual (Fraser et al., 2008).

To evaluate whether behavioral changes indicate an uncomfortable situation, analysis of normal behavior under known favorable situations is required. We know that dairy cows are highly motivated to lie down for up to 12 hours a day (Jensen et al., 2005), and that lying is a priority behavior compared with feeding and social contact when these behaviors were restricted (Munksgaard et al., 2005). Thus, lying time, along with the frequency and duration of lying bouts, has been used as a measure of stall comfort (Haley et al., 2001). However, lying behavior can be difficult and labor intensive to measure in a commercial farm setting. Beginning approximately 8-10 years ago ‘cow comfort’ estimates based on indices that relied on a one-time observation done by walking through the barn began to garner considerable attention. For example, the Cow Comfort Index (CCI) is calculated as the proportion of cows lying in a stall in relation to the total number of cows in contact with it, and was cited as a proxy to daily lying behavior (Cook et al., 2005). However, more recent work has shown that these indices do not reflect actual lying time (Ito et al., 2009).

Researchers have shown special interest in evaluating lying time in part because this is associated with lameness. For instance, reduced rest and longer time standing on concrete floor
are known risk factors for lameness (Cook and Nordlund, 2009). However, recent work has shown that this association is complex; Ito et al. (2010) demonstrated that high lying times, long lying bouts, and variability in the duration of lying bouts were associated with severe lameness, but that those behavioral responses varied with stall surface. Further, Yunta et al. (2012) did not find any association between lying behaviour measurements and lameness, except for longer lying bouts found on lame cows.

Other behavioural indicators used to evaluate reduced lying comfort are the frequency of abnormal lying down and rising behaviors (i.e., interrupted movements, lying down or standing up taking longer than 20 seconds, lying down with hindquarters first, or rising with forequarters first); these behaviours have also been associated with lameness (Dippel et al., 2009). Despite their potential, abnormal lying behaviours are rarely included in on-farm evaluations.

Scientists and producers agree that housing systems that cause disease or injuries to animals are undesirable (Weary and Tucker, 2003). Injury and disease have clear consequences on animal welfare and can reduce milk production (e.g. Warnick et al., 2001). Thus, assessment of injuries as an indicator of welfare continues to receive considerable attention and is now widely used in on-farm dairy assessments (Haskell et al., 2006; Lombard et al., 2010; Husfeldt and Endres, 2012). Lameness, mastitis and transition cow diseases are now widely recognized as serious animal welfare and production issues in the dairy industry (Rajala-Schultz et al., 1999; Warnick et al., 2001; von Keyserlingk et al., 2009). Although it can easily be argued that skin injuries on dairy cows should raise similar concerns, they have received much less attention from dairy producers and researchers. The prevalence of these injuries is surprisingly high among
freestall barns worldwide (Weary and Taszkun, 2000; Rutherford et al., 2008; Kielland et al., 2010; Potterton et al., 2011; von Keyserlingk et al., 2012), and thus worthy of more attention.

1.2 Skin lesions

Skin lesions on cattle tend to occur on areas of their body that are in contact with elements of housing, such as dorsal surface of the neck and joints; including carpal (knee), fetlock, tarsal (hock), and hip (Kielland et al., 2010; Weary and Taszkun, 2000). Lesions in the carpal (knee) and tarsal (hock) joints have been described as more frequent (Busato et al., 2000; Wechsler et al., 2000; Kielland et al., 2009), and appear to be caused by abrasion on concrete surfaces or by collision with stall hardware when cows lie down and stand up (Haskell et al., 2006). The latest reports on hock injury prevalence on dairy farms are disturbing, reaching higher rates than known prevalent health issues such as lameness, and mastitis (Fulwider et al., 2007; Kielland et al., 2009; Husfeldt and Endres, 2012). Reports on the prevalence of knee injuries are lower than hocks, with estimates between 4 and 35% (Regula et al., 2004; Kielland et al., 2009).

1.2.1 Hock injuries: prevalence, etiology and pathogenesis.

As mentioned above, hock lesions can be highly prevalent on some dairy farms; one European assessment reported that up to 100% of cows on some farms were suffering from this condition (Kielland et al., 2009). Another European assessment showed that the prevalence of hock injuries can vary from 37% in organic vs. 49% in nonorganic farms, 60% during spring vs. 22% during fall, and 46% in freestall housed vs. 25% in straw packed cows in the United Kingdom (Rutherford et al., 2008). The prevalence of lesions is also high in North America.
Weary and Taszkun (2000) found that 73% of cows on 20 Canadian freestall farms had at least 1 cm² of hair loss or skin breakage on the hock, and that 78% of scored as moderate severity (skin breakage or hair loss > 10 cm²). A more recent study reporting data from the NAHMS 2007, showed 33% of the cows were scored as having hocks with at least hair loss or swelling (Lombard et al., 2010). The lack of progress in reducing the prevalence of these injuries is surprising, given that these are relatively easy to recognize (Potterton et al., 2011).

In the veterinary literature this condition is referred to as tarsal cellulitis, tarsal bursitis or tarsal periarthritis; cases are defined as a chronic cellulitis of the epidermis, dermis and subcutis of the hock joint, with unilateral or bilateral presentation (Greenough, 1997). Injuries on the lateral surface of the hock are typically more common and more severe than those located on the medial surface and their clinical signs range from a small area of hair loss and hyperkeratotic skin to open sores, and in some cases, swelling of the entire joint (Greenough, 1997; Weary and Taszkun, 2000).

The exact conditions that trigger the development of these types of injuries are unknown; literature suggests that the lesion may start as a bed sore (Greenough, 1997). Bed sores or pressure sores have been well studied in humans and are caused primarily by the pressure from the body weight that reduces blood perfusion to skin, leading to localized ischemia and eventual necrosis over the area of contact with the lying surface (O'Sullivan et al., 1997; Bass and Phillips, 2007). Other contributing factors for the development of pressure sores are time, spasticity, denervation, edema, moisture, infection, and poor nutrition (Bass and Phillips, 2007). In their review, Bass and Phillips (2007) explain that there is an inverse relationship between time and pressure with only low levels of constant pressure required along with a prolonged
timeframe to cause tissue damage. Immobility due to neuronal deficiencies or denervation increases the time in which pressure is applied. They also reported that compressed skin has less resistance to bacterial invasion, thus good hygiene of the lying surface and skin is essential to avoid infection. Malnutrition and liver dysfunction can cause lack of minerals, vitamins and collagen essential for healing, as well as hypoalbuminemia which in turn causes edema. Edema affects tissue perfusion and with time will end in necrosis.

