Acta Universitatis Agriculturae Sueciae

Doctoral Thesis No. 2014:23
Faculty of Landscape Architecture, Horticulture and Crop Production Science

Risk Factors for Occupational Injuries during Cattle Handling on Swedish Dairy Farms

Cecilia Lindahl

Risk Factors for Occupational Injuries during Cattle Handling on Swedish Dairy Farms

Cecilia Lindahl
Faculty of Landscape Architecture, Horticulture and Crop Production Science
Department of Work Science, Business Economics and Environmental Psychology
Alnarp

Doctoral Thesis
Swedish University of Agricultural Sciences
Alnarp 2014

Acta Universitatis agriculturae Sueciae
2014:23

Cover: Väntan
(illustration by C. Lindahl)

ISSN 1652-6880
ISBN (print version) 978-91-576-7994-9
ISBN (electronic version) 978-91-576-7995-6

Print: SLU Repro, Alnarp 2014

Risk Factors for Occupational Injuries during Cattle Handling on Swedish Dairy Farms

Abstract

Dairy farming is known to be associated with a high risk of occupational injury and dairy cattle are repeatedly cited as one of the major sources of injuries on dairy farms. This thesis examines the underlying factors relating to risks of injury in dairy cattle handling. Different qualitative and quantitative methods were used to cover a number of risk and safety aspects in dairy cattle handling, including in-depth interviews with dairy farmers, behavioural observations and heart rate measurements on handler and cows during routine work tasks (moving cows to milking and hoof trimming), documentation of handling facility characteristics and questionnaires. All data collection was conducted on commercial Swedish dairy farms.

The results indicate that while Swedish dairy farmers are aware of the dangers in working with cattle and recognise safety as an important and relevant issue, safety is often overlooked or not prioritised.

Moving cows to hoof trimming involved much higher injury risk exposure to the handler than moving cows to milking. When moving cows to milking, risk situations were primarily associated with facility design and the perceived energy level of the handler. The more aversive hoof trimming procedure involved higher frequencies of fear responses by the cows, more forceful interactions by the handler and higher rates of incidents and risk situations. Incidents (*i.e.* physical contact between cow and handler that could have resulted in an injury) were directly correlated with job strain, cow heart rate and time spent in the risk zone. Furthermore, correlations were found between specific human-cow interactions and facility characteristics and incidents. These results indicate a need for changes in the way aversive routine procedures are performed on dairy farms so as to increase handler safety, but also improve animal welfare, ease of handling and efficiency.

In conclusion, this thesis shows that many factors contribute to the occurrence of animal-related injuries in dairy farming and that injuries result from a complex interplay of multiple risk factors. There is thus a need for interdisciplinary research and multi-targeted prevention strategies. The results presented here will hopefully act as a springboard to future studies and intervention designs.

Keywords: agriculture, animal handling, dairy cow, farming, handler, hoof trimming, human-animal interaction, injury risk, milking, moving cattle, stockperson

Author's address: Cecilia Lindahl, SLU, Department of Work Science, Business Economics and Environmental Psychology, P.O. Box 88, 230 53 Alnarp, Sweden
and
JTI – Swedish Institute of Agricultural and Environmental Engineering,
P.O. Box 7033, 750 07 Uppsala, Sweden
E-mail: Cecilia.Lindahl@ slu.se; Cecilia.Lindahl@jti.se

Dedication

To my parents

Most of the time one is discouraged by the work, but now and again by some grace something stands out and invites you to work on it, to elaborate it or animate it in some way. It's a mysterious process.

Leonard Cohen

Contents

List of Publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I Lindahl, C., Lundqvist, P., Hagevoort, G.R., Lunner Kolstrup, C., Douphrate, D.I., Pinzke, S. and Grandin, T. (2013). Occupational Health and Safety Aspects of Animal Handling in Dairy Production. *Journal of Agromedicine* 18(3), 274-283.

II Lindahl, C., Lundqvist, P. and Lindahl Norberg, A. (2012). Swedish Dairy Farmers' Perceptions of Animal-Related Injuries. *Journal of Agromedicine* 17(4), 364-376.

III Lindahl, C., Pinzke, S., Keeling, L.J. and Lundqvist, P. The Effect of Stress, Attitudes and Behavior on Safety during Animal Handling in Swedish Dairy Farming (submitted).

IV Lindahl, C., Pinzke, S., Herlin, A. and Keeling, L.J. Human-Animal Interactions and Safety during Dairy Cattle Handling – A Comparison of a Stressful and Non-Stressful Situation (manuscript).

V Lindahl, C., Pinzke, S., Herlin, A. and Keeling, L.J. Handling Facility Design and its Effect on Handler-Cow Interactions, Cow Behaviour and Handler Safety (manuscript).

Papers I-II are reproduced with the permission of the publishers.

My contribution to the papers included in this thesis was as follows:

I Reviewed the literature and wrote significant parts of the paper in collaboration with the co-authors.

II Planned and carried out the study, analysed the data and wrote the paper in collaboration with the co-authors.

III Planned and carried out the study, processed and analysed the data and wrote the paper in collaboration with the co-authors.

IV Planned and carried out the study, processed and analysed the data and wrote the paper in collaboration with the co-authors.

V Planned and carried out the study, processed and analysed the data and wrote the paper in collaboration with the co-authors.

Abbreviations, terms and definitions

Animal handling	Working and interacting with animals.
Attitude	A predisposition or a tendency to respond positively or negatively towards a certain idea, object, person or situation.
Dairy farming	Agricultural husbandry dealing with milk production from dairy cows.
Farmer	Farm owner, self-employed.
Handler	A farmer or employee who manages, cares for and works with dairy cattle on a farm.
Hazard	The potential of any source that may cause harm to people (IAPA, 2007).
Hoof trimming	Trimming of the cow's claws to restore proper conformation (toe length, toe angle and symmetry), during which claw lesions are usually also detected, diagnosed, recorded and treated.
Incident	A variable in Paper III-V defined as physical contact between handler and cow that could have resulted in an injury, *e*.g. handler being kicked, head butted or run over.
Injury	Acute harm or damage to the body caused by exposure to physical energy (such as mechanical, chemical, thermal etc.) in amounts or at rates that exceed the threshold of human tolerance (WHO, 2001).