Mowbray et al. (2003) showed that hair loss and skin breakage on the hocks of dairy cattle could develop rapidly, just over the course of 6 weeks, following the movement from pasture to a freestall barn. However, the progression of the disease into advanced phases has not been well defined. Greenough (1997) describes a pathogenesis as a progressive swelling with little effect on joint mobility or pain. Chronic irritation results in collection of blood and fibrin in a thick-walled subcutaneous bursa. Contusions may result in skin rupture, followed by infection and development of a chronic fistulous discharge of pus. In extreme cases, articulations in the joint might become infected (Greenough, 1997). A descriptive report from Turkey (Seyrek-Intas et al., 2005) discussed clinical, ultrasonographic and macroscopic findings of carpal and tarsal bursitis on 16 dairy cows. Swelling varied from mild to severe (~ 6 cm) across cases, from which six had fluctuation and 10 had a firm bursa. From all patients, nine of them were classified as acute/subacute (history of ≤ 1 month), which showed heat and/or pain when palpated, accompanied with mild to moderate lameness. Chronic patients had no heat or pain, and mostly no lameness. Sonography showed there was fluid accumulation in all but one bursa. Contents were serous, serofibrinous, serohemorrhagic, or purulent and most of them had free-floating particles. Seyrek-Intas et al. (2005) showed that sonography was a useful tool for evaluating the
extent and consistency of inflammation, detection of capsule thickness and content in the synovial cavities.

### 1.2.2 Risk factors

Some features of the freestall system are associated with higher rates of skin injuries. Harder stall surfaces such as concrete (Rushen et al., 2007), compact rubber mats and mattress stalls (Wechsler et al., 2000; Kielland et al., 2007), have been associated with the presence of hock and knee injuries. In contrast, deep-bedded surfaces with dirt or sand as bedding have been associated with fewer and less severe hock injuries in observational studies (Weary and Taszkun et al., 2000, Lombard et al., 2010; Husfeldt and Endres, 2012), as well as cleaner cows (Norring et al., 2008), compared to facilities with poorly bedded concrete, rubber mats or mattresses. Freestalls are sometimes designed to be sloped allowing urine to drain keeping bedding dry to prevent udder infections (McFarland and Gamroth, 1994). However, the presence of stall gradient has been associated to an increased number of hock swellings (Haskell et al., 2006); maybe due to a greater contact of the hock on the edge of the rear curb, causing abrasion and swelling. Risk factors at the cow level include higher parity (Weary and Taszkun, 2000), 60 days before calving to 59 days in milk (DIM) (Kielland et al., 2009), and larger herd size (Haskell et al., 2006).

There are some inconsistencies in the literature regarding other risk factors. For example, studies in Canada (Weary and Taszkun, 2000) and in Switzerland (Keil et al., 2006) both reported that longer stalls decreased the prevalence of hocks lesions, but a Norwegian study (Kielland et al., 2009) reported that cows on farms with longer stalls (> 260 cm against a wall or > 250 cm in double-row stalls) had increased risks of lesions. Weary and Taszkun (2000) found
that sand bedded stalls had the lowest risk of hock injuries, but Keil et al. (2006) found that straw bedding worked best on Swiss dairies. Further, Kielland et al. (2009), found a negative relationship between body condition score (BCS) and knee injuries, while a Swiss study (Regula et al., 2004) found hock and knee injuries to be more prevalent on farms with a higher prevalence of over-conditioned cows. These discrepancies may be due to regional differences in housing, management practices, and local availability of different resources. Lombard et al. (2010) reported that farms in the eastern US had approximately 8 times the number of severe hock injuries compared with farms in the west, and those differences were larger than what could be explained by any single management factor. This variation among freestall farms is currently raising great interest from researchers attempting to address other welfare issues such as lameness on the dairy herds (Cook and Nordlund, 2009). Thus, further research is needed to establish housing and management risk factors for the development of hock injuries and establish how those factors vary across regions.

1.2.3  Hock scoring assessment

Unfortunately, there is presently no validated gold standard available regarding the evaluation of hock injuries in cattle. Evaluations used in previous studies have considered a variety of definitions and scales: from just assessing the presence/absence of any hock lesion (sound vs. damaged hock) (Rutherford et al., 2008), evaluation of different locations of the hock (e.g. lateral, medial and dorsal aspects) (Keil et al., 2006; Fulwider et al., 2007), quantitative measurement of the area of the hair loss or wound (e.g., score 1 = hair loss ≤ 10 cm², and score 2 = hair loss > 10 cm² or broken skin or dark scab; Weary and Taszkun, 2000), to a more detailed
characterization assigning a different scale to each clinical sign (e.g., hock hair loss, ulceration and swelling scored separately; Huxley and Whay, 2006; Potterton et al., 2011). Lack of a fundamental understanding of hock injury development might explain this wide range of scoring systems, making comparisons among studies difficult. Recent studies in the US have used a 3-point scale developed by Cornell University (http://www.ansei.cornell.edu/prodairy/pdf/hockscore.pdf; see Figure 1.2) (Lombard et al., 2010; Husfeldt and Endres, 2012).
1.3 Thesis objectives

Despite years of research investigating the effects of facility design and management on animal welfare issues, hock injuries are still common on dairy cows housed in freestall barns. The objective of this thesis was to investigate housing and management risk factors associated with the prevalence of hock injuries in freestall herds within two areas of intensive dairy production (North Eastern United States and California) that vary greatly in the design and management of freestalls.
Figure 1.1. Lying stall dimensions typically considered when looking for comfortable lying behaviour: A) Stall length to the brisket locator; B) Total stall length, as distance from the external side of the curb to the front barrier or wall; C) Neck rail position, distance from the vertical plane above the rear curb to the internal side of the rail; D) Neck rail height, distance from the bedding surface to the bottom of the rail; E) Rear curb height; and F) Rear curb width.
Score = 1
No swelling. No hair is missing.

Score = 2
No swelling. Bald area on the hock.

Score = 3
Swelling is evident and/or there is presence of severe injury.

Figure 1.2. Hock assessment scale used in recent studies in North America. Adapted from Hock Assessment Chart for Cattle, Cornell Cooperative Extension, Cornell University.
Chapter 2: Hock injuries in freestall housed dairy cows in Northeastern US and California

2.1 Introduction

Despite over a decade of research (Weary and Taszkun, 2000; Fulwider et al., 2007; Cook et al., 2008; Kielland et al., 2009; Potterton et al., 2011; Lombard et al., 2010; Husfeldt and Endres, 2012) showing the effects of facility design and management on skin lesions, these injuries remain common on dairy cows. Skin lesions on the legs of cattle are most often observed on anatomical protrusions, such as joints, with the most common lesions found on the tarsal joint (hock) (Rutherford et al., 2008; Kielland et al., 2009). These injuries range from a small area of hair loss to open wounds, and are often accompanied by swelling of the entire joint (Weary and Taszkun, 2000). Assessments on European commercial dairy farms have shown that the prevalence of hock lesions is as high as 100% in some farms (Kielland et al., 2009), and that substantial variation in the prevalence exists, averaging from 22 to 61%, depending on the characteristics of the system and season (Rutherford et al., 2008). The lack of progress in reducing prevalence is surprising, given that these injuries are relatively easy to recognize.

In North America, three studies (e.g. Weary and Taszkun, 2000; Fulwider et al., 2007; Lombard et al., 2010) have estimated the prevalence of hock injuries in dairy cattle and some have shown associations between housing and lesions. Hock injuries appear to be most prevalent and severe in poorly bedded freestall barns (often using concrete, rubber mats or mattresses as a

stall base) compared with deep bedded freestalls or open bedded packs (Fulwider et al., 2007). However, there are major regional differences in housing and management practices (driven in part by local availability of different types of bedding). These regional differences may explain some of the apparent disagreements in previous work. For example, Weary and Taszkun’s (2000) study in British Columbia found that the risk of lesions was lowest on farms using sand bedding, while Keil et al. (2006) found that straw bedding worked best on Swiss dairies. To our knowledge no work has investigated how risk factors vary across regions.

The current study was part of a larger cross-sectional project that aimed to describe variation in the prevalence of lameness, leg injuries, lying behavior, facility design, and management practices for high producing cows on freestall dairy farms in North America (von Keyserlingk et al., 2012; Chapinal et al., 2013). This study reports the risk factor analysis for two regions of the US with different environmental conditions and different traditions of barn design and management: The Northeastern-US (Vermont, New York and Pennsylvania; NE-US) and California (CA). The aim was to investigate the association between management and facility design factors and the prevalence of hock injuries in high-producing dairy cows in freestall herds in these two regions.

2.2 Methods

2.2.1 Farm selection and visits

This study was part of a benchmarking project intended as a service for producers (see Appendix A). The C.O.W.S. program (a partnership between The University of British Columbia and Novus International Inc.; http://www.novusint.com/en/Market-Segments/Dairy/COWS) was
designed to monitor the high-producing group on freestall farms (see von Keyserlingk et al., 2012 for a complete description of the benchmarking project). Although all participating farms made use of freestall housing, farms varied in facility, management and production characteristics with important geographical differences. A total of 38 farms in NE-US (New York n = 28, Pennsylvania n = 6, and Vermont n = 4) and 38 farms in CA were selected for this study, using the same inclusion criteria described in Chapinal et al. (2013) which involved freestall housing and provision of a total mixed ration (TMR). The number of farms recruited for this study was the maximum sample feasible considering logistic limitations of time and resources. All methods used to collect data were approved by the University of British Columbia’s Animal Care Committee, which follows the standards outlined by the Canadian Council on Animal Care (2009).

Farms were visited from March to May 2010 in CA, and from July to October 2010 in NE-US. Each farm was visited twice, with approximately three to five days between visits. The same two trained observers performed all animal and facility-based measures (Table 2.1) on all farms. At the beginning of the first visit to each farm, the producer was asked to identify one group of high-producing, primarily multiparous cows, which was then assessed.

2.2.2 Hock assessment

Prior to data collection, a target sample per assessment group was estimated to be 21 cows, based on 90% confidence of detection of a 10% prevalence of severe hock injuries in a pen of 200 cows (Dohoo et al., 2009). However, due to a larger sample required for other animal based measurements sampled in the same project (i.e. lying time), according to Ito et al. (2009); 40 focal cows from the assessment group were randomly selected while entering the milking
parlor and were evaluated for hock injuries. Only data from multiparous cows were used in this study; thus one farm in CA and two in NE-US were excluded from the analysis since \( \leq 20 \) multiparous cows were assessed for hock injuries in the assessment group. The number of multiparous focal cows sampled per assessment group in the remaining farms was \([\text{mean} \pm \text{SD (range)}] 38 \pm 3 (27 \text{ to } 40)\) individuals.

Each selected animal was scored for hock condition (lateral surface of the tarsal joint) on a 3-point scoring system where 1 = healthy hock without alopecia, 2 = bald area on the hock without evident swelling, and 3 = evidently swollen and/or severe injury. This scoring system was based on the Hock Assessment Chart for Cattle developed by the Cornell Cooperative Extension (http://www.anasci.cornell.edu/prodairy/pdf/hocksore.pdf; Figure 1.2.). No other locations of the rear limb were evaluated for injuries. Only 1 limb per animal was considered for this assessment due to the difficulty in examining the opposite side in some type of parlors (i.e. herringbone parlor).

### 2.2.3 Management and facility design measures

Management and facility design measures for the herd and assessment pen were collected using direct observation combined with information obtained during a face-to-face interview with the herd manager, bedding samples and compilation of herd records. Due to differences in management and facility design, some of the variables collected differed between regions. See Table 2.1 for full description of variables collected within each region.

#### 2.2.3.1 General management

General management factors included barn age, herd size (number of milking cows), number of milking cows per full time employee, and access to pasture during the dry period.
(commonly for 3 to 6 weeks during the dry period in NE-US). The latter two were recorded as reported by the manager.