Job strain	The physical and psychological hardships that occur when a worker is facing high psychological workload demands or pressures, combined with low control or decision latitude in meeting those demands (Karasek, 1979).
Locus of control	The degree to which outcomes are attributed to one's own ability to alter a situation as opposed to external factors such as powerful others, luck or chance (Elkind, 2007).
Near-miss	An unwanted event which, in different circumstances, could have resulted in harm to people (IAPA, 2007).
Risk	The likelihood (probability) of injury or damage occurring to people as a result of exposure to, or contact with, a hazard (Ridley & Channing, 1999).
Safety	A state in which hazards and conditions leading to physical or psychological harm are controlled in order to preserve the health and well-being of individuals (WHO, 1998).
Stress	A set of physical reactions that take place in the body in response to demands that are placed on it. These reactions prepare the body for action (IAPA, 2007).
Stress level	The perceived stressfulness of a situation or intensity of a stress reaction.
WHO	World Health Organisation

1 Background

This thesis focuses on handler safety and the underlying risk factors for animal-related occupational injuries when handling cattle on Swedish dairy farms. This section contextualises the work by describing the structure and development of the Swedish dairy industry, official regulations regarding the working environment and the official statistics on animal-related injuries and fatalities in Swedish agriculture.

1.1 Swedish dairy production

Dairy production is of significant importance to Swedish agriculture (SCB, 2013) and accounts for 35% of the total income in the agricultural sector (Eurostat, 2013). However, there have been major structural changes in Swedish dairy production during recent decades, with a rapid decrease in number of dairy farms and an increase in herd size (*Figure 1*). From 1980 to 2012, the number of dairy farms decreased by 89%. During the same period, the number of dairy cows decreased by 47% (SCB, 2013). A lack of profitability and increased imports of milk products are probable contributors to this development (LRF, 2012).

The agricultural sector engages approximately 177,000 people including family, employees *etc*. Of these, 60% are male and 40% are female. Most Swedish farms are family businesses, and the work is primarily performed by the family members themselves. In 2010, dairy production occupied 29% of the total number of people working full-time (*i.e.* at least one person working full-time) in Swedish agricultural holdings (SJV, 2011b).

In 2012, there were less than 5000 farms specialising in milk production in Sweden and the total number of dairy cows was just under 348,000. Of these dairy farms, 19% had a herd size of 100 dairy cows or more, and the average herd size was 70 dairy cows. In 2011, the average milk yield in Sweden was 8341 kg per cow, which was the second highest average milk yield in all EU countries, after Denmark. Canada and USA have an average milk yield of 8699 and 9678 kg/cow, respectively (SCB, 2013).

Dairy cows in Sweden have traditionally been kept in tether systems with pipeline milking. However, the trend is now that tether systems are decreasing and loose housing with cubicles is increasing. In 2013, approximately 60% of cows were kept in loose housing systems with cubicles. The milking system is also changing, from pipeline milking to parlour milking, rotary milking and automatic milking systems (Stormwall[1], pers. comm.). As a consequence of this development, labour input per cow has decreased (Hedlund, 2008).

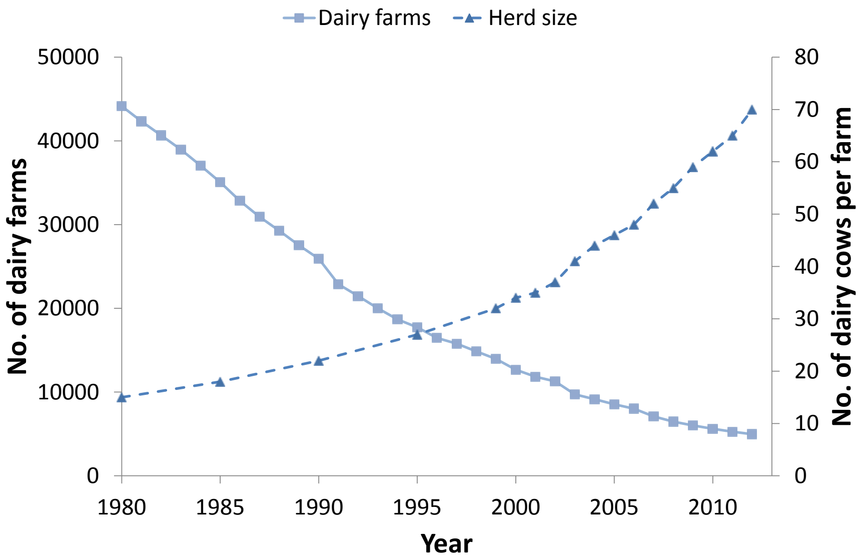

Figure 1. Changes in the number of dairy farms in Sweden and average herd size during the period 1980-2012 (SCB 2013; 2010; 2005; 2000; 1995; 1990; 1986).

1.2 Swedish legislation

1.2.1 The Work Environment Act

The Swedish Work Environment Act (WEA, 1977) defines the framework concerning work environment regulation. The purpose of the Work Environment Act is to protect against work-related ill-health and injuries, and to promote a good work environment generally. The Work Environment Act

1. Eva Stormwall, Växa Sverige, Stockholm, personal communication [06-03-2014]

was first enacted by Parliament in 1977 and it has been amended several times since then. The Act is applicable to any business in which an employee performs work on behalf of an employer.

The Act includes many aspects of the work environment; it takes account of technical and physical factors, as well as work organisation, job content and psychosocial concerns. The Act states that work conditions must be adapted to people's differing physical and mental capabilities, and that employees must be given the opportunity to participate in the design of their own work situation and in processes of change and development affecting their work. The main emphasis in the Act is on prevention, and it states that employers must take all measures necessary to ensure that employees are not placed at risk of ill-health or injuries.

For business owners who have no employees but run the business alone or with family members (relevant to many Swedish farms), only parts of the Work Environment Act apply. According to the Act (chapter 3, § 5), these businesses only have to follow the regulations regarding technical devices and risks from dangerous substances.

The Work Environment Act defines the framework for the Provisions issued by the Swedish Work Environment Authority. These Provisions contain more detailed conditions and obligations with reference to the work environment. For example, they may concern specific risks, for example mental stress and physical loads, dangerous substances, machinery or animals.