2.2.3.2 Pen management

The high-producing group was assessed for variables such as stall stocking density (calculated as the number of cows per available stall and multiplied by 100), and access to an exercise corral. All but six farms provided access to their high-production group to an exercise corral in CA, thus this variable was not considered in the analysis. In NE-US, manure was removed either continuously or at a high frequency using an automatic scraper, or just a few times per day using other methods, such as flushing or a skid steer. Therefore, a dichotomous variable was created for the presence of an automatic scraper as opposed to other methods involving a lower frequency of manure removal. In CA, manure removal was accomplished several times per day by flushing, skid steer or a combination of both, and thus the frequency of manure removal was measured for this region.

2.2.3.3 Stall design

Stall dimensions were measured on (mean ± SD) 4 ± 1 stalls per pen ranging from 3 to 7 stalls (depending on the uniformity of the stall design within the pen) and included brisket locator presence (22 of the 38 farms in NE-US and no farms in CA used brisket locators), stall width, neck rail height from bedding surface, neck rail position (calculated as the horizontal distance between the rear edge of the neck rail and the back side of the rear curb), rear curb height and width. Neck rail height was strongly influenced by bedding maintenance, which in turn varied greatly across farms, so it was not considered in the analysis. Rear curb width could only be assessed in the stall base types where this structure was exposed (i.e., deep bedding), and
was thus only included in the analysis for CA (where all farms assessed used deep bedding). Stall length (from the cow’s perspective) depends on the presence and position of the brisket locator, any barrier blocking the lunge space, and whether the stalls are in a single row (facing a wall or feed alley) or double row (two stalls, head to head). Due to the variability observed in these factors, both within and between farms, stall length was not considered in the analysis. Continuous stall measurements were averaged to obtain one value per farm. More details on how stalls were measured are provided in von Keyserlingk et al. (2012).

2.2.3.4 Bedding

In CA, all the farms used deep-bedded stalls filled with dry manure solids, with the exception of 4 farms that used deep-bedded sand stalls, so bedding depth and type were not considered in the analysis for this region. Instead, bedding amount was assessed as concavity (continuous variable; measured as the depression in bedding in the middle of the stall) taking as a reference the upper edge of the rear curb (i.e. the larger the number the greater the concavity; bedding amount that was level or higher than the curb was assigned a concavity of 0 cm). The NE-US had more variability in stall base and bedding material. Dichotomous variables were created for deep bedding (described as a stall base that was not exposed by digging at least 10 cm into the bedding) as opposed to smaller amounts of bedding placed on top of a stall base (such as mattress, concrete, rubber mat, etc.) and the most frequent bedding materials, such as sand and sawdust. For stalls that were not deep bedded, bedding maintenance was classified as “covered” if the stall base surface was 100% covered with bedding, < 50% exposed or ≥ 50% exposed. However, due to lack of variability in this measurement (84% of non deep bedded farms had ≥ 50% exposed stall surface), this variable was not considered in the analysis. Bedding samples
were collected in both regions from 10 systematically selected stalls per assessment pen (e.g., if there were 100 stalls in the pen, every 10th stall was sampled). Samples (approximately 50 ml/stall) were taken from the back 1/3 of each stall and pooled together to provide one sample per farm; samples were taken on each visit to avoid bias due to addition of fresh bedding. The percentage of DM of the bedding was analyzed at Rock River Laboratory West, Inc. (Visalia, CA) and Dairy One, Inc. (Ithaca, NY) for CA and NE-US, respectively. The same stalls used to measure bedding DM were also assessed for fecal contamination before milking (for more details of scoring method, see Chapinal et al., 2013).

2.2.4 Data analysis

Outcomes variables were defined as: a) proportion of cows from the total number of animals evaluated in the assessment group having at least a minor injury (score ≥ 2), and the proportion of cows having severe injuries (score = 3).

Statistical analyses were performed with SAS (version 9.3, SAS Institute Inc. 2003, Cary, NC) considering the assessment group as the experimental unit. Both regions were analyzed separately due to regional differences in facility design and management (for more details see von Kerserlingk et al., 2012). A logit transformation with a bias correction factor of 0.25 was applied to meet the assumptions of normality and homogeneity of variance to ensure that estimates and CI were correctly calculated. Univariable analyses (PROC GLM) were first performed to evaluate the association between the outcome variables and each of the management and facility design predictors (Table 2.1) as well as the proportion of older cows (lactation ≥ 3) in the assessment group, although this variable did not have an effect in any case. Only categorical predictors with at least eight farms per category were considered. When
linearity between continuous predictors and outcome variables was assessed graphically and by testing the quadratic term, the predictor bedding DM in NE-US did not show a linear relationship. The four quartiles were used as cutpoints to dichotomize bedding DM, and the cutpoint yielding the largest $R^2$ was chosen ($< \text{ or } \geq 83.9\%$). Predictors with a univariable association of $P \leq 0.05$ were submitted to a multivariable model (PROC GLM). Correlations between the predictors were also calculated to avoid submitting highly correlated variables ($r > 0.70$) into the same model. When two predictors were highly correlated, the predictor with the strongest univariable association (largest $R^2$) was selected. Variance inflation factors were calculated after each model to confirm a lack of multicolinearity. Models were built by manual stepwise selection: first predictors were removed from the final model if $P > 0.05$. If the removal of a variable changed the parameter estimate of any of the remaining predictors by $> 30\%$ on the logit scale, the eliminated variable was retained as a confounder regardless of its $P$-value (Dohoo et al., 2009). Eliminated predictors were then reentered in the model and retained if $P \leq 0.05$. Two-way interactions between the predictors that remained in the final model were tested and retained if $P \leq 0.05$. Residuals were examined after each model to verify normality and homogeneity of variance. Outliers and observations with an undue influence were examined using residuals, leverage values and Cook’s distances. Parameter estimates were backtransformed and results are presented as OR and 95% CI. The OR expresses how a predictor affects the odds of experiencing overall and severe hock injuries in a particular herd.
2.3 Results

The multiparous focal cows assessed in each high-producing assessment group consisted of [mean ± SD (range)] 2.8 ± 0.4 (2.1 to 3.6) lactations and 138 ± 37 (67 to 226) DIM in NE-US, and 3.1 ± 0.5 (2.0 to 4.3) lactations and 131 ± 37 (69 to 221) DIM in CA. The prevalence of cows having overall and severe injuries (mean ± SD) was 81 ± 22 and 5 ± 6% in NE-US, and 57 ± 22 and 2 ± 3% in CA, respectively.

2.3.1 Northeastern United States

At the univariable level, hock injuries increased with the percentage of stalls with fecal contamination and the use of sawdust bedding, and decreased with deep bedding, sand bedding, bedding DM $\geq$ 83.9%, and access to pasture during the dry period (Table 2.2). Deep bedding and sand bedding were highly correlated ($r = 0.93; P < 0.001$) since all farms but one that used deep bedding also used sand, and all farms using sand had deep bedding. Bedding DM $\geq$ 83.9% was also highly correlated with both deep bedding ($r = 0.85; P < 0.001$) and sand bedding ($r = 0.86; P < 0.001$), such that 80% of the farms that had bedding DM $\geq$ 83.9% used deep-bedded sand stalls. Given these correlations, only deep bedding was considered in the multivariable analysis since it had the largest $R^2$ at the univariable level. Deep bedding, access to pasture during the dry period, percentage of stalls with fecal contamination, and sawdust bedding were submitted to a multivariable model. Deep bedding was correlated to access to pasture ($r = 0.56; P < 0.001$), percentage of stalls with fecal contamination ($r = -0.65; P < 0.001$), and sawdust ($r = -0.41; P = 0.01$), and was the only variable that remained in the final model, explaining 54% of the variation in overall hock injuries.
Severe hock injuries increased with the use of automatic scrapers and the percentage of stalls with fecal contamination, and decreased with sand bedding, deep bedding, bedding DM $\geq 83.9\%$, and access to pasture during the dry period. The final model for severe hock injuries included the use of automatic scrapers (OR = 1.91; CI = 0.99 to 3.69; $P = 0.05$), and deep bedding (OR = 0.27; CI = 0.13 to 0.59; $P = 0.002$), and explained 36% of the variation.

### 2.3.2 California

At the univariable level, increased stall stocking density was associated with increased hock injuries. Severe hock injuries increased with bedding concavity, in other words were more common on farms where bedding was hollowed out within the stall (Table 2.2).

### 2.4 Discussion

This study assessed the prevalence of hock injuries in two regions of the US that differed greatly in facility design and management practices. Similarly to previous studies (Fulwider et al., 2007; Lombard et al., 2010), the sampling strategy targeted high-producing cows. This cohort of early/mid-lactation multiparous cows has been identified to be at the highest risk for health problems such as lameness and metabolic disease (Lombard et al., 2010). Kielland et al. (2009) reported that knee lesions occurred more often at the beginning of the lactation as compared to late lactation. Similarly, Weary and Taszkun (2000) found that presence and severity of hock lesions increased with parity. Despite this sampling strategy having the risk of overestimating the prevalence of hock injuries, we did not find a relationship between the proportion of older cows and outcome variables. The sampling strategy described in this study could also be advantageous as the early/mid-lactation multiparous cows may show the strongest
association with failure in environmental management practices (Espejo and Endres, 2007; Chapinal et al., 2013). Furthermore, high-producing cows represent the group of animals with greatest economic value on a dairy farm.

Another source of potential bias is that we assessed only one limb per animal (due to practical limitations described above). Potterton et al. (2011) reported that an animal with a given hair loss score on one limb was likely to be assigned the same score for the contralateral limb, and that only a small proportion of animals showed large disparities between limbs (< 9% and < 2% for difference of 2 and 3 scores, respectively, in a 4-point scale.

2.4.1 Northeastern United States

In agreement with previous studies, numerous aspects of bedding management were associated with the prevalence of hock injuries. Deep bedding, sand bedding, and bedding DM ≥ 83.9% were associated with reduced prevalence of overall and severe hock injuries. There is growing consensus that deep-bedded stalls provide advantages over other lying surfaces, including reduced risk of hock injuries (e.g. Weary and Taszkun, 2000; Lombard et al., 2010; Husfeldt and Endres, 2012), lameness (e.g. Chapinal et al., 2013), and longer lying times for severely lame cows (Ito et al., 2010). When animals lie down, the soft tissue of the joint is compressed against the lying surface. More bedding adds cushioning likely preventing hair loss, skin breakage and inflammation. Deep bedding might also have beneficial effects in joint flexion (Cook and Nordlund, 2009), aiding in the prevention of stiffness.

In agreement with the current study, Lombard et al. (2010) reported the lowest percentage of severe hock scores on farms that made use of sand bedding compared with straw, sawdust, or dry or composted manure. Norring et al. (2008) also reported that hock lesions on
cows healed more quickly on stalls using sand compared with straw. There are now a number of lines of evidence indicating that sand is one of the best bedding materials for use in freestall barns. This bedding material is not easily scraped aside to reveal hard or abrasive surfaces (Weary and Taszkun, 2000), provides a poor medium for bacterial growth compared with sawdust (Fairchild et al., 1982), and drains quickly so that the surface stays dry (Stowell and Inglis, 2000). Dry matter content of sand bedding was found to vary little within a week of sampling, compared with a significant decrease for sawdust bedding throughout the same period (Zdanowicz et al., 2004). Our own findings show that farms using sand bedding had drier bedding. Moreover, farms that did not have deep-bedded stalls often used sawdust bedding, which in turn was associated with increased hock injuries. This association makes it impossible to say which of these factors are protective, but we recommend that farms using organic bedding routinely monitor bedding DM to ensure that bedding does not become wet. Experimental work has also shown that wet bedding is highly detrimental to lying times in dairy cattle (Fregonesi et al., 2007b; Reich et al., 2010).

The proportion of stalls with fecal contamination was associated with increases in overall and severe hock injuries. Zdanowicz et al. (2004) reported that stalls bedded with sawdust were more likely to become contaminated with manure, compared with sand. Indeed, we found that deep- and sand-bedded farms had less contaminated stalls, as opposed to farms that used sawdust, which had increased percentage of soiled stalls. Organic, wet and soiled bedding may provide a medium for infection following some trauma to the skin.

Access to pasture during the dry period was also associated with a decrease in overall and severe hock injuries. This finding is in agreement with a UK study (Rutherford et al., 2008) that
found approximately 50% fewer hock injuries on farms having longer summer grazing periods (5 vs. ≥ 10 months). Farms visited in this study provided cows access to pasture for only a few weeks during the dry period, suggesting that even a short period on pasture can help in recovery and prevention of hock injuries. Experimental work has also shown that short periods on pasture results in rapid healing of hock lesions (Mowbray et al., 2003). A Swiss study (Keil et al., 2006) reported that the number and severity of hock lesions was negatively associated with the duration of outdoor exercise (pasture or outdoor run).