1.2.2 Provision for Work with Animals

One Provision issued by the Swedish Work Environment Authority in 2008, contains specific regulations regarding working with animals (PWA, 2008). The Provision covers all sectors and activities where people are exposed to animals in their work. It includes requirements on facilities and equipment, as well as the acquisition of knowledge of animal behaviour, characteristics and possible reactions in different situations. There are also some specific demands on work with cattle, horses and pigs.

The two paragraphs (§ 14 and § 15) especially aimed at those working with cattle state that:

- Measures must be taken to decrease the risk of injuries from head butting.
- Specific caution must be taken when working with heifers or cows if there is a loose bull among them and when handling newly calved cows. An escape route or safety device must be accessible in the event of a risk situation.

1.3 Occupational injuries and fatalities

Farming has long been recognised as a hazardous occupation. In Sweden, occupational fatalities among agricultural workers were reported to be 13 per 100,000 workers in 2007, compared with 1.7 per 100,000 for all sectors. Injuries in agriculture are most commonly related to machinery, animals and falls (SWEA, 2009).

During a five-year period (2008-2012), a total of 1122 injuries in agriculture were reported to the Swedish Work Environment Authority. Thirty of these injuries were fatal. Of the victims, 68% were male and 32% were female. The relative frequency of reported injuries was higher for females than for males (6 and 3 injuries per 1000 workers for females and males, respectively). Of the reported injuries, 27% involved animals and 17% involved cattle specifically. Each year, 1-2 fatal injuries inflicted by animals are reported and these are mainly due to bull attacks (ISA, 2013).

Cattle are cited as the source of injury in the majority of the animal-related injuries, with around 40 such injuries reported per year (*Figure 2*). As can be seen in the diagram, farms specialising in milk production seem to suffer most from these injuries. Injuries inflicted by cattle are often severe and result in long periods of sick leave (ISA, 2013).

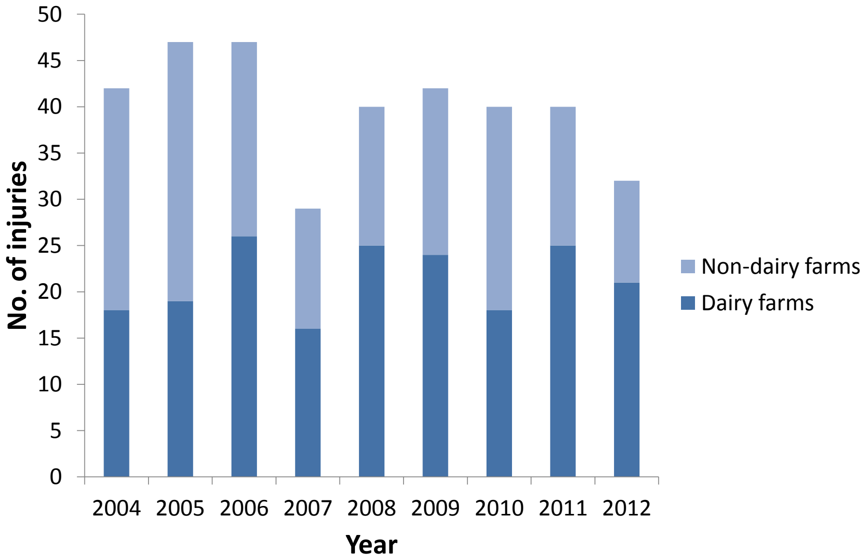

Figure 2. Number of cattle-related injuries in agriculture reported to the Swedish Work Environment Authority for the years 2004-2012 (ISA, 2013).

The official statistics on occupational injuries are based on injuries reported to the Swedish Social Insurance Agency. However, it is well known that there is a high level of under-reporting, especially in agriculture, where farmers are self-employed. Thus, the true injury frequency is unknown, but is most probably a great deal higher than the official statistics show. Pinzke & Lundqvist (2007) investigated the number of unreported injuries in agriculture and found that only 8% of injuries emerged in the official statistics. Thus the situation resembles as an iceberg, with the visible part (fatalities and reported injuries) being very small compared with the submerged part (unreported injuries and near-misses). This means that knowledge is lacking on the origin and extent of injuries, which constitutes an obstacle in the work to reduce injuries both when it comes to designing preventive strategies and to evaluating the effectiveness of a preventive measure.

2 Introduction

2.1 Concepts

The terms used in safety research constitute a continuum of meanings and the terminology used varies between sectors and professions. Therefore, there is a need to discuss the definitions and clarify what is meant. Below, the concepts hazard, risk, accident, injury and safety, which are very relevant in this thesis, are defined and clarified.

2.1.1 Hazard and risk

The terms hazard and risk can be defined separately, even though they sometimes are used synonymously. A *hazard* is the potential of any source (machine, equipment, process, material or physical factor) that may cause harm to people, or damage to property or the environment (IAPA, 2007). A *risk* is the likelihood of injury or damage occurring to property or the environment as a result of exposure to, or contact with, a hazard (Ridley & Channing, 1999).

Risk is often used synonymously with 'high risk' (Pless & Hagel, 2005). For example, in this thesis 'risk factor' is used for factors associated with a relatively high risk of injury.

2.1.2 Accident and injury

There has been some debate about the use of the term *accident*, because of the lack of a clear definition and the word's misleading connotation (Loimer & Guarnieri, 1996). The definition of an accident used by WHO is: "an event that results or could result in an injury" (WHO, 1989). In other definitions, events are commonly referred to as unexpected or unplanned and sometimes only harmful events (to people or property) are included. The criticism regarding the use of 'accident' is that the word is associated with fate, chance or unpredictability, which implies that these events are unpreventable (Pless & Hagel, 2005; Neira & Bosque, 2004).

The commonly suggested term to use instead of 'accident' is the word 'injury'. Injury is neutral with respect to predictability, causation and intentionality. The standard definition of an *injury*, as used by WHO, is: "Injuries are caused by acute exposure to physical energy (such as mechanical, chemical, thermal *etc*.) in amounts or at rates that exceed the threshold of human tolerance. It may also result from sudden lack of essential energy such as heat or oxygen" (WHO, 2001; Baker *et al*., 1992). Injuries can be divided into two main categories: unintended and intended.

However, the replacement of 'accident' with 'injury' is not altogether trouble-free. As Bijur (1995) pointed out, injury refers to the outcome of a process in which an event or a sequence of events plays a central role. Thus, when referring to prevention of the events that lead to injury, a concise term is lacking. Bijur (1995) suggested the use of injury-producing event (IPE) and potentially injury-producing event (PIPE), but it is difficult to get new terms universally adopted.