Increase in the prevalence of severe hock injuries was also associated with the use of automatic scraper. The use of automatic scrapers has been previously associated with increased hoof injuries and lameness (Barker et al., 2010; Cramer et al., 2009), but to our knowledge this is the first study to show that manure removal method can also affect the prevalence of hock injuries. A possible explanation for this association is that the movement of the scraper may increase the risk of cows tripping and falling, increasing the risk of joint contusion. Stefanowska et al. (2001) reported that 94% of incidents of tripping or stumbling by cows in houses with automatic scrapers resulted from direct contact with the scraper. Another alternative is that the wave of slurry in front of the scraper increases pathogen load in contact with the cows’ legs, and may increase the risk that skin lesions on the hock become infected. Other work has shown that scraper use increases the risk of infectious diseases on the hoof, such as digital dermatitis (Cramer et al., 2009).

2.4.2 California

There was little variability in stall and bedding variables among the farms in CA. With the exception of four farms, all had deep-bedded stalls filled with dry manure solids. Under these
circumstances, only increased stall stocking density was a risk factor for overall hock injuries. Overstocking at the stalls has been shown to reduce overall lying time, increase the time spent standing in the alleys, and increase the number of displacements from the stalls in mid-lactation cows (Fregonesi et al., 2007a). When competition for stalls is high, cows may elect to have less frequent but longer lying bouts, increasing the duration when the soft tissue of the hock is compressed against the stall surface. Prolonged periods of pressure on bony prominences is known to be one of the main causes of pressure sores in humans (Bass and Phillips, 2007).

Drissler et al. (2005) found that deep-bedded freestalls with less sand bedding (i.e. increased concavity) were less likely to be used by cows, reducing total lying time. These authors concluded that an important factor in keeping cows comfortable and preventing injury in deep-bedded stalls was ensuring that the stalls were filled and well maintained. Our findings, showing more lesions on farms with less bedding (more concavity), support this conclusion.

In CA no farms used pasture, and most farms allowed milking cows access to dirt exercise corrals when weather permitted. The lack of variation in this practice made it impossible to assess the effects on hock lesions. We speculate that access to well-maintained dirt exercise corrals in CA may mitigate the negative effects of the freestall environment on hock injuries, similar to the effects of pasture in the NE-US and encourage future work in this area.

2.5 Conclusion

In NE-US, providing cows with deep-bedded stalls, clean bedding, access to pasture, and the use of a manure removal method other than automatic scrapers, were key factors preventing hock injuries. In CA, where all farms used deep bedding, injuries were less common on farms
with better stall management. This regional variation in risk factors should be considered when formulating on-farm recommendations, but the results from both regions agree with all previous studies showing that hock injuries can be greatly reduced by using well-maintained deep-bedded stalls.
Table 2.1. Management and facility design variables of interest considered in the univariable analysis for each region. Units and categories are shown for continuous and categorical variables, respectively.

<table>
<thead>
<tr>
<th>Variables measured</th>
<th>Units/categories</th>
<th>Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>General management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barn age</td>
<td>yr</td>
<td>NE-US, CA</td>
</tr>
<tr>
<td>Herd size</td>
<td>no. milking cows</td>
<td>NE-US, CA</td>
</tr>
<tr>
<td>Milking cows per full time employee</td>
<td>cows/employee</td>
<td>NE-US, CA</td>
</tr>
<tr>
<td>Pasture access (dry period)</td>
<td>yes/no</td>
<td>NE-US</td>
</tr>
<tr>
<td>Pen management (high-producing assessment group)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stall stocking density</td>
<td>% cows/stall</td>
<td>NE-US, CA</td>
</tr>
<tr>
<td>Use of automatic scraper</td>
<td>yes/no</td>
<td>NE-US</td>
</tr>
<tr>
<td>Frequency of manure removal</td>
<td>times/d</td>
<td>CA</td>
</tr>
<tr>
<td>Stall design</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brisket locator presence</td>
<td>yes/no</td>
<td>NE-US</td>
</tr>
<tr>
<td>Stall width(^1)</td>
<td>cm</td>
<td>NE-US, CA</td>
</tr>
<tr>
<td>Neck rail distance to the rear curb(^1)</td>
<td>cm</td>
<td>NE-US, CA</td>
</tr>
<tr>
<td>Rear curb height(^1)</td>
<td>cm</td>
<td>NE-US, CA</td>
</tr>
<tr>
<td>Rear curb width(^1)</td>
<td>cm</td>
<td>CA</td>
</tr>
<tr>
<td>Bedding</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bedding concavity (decrease in bedding depth measured from the rear curb)</td>
<td>cm</td>
<td>CA</td>
</tr>
<tr>
<td>Deep bedding</td>
<td>yes/no</td>
<td>NE-US</td>
</tr>
<tr>
<td>Sand bedding</td>
<td>yes/no</td>
<td>NE-US</td>
</tr>
<tr>
<td>Sawdust bedding</td>
<td>yes/no</td>
<td>NE-US</td>
</tr>
<tr>
<td>Bedding DM(^2)</td>
<td>%</td>
<td>NE-US, CA</td>
</tr>
<tr>
<td>Percentage of stalls with fecal contamination (before milking)(^2)</td>
<td>%</td>
<td>NE-US, CA</td>
</tr>
</tbody>
</table>

\(^1\)n = Measured in 3 to 7 stalls/pen.
\(^2\)n = Measured in 10 stalls/pen
Table 2.2. Univariable associations of the logit-transformed proportion of all hock injuries and only severe hock injuries with management and facility design factors in the NE-US and CA. Management and facility design factors are sorted by $R^2$. Parameter estimates were back-transformed and results are presented as OR and 95% CI.