Because of the criticism and discussion concerning the word 'accident', the term is avoided as far as possible in this thesis. Instead, the terms 'injury' (meaning unintentional injury) and 'injury-producing event' are used. However, when citing farmers, the word 'accident' is used to translate the corresponding Swedish word (*olycka*).

2.1.3 Safety

Safety can be defined as freedom from the occurrence of risk of injury, danger, loss or any other event that could be considered non-desirable. However, total absence of risk may not be realistic. WHO defines safety as "a state in which hazards and conditions leading to physical, psychological or material harm are controlled in order to preserve the health and well-being of individuals and community" (WHO, 1998). Safety also contributes to a perception of being sheltered from danger. Thus, this definition takes into account two dimensions of safety: the objective and the subjective dimension. The objective dimension is assessed by behavioural and environmental factors (external criteria), while the subjective dimension relates to the individual's internal perceptions and feelings of being safe (WHO, 1998). The WHO definition is used in this thesis.

Thus, the term safety is defined more by its absence than its presence. As a consequence, people are better at describing and quantifying 'unsafety', *i*.e. deviations from a state of safety, than safety. Safety is commonly measured by frequency of fatalities, injuries, near-misses and other negative outcomes (Reason, 2008).

2.2 Conceptual model of injury causation

Understanding how injury-producing events occur is fundamental for establishing effective prevention strategies. Since these events are often complex, understanding the causal factors and relationships is problematic. Several theories of injury causation have evolved that attempt to explain why such events occur. Based on these theories, a large number of conceptual models of injury causation have been developed to help predict and prevent injuries (HaSPA, 2012).

Early models, like the 'domino' theory proposed by Herbert W. Heinrich (1931) suggested that injury-producing events have only one cause and that the sequence of events leading to an injury interact in a one-dimensional linear way. Later approaches are complex non-linear models which assume that multiple factors act simultaneously and that their combined influence leads to the injury-producing event (HaSPA, 2012). Different models have different strengths and are useful for different purposes. There is naturally a degree of divergence between any model of injury causation and reality, and the models often provide a simplified version of the truth.

The epidemiological model of injury causation is applicable to the approach to injury causation adopted in this thesis. It is a complex linear model, meaning that it has a sequential approach but acknowledges the significance of multi-factor causation. With an epidemical model approach, injury prevention methods focus on the underlying causes of the event leading to injury, and prevention is achieved by reducing or eliminating these risk factors.

2.2.1 The epidemiological approach

Epidemiology is the study of causal relationships between environmental factors and disease. As first recognised by Gordon (1949), the same model can also be used to study causal relationships between environmental factors and injury-producing events. According to this model, the cause of any injury is a combination of interacting forces from three sources: the host, the agent and the environment. The host refers to the person affected by the injury. The agent is energy that is transmitted to the host through a vehicle (inanimate object *e.g.* machine) or vector (person or other animal). The environment is subdivided into a physical and socio-cultural environment. The physical environment includes all the characteristics of the setting in which the injury event takes place. The socio-cultural environment includes social and legal norms and practices in the culture (Haddon, 1980; Gordon, 1949). Thus, applied to the context of this thesis, the host is the handler and the vector refers to the cattle.

Dr. William Haddon Jr. is widely considered to be the father of modern injury epidemiology (Runyan, 2003). Haddon developed two complementary conceptual frameworks to guide the understanding of how injuries occur and to aid the development of prevention strategies; the Haddon Matrix and the Ten Countermeasure Strategy for reducing injuries (Haddon, 1980). The Haddon Matrix, in its simplest form, has two dimensions. The first (the columns) consists of the three factors host, vector (or vehicle) and environment (physical and socio-cultural). The second (the rows) consists of three phases of an injury-producing event, labelled pre-event, event and post-event. By filling in each cell of the matrix, it is possible to identify a range of potential risk and protective factors, as well as strategies for prevention directed at each combination of factors and phases (Haddon, 1980).The Ten Countermeasure Strategy was developed as a tool to reduce the risks of injury or loss (Haddon, 1973). In short, the countermeasures are:

1. Prevent the creation of the hazard.
2. Reduce the amount of hazard brought into being.
3. Prevent the release of the hazard.
4. Modify the rate of release of the hazard from its source.
5. Separate the hazard from that which is to be protected by time and space.
6. Separate the hazard from that which is to be protected by a physical barrier.
7. Modify relevant basic qualities of the hazard.
8. Make what is to be protected more resistant to damage from the hazard.
9. Begin to counter damage done by the hazard.
10. Stabilise, repair and rehabilitate the object of damage.

(rephrased by Runyan, 2003; Haddon, 1973).

2.3 Dairy farming – a dangerous occupation

This section includes some of the findings from the literature review. For more details, see Paper I.

2.3.1 Injuries in dairy farming

Dairy farming has long been known to be associated with a high risk of occupational injuries. In 2004, about 5000 injuries occurred on agricultural farms in Sweden according to a survey by Pinzke & Lundqvist (2007). Of these injuries, 30% occurred on dairy farms, which means that 15% of all Swedish dairy farms had one or more injury that year. A high injury rate in dairy farming has also been reported in other studies from different countries (Karttunen, 2014; Douphrate *et al.*, 2006; Hartman *et al.*, 2004; Nordstrom *et al.*, 1995; Zhou & Roseman, 1994; Hoskin & Miller, 1979). Nordstrom *et al.*

(1995) found that dairy farmers were 2.5 times more likely to be injured than farmers on non-dairy farms.

Dairy farm operators and workers have to engage in many different and widely varied activities, *e.g.* operating large machinery, handling and tending animals, maintaining and repairing machinery and facilities, and administrative work. They also face many demands and stressors in their daily work, many of which they cannot control, such as weather conditions, machinery breakdowns, economic problems and changes to laws and regulations. Work tasks involving heavy lifting, moving and carrying equipment and awkward working postures are not uncommon. Compared with other occupations, farmers also often work longer hours and work alone. Despite major technical developments to facilitate farm work, the frequency of injuries has been found to be almost as high as it was 20 years ago (Pinzke & Lundqvist, 2007). During that same period, the farming population has decreased quite rapidly, indicating that injury rates are actually increasing.

The main injury sources in dairy farming are repeatedly reported to be machinery, animals and falls (Brison & Pickett, 1992; Pratt *et al.*, 1992). Increased injury risk has been found to be associated with male sex, younger age, older age, an increased number of working hours and heavier workloads (Douphrate *et al.*, 2009; Sprince *et al.*, 2003; Layde *et al.*, 1996; Pratt *et al.*, 1992). Pratt *et al.* (1992) found that it was the owners/operators, *i.e.* often the most experienced and knowledgeable people on dairy farms, who were hurt more frequently. Increased injury risk with increasing experience of farm work was also found by Brison and Pickett (1992). However, a study of livestock injuries in particular found less experienced workers at higher risk of injury (Douphrate *et al.*, 2009).

2.3.2 Injuries specifically related to cattle handling

Among farmers, working with livestock is considered to be the most hazardous activity performed on the farm (Kallioniemi *et al.*, 2011; Allen *et al.*, 1995). This is supported by numerous studies in which livestock are consistently mentioned as one of the main contributors associated with agricultural injury (Erkal *et al.*, 2008; Pinzke & Lundqvist, 2007; Carstensen *et al.*, 1995; Brison & Pickett, 1992; Pratt *et al.*, 1992; Waller, 1992; Doyle & Conroy, 1988). Cattle represent the vast majority of animal-related injuries in agriculture (Karttunen, 2014; Pinzke & Lundqvist, 2007; Layde *et al.*, 1996; Carstensen *et al.*, 1995). Douphrate *et al.* (2009) analysed livestock-handling compensation claims and found that injuries caused by livestock were more costly and resulted in more time off work than other causes of agricultural injury. Cattle-related injuries in particular have been reported to be more serious than other farm-related injuries (Carstensen *et al.*, 1995).

Work activities that increase exposure and proximity to the animals are associated with animal-related injuries (Douphrate *et al.*, 2006; McCurdy & Carroll, 2000). Milking in particular has been mentioned in several studies as one of the major tasks involving injuries (Douphrate *et al.*, 2009; Erkal *et al.*, 2008; Boyle *et al.*, 1997). Other animal-related activities found to be associated with a high injury risk in dairy farming are herding/moving and feeding (Erkal *et al.*, 2008; Rasmussen *et al.*, 2000), and trimming and treating hooves (Boyle *et al.*, 1997). The main mechanisms of injury associated with cattle are the handler being kicked, crushed between cattle and other objects, stepped on, pushed and head butted (Watts & Meisel, 2011; Douphrate *et al.*, 2009).

2.4 Limitations

This thesis is based on data from Swedish dairy farms with various herd sizes. Even though many Swedish cows are still housed in tether systems, these systems are gradually being replaced by loose housing barns with cubicles. Therefore, this thesis focuses on dairy farms with loose housing. Since it was not possible to include all hazardous activities related to animal handling, one activity (moving cows) in two different settings (milking and hoof trimming) was selected to serve as a model in more detailed studies of injury risk factors.

3 Aims of the thesis

3.1 General aim

The overall aim of this thesis was to contribute to the future prevention of cattle-related occupational injuries in dairy farming by obtaining a deeper knowledge and understanding of the risk factors related to dairy cattle handling. The results were intended to be used as a basis for developing effective prevention strategies.

3.2 Specific aims

The specific aims of Papers I-V were to:

- Review the scientific literature so as to determine the state of the art and gain an overview of research on animal-related injuries in dairy farming (Paper I)
- Explore and reach an in-depth understanding of Swedish dairy farmers' own experiences, perceptions and attitudes to animal-related injuries, including risk and safety issues and prevention measures (Paper II)
- Identify potential risk factors and underlying causes of animal-related injuries in dairy farming (Paper II)
- Study the relationship between potential risk factors and safety during handling of dairy cattle, with particular focus on:
    - Stress, attitudes and handler behaviour (Paper III)
    - Human-animal interactions (Paper IV)
    - Handling facility characteristics and design (Paper V)
- Suggest preventive strategies (Papers III-V)

4 Structure of the thesis

The initial approach to the subject of this thesis was broad and general, originating in the overall aim but without any specific hypothesis. The angle of approach was then gradually narrowed down to a specific focus and explicit hypotheses. Paper I summarises the state of the art for the subject and contributes to the general understanding and identification of knowledge gaps. Paper II provides a deeper understanding of the cause of injuries and potential risk factors related to animal handling in Swedish dairy production, and serves a hypothesis-generating purpose. Papers III, IV, and V focus on testing the hypotheses generated in Paper II. The structure is illustrated in *Figure 3*.

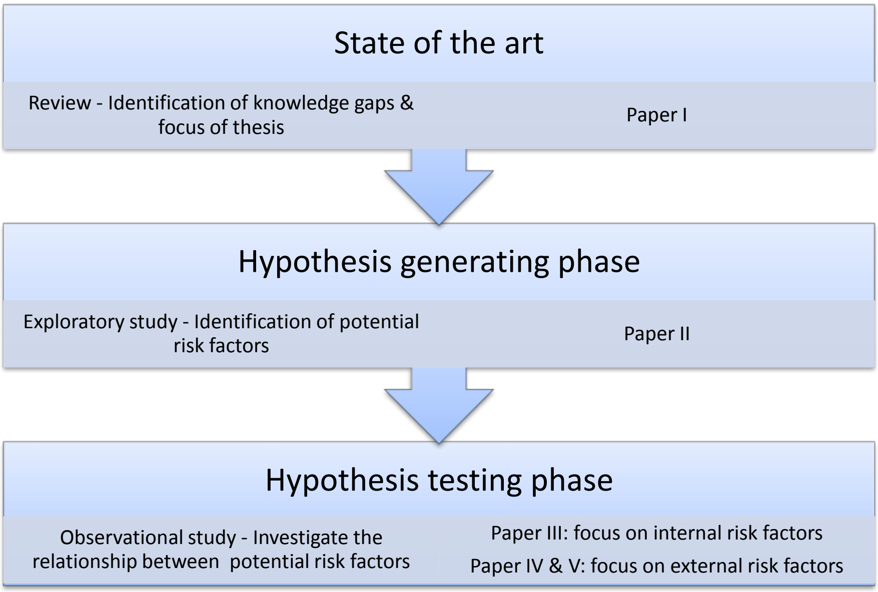

Figure 3. Structure of the thesis and the contribution of Papers I-V.