<table>
<thead>
<tr>
<th>Region</th>
<th>Variable</th>
<th>OR</th>
<th>95% CI</th>
<th>$R^2$</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>All hock injuries</td>
<td>Deep bedding</td>
<td>0.05</td>
<td>0.02 – 0.14</td>
<td>0.54</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Sand bedding</td>
<td>0.06</td>
<td>0.02 – 0.15</td>
<td>0.49</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Bedding DM ($\geq 83.9%$)$^1$</td>
<td>0.08</td>
<td>0.03 – 0.20</td>
<td>0.47</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Access to pasture (dry period)</td>
<td>0.17</td>
<td>0.05 – 0.53</td>
<td>0.22</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>Percentage of stalls with fecal contamination (10% increase)$^1$</td>
<td>1.26</td>
<td>1.02 – 1.54</td>
<td>0.13</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>Sawdust bedding</td>
<td>3.47</td>
<td>1.14 – 10.62</td>
<td>0.13</td>
<td>0.03</td>
</tr>
<tr>
<td>NE-US</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All hock injuries</td>
<td>Sand bedding</td>
<td>0.22</td>
<td>0.10 – 0.49</td>
<td>0.29</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Deep bedding</td>
<td>0.24</td>
<td>0.11 – 0.52</td>
<td>0.28</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Bedding DM ($\geq 83.9%$)$^1$</td>
<td>0.28</td>
<td>0.14 – 0.58</td>
<td>0.27</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>Use of automatic scraper</td>
<td>2.29</td>
<td>1.11 – 4.71</td>
<td>0.13</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>Access to pasture (dry period)</td>
<td>0.42</td>
<td>0.18 – 0.97</td>
<td>0.11</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>Percentage of stalls with fecal contamination (10% increase)$^1$</td>
<td>1.14</td>
<td>1.00 – 1.31</td>
<td>0.11</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CA</td>
<td>Stall stocking density (10% increase)</td>
<td>1.41</td>
<td>1.00 – 2.01</td>
<td>0.10</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Severe hock injuries</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bedding concavity (2.5-cm decrease in bedding depth)</td>
<td>1.08</td>
<td>1.01 – 1.16</td>
<td>0.14</td>
<td>0.02</td>
</tr>
</tbody>
</table>

$^1$10 stalls/pen sampled per assessment group
Chapter 3: General Discussion

This thesis showed that hock injuries are prevalent in CA and NE-US, two of the most important regions for the US dairy industry, and that housing and management risk factors associated with the prevalence of hock injuries varied between these two regions. This study also revealed that there is room for improvement in leg injury prevention and the results described in this thesis provide a basis for practical recommendations to achieve this improvement. This chapter discusses the importance of hock injury assessment, provides recommendations on how to develop more reliable hock injury scoring protocols, and discusses the lying surface as one of the most important risk factors revealed in the results of my thesis. Finally, I outline ideas for future research that arise from the results of the current work.

3.1 Relevance of hock injury assessment

Hock injuries affect dairy cows housed in freestall barns worldwide (Switzerland – Wechsler et al., 2000; Canada – Weary and Taszkun, 2000; UK – Haskell et al., 2006; and Rutherford et al., 2008; Norway – Kielland et al., 2009; USA – Lombard et al, 2010; North America – von Keyserlingk et al., 2012). Despite the common occurrence of these injuries and the associated animal welfare concerns there appears to be a lack of recognition within the dairy industry regarding the severity of this problem. To my knowledge, only studies in Europe have investigated the perception and attitudes towards leg injuries. Huxley and Whay (2006) reported that veterinarians in UK assigned a median pain score of 3 and 5 (on a 10-point scale, where 0 = no pain and 10 = worst pain imaginable) to hocks with hair loss and swelling, respectively; these
injuries as well as neck calluses, mastitis (clots in milk only), and acute metritis received the lowest pain scores. Interestingly, another UK study examining producers’ attitude reported that 90% of participants were aware of hocks lesions, but only when associated with severe swelling (Potterton et al., 2011). Hair loss and ulceration may not be seen as an important issue to address by dairy producers, perhaps because these injuries are viewed as ‘normal’ due to their high prevalence on many herds. To my knowledge, no work to date has examined producer (or other stakeholder) attitudes concerning these leg injuries in North America. Lack of attention to hock lesions might be based on poor information provided to producers about the development of these injuries, which in turn might limit activities directed at prevention.

The extent to which hock damage is painful or otherwise unpleasant for the individual cow remains largely unknown, but the human literature describes pressure sores as painful (Bass and Phillips, 2007), and these injuries appear to be analogous to hock lesions in cattle. Thus it appears reasonable to assume that hock injuries can also be painful for animals. Moreover, an association has been found between farms having increased hock injuries and other animal welfare issues. For example, wounds and swellings in the hock have been associated with more clinical mastitis and teat injuries (Sogstad et al., 2006), poor BCS and lameness (Kielland et al., 2009). Rather than a causal relationship among health issues, all of these issues might be the result of similar housing and management risk factors in problem herds. For example, poorly bedded stalls is a risk factor for lameness (Espejo et al. 2006; Chapinal et al, 2013) and for hock injuries (Weary and Taszkun, 2000; Husfeldt and Endres, 2012).
3.2 Developing a reliable hock scoring protocol

A variety of scoring systems for hock injury detection have been used in previous studies and the development of a standard and systematic hock scoring scale is urgently needed. To that end, I suggest that subsequent efforts be focused on the validation of a scoring scale. I propose that any hock injury scoring system should take into consideration pain and inflammation; specifically signs of heat in the injured area, and humoral and cellular indicators of chronic inflammation. Any proposed scoring system should be accompanied by a protocol with clear definitions and visual material to facilitate learning, aiming for a high repeatability among observers (Gibbons et al., 2012). Estimation of sample size will also have to be adjusted with the new data available on hock injury prevalence and variance, which has been shown to vary regionally (von Keyserlingk et al., 2012).

Another point to consider when developing a hock scoring protocol is where to score the lesion. Previous studies have scored hock injuries at either the feed bunk (Potterton et al., 2011) or the lying area (Andreasen and Forkman, 2012). The disadvantage of both of these locations is that it is virtually impossible to physically manipulate the hocks to determine if skin breakage, swelling, and different aspects of the swelling (firm or soft) are present. Although my decision to score the cows in the milking parlour allowed me to manipulate closely the cows’ legs, I had difficulties in some parlours in which cows were positioned in such a way that only one hock was visible (i.e., herringbone parlours). It should be noted that this practical limitation of only being able to score one hock could have underestimated my estimation of the proportion of cows affected by hock injuries. The best decision regarding where to score hock injuries on
commercial farms must consider the specific management practices of each farm, that best allows the researchers to score both limbs in a reliable way.