5 Materials and methods

Several different methods, both qualitative and quantitative, were used to cover a number of aspects of risks and safety in animal handling (Table *1*). Paper I is based on a literature review, Paper II on qualitative data from in-depth interviews with dairy farmers and Papers III-V on data from observational studies including behavioural observations, heart rate measurements, documentation of handling facility characteristics, questionnaires and short interviews.

5.1 Materials

5.1.1 Subjects in Paper II

Due to the qualitative approach of this study, the aim of sampling was to identify participants who reflected the range and depth of dairy farmers' perceptions of animal-related injuries. Therefore, efforts were made to select farmers of different age and gender, dairy farms from different parts of Sweden and dairy farms with different herd sizes and milking systems. The common selection criteria were dairy farms with loose housing and the farmer involved in daily work with the animals. Agricultural advisors active in four different parts of Sweden were consulted to find farmers that matched these criteria. Farmers were contacted by phone and invited to participate. Two farmers declined to participate due to lack of time.

Twelve dairy farmers participated in the study, three from each of four regions ranging from the south to north of Sweden (Skåne, Uppland/Södermanland, Jämtland and Västerbotten). Two of the farmers were female and ten were male. The age of the farmers ranged from 26 to 60 years. The farm size ranged from 55 to 300 dairy cows. Two farms had a rotary milking parlour, five had milking parlour pits and five had an automatic milking system.

Table 1. *Summary of the research design used in Papers I-V.*

	Paper I	Paper II	Paper III	Paper IV	Paper V
Title	Occupational health and safety aspects of animal handling in dairy production	Swedish dairy farmers' perceptions of animal-related injuries	The effect of stress, attitudes, and behavior on safety during animal handling in Swedish dairy farming	Human-animal interactions and safety during dairy cattle handling – a comparison of a stressful and non-stressful situation	Handling facility design and its effects on handler-cow interactions, cow behaviour and handler safety
Human subjects		12 dairy farmers (farm owners)	12 dairy farm workers (4 farm owners and 8 employees)		
Animal subjects			A total of 960 cows being moved to milking and 675 cows being moved to hoof trimming		
Method	Literature review	Semi-structured interviews	Questionnaires, behavioural observations, heart rate measurements, structured interviews	Behavioural observations, heart rate measurements	Documentation of handling facility design, behavioural observations, heart rate measurements, questionnaire, structured interviews
Analysis method		Inductive thematic method	T-test, Wilcoxon signed rank test, Spearman correlation, Mann-Whitney U test	T-test, Wilcoxon signed rank test, Spearman correlation	Spearman correlation

5.1.2 Subjects in Papers III-V

In order to obtain a sample of suitable farms for Papers III-V, agricultural advisors and professional hoof trimmers in Central and Southern Sweden were contacted. The criteria for selection were dairy farms with loose housing with cubicles and parlour milking. It was also important to be able to observe the same person moving the cows to milking and hoof trimming. Suitable farmers were contacted by phone, informed about the study and invited to participate. A total of 40 farmers were contacted and twelve agreed to participate. The main reasons cited for not participating were that the date of hoof trimming was unsuitable, the handler was not the same during milking and hoof trimming, and a general lack of interest in the study.

None of the twelve commercial dairy farms which agreed to participate in the study was the same as in Paper II. Herd size ranged from 45 to 430 dairy cows. Handler age ranged from 23 to 64 years, and their experience of working with dairy cattle ranged from 3 to 40 years. Three were female and nine were male. Four of the handlers were self-employed farm owners and eight were employees.

On each farm visit, three cows were randomly selected for heart rate measurements. The behavioural observation studies included a total number of 960 cows being moved to milking and 675 cows being moved to hoof trimming.

5.2 Methods

5.2.1 Literature review (Paper I)

The literature search was conducted through electronic searches in selected databases and extended searches by reference checking. Each co-author to Paper I contributed to the literature search within their field of expertise. The review focused on research on dairy livestock handling injuries, with special emphasis on human behaviour and facility design as risk factors. Safety management and the effectiveness of training programmes on livestock handling were briefly examined.

5.2.2 In-depth interviews (Paper II)

In Paper II, an inductive approach was used to reach a complex and detailed understanding of the farmers' perceptions and experiences of animal-related injuries. Semi-structured in-depth interviews with twelve dairy farmers were conducted in spring 2010. A semi-structured interview is open and allows the informant to bring up new ideas and aspects, while the interviewer guides the interview through the topics to be explored. An interview guide was used which covered the farmers' experience of animal-related injuries and near-misses, the perception of risk factors and safety in working with cattle, thoughts on the prevention of animal-related injuries and attitudes to risks and safety when handling cattle. The interviews lasted between 1 h and 1 h 50 min and took place in the farmers' homes. The interviews were recorded digitally and later transcribed *verbatim*.

5.2.3 Behavioural observations (Papers III-V)

Behavioural observations were conducted on twelve farms at two occasions; during moving the cows to afternoon milking and moving the cows to hoof trimming. Milking is performed 2-3 times a day. The cows are used to the procedure and the environment and are moved as a herd. Moving cows to milking was chosen to represent a situation with probable low stress and fear levels and a relatively low risk of injury. Hoof trimming is done more rarely, normally 2-3 times a year. The procedure includes unfamiliar environments to the cows, separation from the herd, loud noises, restraint and possibly painful treatments, and can consequently be perceived as stressful and frightening to the cows (*Figure 4*). Therefore moving cows to hoof trimming was chosen to represent a situation of probable high stress and a high risk of injury. The visits were carried out between April 2012 and February 2013.

The observations included the behaviour of both the handler and the dairy cows being handled. The same person was observed during the two visits to each farm. The behaviour of the handler and of cows within a 2 m radius of the handler was recorded continuously at 1-minute intervals using pen and paper. Each observation session started when the handler began to move the cows to milking/hoof trimming and ended when the cows were in the waiting pen to be milked or in the trimming chute. The observations were conducted simultaneously by the same two researchers on each farm, one observing the handler and one observing the cows.

Pilot observations were conducted repeatedly on two farms before the actual data collection started in order to practise and try out the procedures, protocols and inventory of behaviours and definitions.

Figure 4. Hoof trimming includes restraint and can be stressful to the cows. (Photo: Sofia Åström).

Behaviour of the handler

The handler's interactions with the cows were specified and defined in an ethogram, which can be found in Papers III and IV. Two categorisations of behaviours were used, one for type of interaction and one for the level of intensity (force). Table *2* shows the categories and behaviours included.

Table 2. *Categorisation of interactions depending on the nature of the interaction.*

Category	Interactions
Acoustic	Talking, shouting, noise
Visual	Waving, running
Tactile	Tail twisting, pulling cow's neck strap or halter, other physical contact with or without object
Gentle	Calm, soft talking and petting
Moderately forceful	Loud talking and moderately forceful physical contact with or without object
Forceful	Shouting, tail twisting and other forceful physical contact with or without object

Time spent in the risk zone

The time the handler spent in the risk zone was recorded during the behavioural observations. The 'risk zone' was defined as the area around the cow where the handler could be hit by the cow's head or hind legs in the case of head butting or kicking, respectively (*Figure 5*). At the end of each observed minute, the handler's time spent in the risk zone was estimated on a scale ranging from *1=No time in the risk zone* to *5=The whole minute spent in the risk zone*. The remaining classes (2-4) divided the minute into thirds. When calculating the mean percentage of the time spent in the risk zone, the mid-point percentage of each class was used as an approximation of the observed time.

Figure 5. The area around the cow defined as the risk zone.[2]

Behaviour of the cows

An ethogram was also developed for cow behaviours and the definitions are presented in Paper IV. Each of the behaviours was divided into different levels depending on the intensity or severity of expression of the behaviour. Behavioural data were calculated as frequency of behaviour per total number of cows moved and observed active minutes (*i.e.* inactive minutes, *e.g.* waiting time, were excluded).

2. Cow image by Jason C. Fisher, Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/imagelibrary/); Human image by Florian Müeller (http://exertioninterfaces.com/cms/jogging-over-a-distance.html)

Incidents and risk situations

Any observed risk situation/incident was recorded, *e.g.* the handler slipping, tripping or falling, the handler being run over by a cow, a cow balking into the handler and the handler being crushed between cows or cow and interior wall/fitting. The frequency of situations and incidents possibly related to an increased injury risk during the observations were calculated.

Incidents were defined as events where there was physical contact between handler and cow that could have resulted in an injury, for example if the handler was kicked, head butted, run over or crushed.

Risk situations were defined as slips, trips and falls by the handler, incidents (as defined above) and cow behaviours indicating fear/stress (including flight, resistance, balking, freezing, kicking, head butting and forcing the interior).

5.2.4 Heart rate measurements (Papers III-V)

During the behavioural observations, heart rate was measured on the observed handler and three randomly chosen dairy cows. These cows served as representatives of the herd. The heart rate was used as an indicator of the individual's physiological response.

Heart rate was logged every 15 s using heart rate monitors. For the handler, a Polar S610 heart rate monitor was used. It was put in place some time before the observations started to make sure it functioned properly and to allow the handler to get used to it. The handler's mean heart rate during the whole observed time (inactive minutes, *e.g.* waiting time, excluded) was used in the statistical analysis.

Heart rate of cows was measured using Polar Equine CS600X heart rate monitors (Polar Elektro Oy, Helsinki, Finland) with Polar Equine Wearlink W.I.N.D transmitter belts (*Figure 6*). The equipment was fitted on the cows approximately one hour before observation started. The average heart rate during an undisturbed period (*i.e.* no handling) 20 min before the observation began was used as a baseline. In the statistical analysis, the mean deviation from the baseline heart rate was used. At milking, the entire group of cows was collected at the same time and therefore mean heart rate of the whole observation was used (inactive minutes excluded). At hoof trimming, only a few cows were collected at a time, so even if the heart rate measurement lasted a few hours the actual time the cow was handled only lasted a few minutes. To ensure that the heart rate of each individual cow was represented the time when that specific cow had been handled, the mean heart rate in the 5 minutes before a cow with a heart rate device entered the trimming chute was used.

Figure 6. Cow with heart rate transmitter belt with the monitor in a plastic bag attached to the belt.

5.2.5 Documentation of handling facilities (Paper V)

The design of the handling facilities for moving cows to milking/hoof trimming was documented following a protocol, which listed factors such as type of flooring, walls and layout of transfer alleys, design of the waiting pens (if used), placement of the trimming chute, and possible distractions that could cause balking, *e.g.* lighting conditions, reflections/shadows, loud noises, sharp bends, bottlenecks, differences in floor levels and flooring, and drain grates. A simple drawing of the layout of each handling facility was made.

5.2.6 Questionnaires (Papers III and V)

On completion of each behaviour observation session, the handler was asked to fill in a questionnaire. On the first visit, the categories of questions were background information (about the farm and handler), perceived stress and energy levels, job strain (psychosocial work environment), safety locus of control, attitudes to risk, and design of the handling facility. On the second visit, the categories included experience of cattle-related injury since last visit, perceived stress and energy levels, attitudes to cows and working with cows, and design of the handling facility. The categories are described in more detail below.

Background

This part consisted of questions on the characteristics of each farm and demographic information on the handler, including sex, age, education, experience of working with dairy cows, main responsibilities and employee/farm owner. There were also questions regarding the participating handlers' prior experience of cattle-related injuries.

The Stress-Energy Questionnaire (Paper III)

The Stress-Energy Questionnaire is an instrument developed to measure emotional stress in a working life setting (Kjellberg & Wadman, 2002; Kjellberg & Iwanowski, 1989). This questionnaire was used to measure the handlers' perceived stress and energy level during the observed animal handling. The Stress-Energy Questionnaire consists of a mood adjective checklist with six words describing the dimensions stress and energy, respectively. Three words represent the negative side of the dimension and three words represent the positive side. The handler was asked to estimate to what extent each adjective described the feeling during the observed handling using a six-grade scale ranging from *0 = Not at all* to *5 = Very much*. The scales of the six negative words were inverted before a mean score for stress and energy was calculated, *i.e.* high mean scores indicated high levels of stress and energy.

Job strain (Paper III)

According to the job strain model (Karasek, 1979), a high stress load at work (job strain) occurs when workers are faced with high psychological workload demands or pressures combined with low control or decision latitude in meeting those demands. Karasek (1979) developed a questionnaire to measure job demands and decision latitude. A modified version (Theorell *et al.*, 1988) of this questionnaire was used in Paper III. The questionnaire consisted of five questions on the job demand dimension and six questions on the decision latitude dimension. The questions had response alternatives from *1 = Almost never* to *4 = Often*. High scores indicated greater control and higher demands. By dividing the demand score by the decision latitude, a job strain score was computed (Theorell *et al.*, 1988).