An additional source of bias that needs to be taken into account when measuring and comparing prevalence of leg injuries across farms is season. Seasonal effects on the prevalence of hock injuries have been reported in the literature, with lower rates found in fall and higher rates reported at the beginning of spring (Rutherford et al., 2008). These seasonal differences are likely due to the beneficial effect of pasture access used on herds during summer in some regions such as NE-US (see Chapter 2). In the case of my thesis, I avoided this bias by running a separate analysis by region (CA was assessed in the spring and NE-US was assessed in summer and at the beginning of fall).

3.3 Lying surface as a risk factor for hock injuries

There is a strong association between hock injuries and lying surfaces such as concrete, and poorly bedded rubber mats and mattresses (Weary and Taszkun, 2000; Lombard et al., 2010; Kielland et al., 2009; Husfeldt and Endres, 2012; and Chapter 2). Collectively this body of evidence indicates that when housing dairy cattle in freestalls, the use of deep bedding is important for ensuring higher welfare standards. In contrast, the use of poorly bedded rubber mats or mattresses are a major risk factor for the development of hock injuries. I suggest that when developing new types of lying surface, only those providing the same beneficial proprieties of deep bedding (i.e. high cushioning, traction, and moisture absorption) should be considered.

This study also showed that the use of sand over other bedding materials was protective for hock injuries. Although some dairy producers appear to be aware of the advantageous
proprieties of deep bedding sand (Bewley et al., 2001), many still advocate for mattress-based systems, given the perceived costs associated with deep-bedded systems (Fulwider et al., 2007). That mattress and rubber mat systems are frequently advertised as cheaper alternatives, given that less bedding is needed (e.g., http://www.realcowcomfort.com/pasturemat.html), is concerning. Although Cook et al. (2008) stated that by providing five to eight cm of sand over a mattress provides similar benefits to deep sand-bedded stalls, I question the practicality of this recommendation given that anecdotal experience indicates difficulties in maintaining bedding on these types of lying surfaces. Trade-offs between higher economic costs and possible complications in manure handling and the benefits of lower rates of leg injuries need to be considered by producers when planning new barn construction. Having increased prevalence of leg lesions might also have long-term costs related to cow longevity, and that should also be taken into account.

Deep-bedded stalls filled with dry manure or compost manure may be an economically viable alternative to sand given the protective effects over hock injuries and lameness (Husfeldt and Endres, 2012). Dry manure mixed with by-products such as almond and rice hulls was a popular type of deep bedding used in most of the farms visited in CA, which might be responsible for the lower rates of hock injuries found in that region compared with NE-US (Chapter 2).

The results of my thesis show that the risk factors associated hock injuries are primarily linked to aspects of the lying surface that we provide to cows housed in freestalls. The ideal stall should be designed to allow cows a comfortable lying place and to prevent any type of injuries. Experimental evidence from behavioural tests indicates that cows prefer dry (Fregonesi et al.,
well-bedded (Tucker and Weary, 2004), and well-maintained (Drissler et al., 2005) stalls. Lying time is also compromised when insufficient lying places are provided (e.g., overstocked) (Fregonesi et al., 2007a). The results presented in this thesis show that hock injuries are a sensitive measure that could be used to evaluate the design and management of the resting areas. Hence, a truly comfortable stall is one that not only optimizes lying behaviour but one that also minimizes leg injuries.

3.4 Future directions

Identifying the magnitude of leg injuries and the associated risk factors is the first step towards reducing the incidence of hock injuries in dairy cattle. The work presented in this thesis was part of a cross-sectional study done in collaboration with the US dairy industry to create a benchmarking database of animal-based welfare issues that currently affect farms. Each participating producer was provided a personalized report that increased awareness of the prevalence of lameness and injuries on his/her farm. In addition to identifying a particular farm’s weaknesses and strengths, opportunities for improvement were acknowledged with the aim to motivate change (Appendix A). However, further research focused on enhancing motivation to change, and developing specific recommendations to avoid leg injuries, is needed. A clearer understanding of the mechanisms involved in the development of hock injuries and their implications on animal welfare is also required. For instance, these injuries are thought to start as a pressure sore which are known to be painful in humans (Bass and Phillips, 2007), so work is required to evaluate the extent to which these lesions are painful to cows.
The welfare consequences of lameness have received considerable attention (von Keyserlingk et al., 2009), likely due in large part to the established association that this disease has in terms of longevity (Booth et al., 2004) and milk production (Warnick et al., 2001). More work is needed to assess the degree to which hock injuries are precursors or consequences of lameness, metabolic unbalance, or immunosuppression.

Recommendations for how to avoid hock injuries are currently poorly defined or non-existent. Extension programs educating farmers about the risk factors presented in this thesis and better enable producers to share their experiences related to this issue will be likely help to achieve a reduction in hock injuries on dairy farms.

Finally, continued attention must be placed to ensure that all threats affecting dairy cows are identified. For instance, during the data collection phase of my thesis I observed that knee (carpal) injuries were also prevalent on some farms in the NE-US and that ocular neoplasia was affecting cows in dry lots farms in the Southwest US. To my knowledge no work has addressed the prevalence of these injuries and the associated risk factors and I encourage research on these issues.
References


Krawczel, P. 2010. “Cow comfort indexes still work. Take note if your cows are comfortable — the cows and milk check will thank you later”. Hoard’s Dairyman. May: 340.


Appendices

Appendix A. Example of benchmarking provided to producers for hock injuries²

Summary of hock evaluation

This graph provided to producers represented the whole range of values for the percentage of cows affected by mild and severe hock injury in each farm. In order to facilitate the understanding of the farmer as where their herd fits in this graph, we included benchmarking lines.

Hock scoring benchmarking line

The colour scale divided in four sections shows the distribution of scores from the 40 farms assessed (NE-US in this example), ranging from best/better (light purple) to worse/worst (dark purple). The Novus swirl indicates where the producer’s herd fits into the range. The overall averages are described in the summary of all herds, and his/her farm’s scores were included below each scale.

² Adapted from C.O.W.S. Individualized report. Printed with permission from Novus International, Inc.