Safety Locus of Control Scale (Paper III)

The Safety Locus of Control Scale was developed to predict employees' disposition to injury and unsafe behaviours (Jones & Wuebker, 1985). It reflects the person's belief or perception of who controls behaviour and events and ranges from internal to external locus of control. People with an external safety locus believe that injuries are due to chance events, bad luck or fate and they see no relationship between their own actions and safety. Those with an internal safety locus believe they are responsible for their safety and that they can avoid injuries. Employees with a more external safety locus of control have been found to report more occupational injuries than those with a more internal safety locus o control (Jones & Wuebker, 1993).

The Safety Locus of Control Scale used in Paper III was a modified version presented by Glasscock *et al.* (2006), altered to be more suitable for farmers. The scale consisted of 17 items regarding the respondent's beliefs about accident causation. A six-point scale ranging from "*Agree very much*" to "*Disagree very much*" was used for each item. The safety scale raw scores were calculated according to Jones and Wuebker (1985) and ranged from -17 (externals) to +17 (internals). The respondents were divided into two groups, one internal and one external group, depending on whether the raw score was above or below zero.

Risk attitudes (Paper III)

Attitude to risk is a variable which examines people's intentions to evaluate a risk situation in a favourable or unfavourable way (Rohrmann, 2008). An individual's attitude to risks is linked to beliefs about locus of control, and is believed to be associated through behavioural intentions to injury outcomes (Elkind, 2007).

Attitude to risk was measured using a five-item questionnaire previously used by Sprince *et al.* (2003) and Alavanja *et al.* (2001). Statements included for example "*Farming is more dangerous than jobs in industry or manufacturing*" and "*Compared with other farmers, I am very conscientious about avoiding accidents*". The respondents were asked to state whether they agreed or disagreed with each statement. The answers were scored as 0 or 1 depending on the nature of the answer. The total sum was computed and if the sum of score was 0 to 2, the respondent was considered to be "risk averse", while if it was 3 to 5 the respondent was considered "risk accepting" (Sprince *et al.*, 2003; Alavanja *et al.*, 2001).

Attitudes to cows and working with cows (Paper III)

The handler's beliefs about the characteristics of cows and working with cows were measured using a modified version of a questionnaire developed by Hemsworth *et al.* (2000). The first part included 25 statements about the characteristics of cows and had five response alternatives from "*Disagree strongly*" to "*Agree strongly*". The second part included 10 questions about the handling of cows at different ages (primiparous cows and older cows). The response alternatives for each question were from 1 to 7.

The statements in the first part were reduced to four factors depending on the essence of the statement; positive attitudes to cow characteristics (PosAtt), negative attitudes to cow characteristics (NegAtt), positive attitudes to working with cows (PosWork), and an opinion that cows are easy to manage (EasyMan). The second part, about the handling of cows, was reduced to three factors; the perceived effort needed to move cows to milking (HandlMilk), the perceived effort needed to move cows to hoof trimming (HandlHoof), and cows' fear of humans (LowFear).

Facilities (Paper V)

The handler's opinion of the design and layout of the transfer alley was documented using five statements with four response alternative scores: *Disagree* (1), *Partly disagree* (2), *Partly agree* (3) and *Agree* (4). The statements were:

- From the cows' perspective, the transfer alley has a good design.
- The cows often slip during handling.
- The design of the transfer alley obstructs safe handling and smooth movement of the cows.
- In my experience, distractions around the transfer alley affect the handling.
- During handling, I can easily escape to a safe place if I need to.

5.2.7 Structured interview (Papers III and V)

A short structured interview (5-10 minutes) was conducted with the observed handler after each behaviour observation session. The questions were:

- Was the observed handling representative of an 'average' milking/hoof trimming?
- Did you ever feel stressed during the observed handling of the cows?
- Did you at any time during the observed handling find that you were exposed to a risk of injury?
- Do you think that the design of the facilities influences the efficiency and safety when handling the cows?
- Have you noticed any specific places where the cows often stop or hesitate about going forward?
- Have you thought of any possible alterations to the design of the facilities to achieve better and safer handling?

5.2.8 Data analyses

Qualitative data analysis (Paper II)

The data were analysed using the inductive thematic method described by Hayes (2000). This analysis involves identification of particular themes which occur in the data material. The transcribed interviews were thoroughly read through and pieces of information relevant for the research issue were marked and coded. The next stage involved sorting the marked bits of information into categories dealing with similar topics, and each category was then read through to find recurrent themes and sub-themes. The themes were developed and changed until they reached their final form in a process which involved repeatedly moving back and forth between the themes and the transcripts to make sure no information was overlooked or misrepresented. The data analysis is a very time consuming and laborious process, and involves continual movement across the different stages. The analysis was conducted using the qualitative data analysis software package ATLAS.ti (version 6.1, Scientific Software Development GmbH, Berlin, Germany).

Statistical analysis (Papers III-V)

The statistical analysis was conducted in SPSS Statistics for Windows, version 20.0 (IBM Corp., Armonk, NY). Data on behavioural observations of handler and cows were not normally distributed and thus human-cow interactions, cow behaviour and risk situations/incidents at milking and hoof trimming were analysed using the related-samples Wilcoxon signed rank test. However, time spent in the risk zone was considered to be normally distributed and was therefore analysed using the paired t-test (two-tailed).

The paired t-test (two-tailed) was also used for comparing differences in heart rate when cows were being moved to milking and to hoof trimming. Farm mean values were used for cow heart rate. Due to technical problems, some heart rate measurements of cows were not reliable and were excluded from further analysis. Two farms were excluded from the analysis due to missing values for all three cows at hoof trimming.

The comparison of handlers' perceived stress and energy levels when moving cows to milking and to hoof trimming was conducted using the paired t-test (two-tailed). One farm was excluded from the analysis due to missing data for milking.

Pair-wise comparisons of variables were made between males and females, employees and farm owners, risk aversive and risk accepting, and external safety locus of control and internal locus of control. For the variables gentle, moderately forceful and forceful interactions, risk situations and incidents, the

Mann-Whitney U test was used. The independent samples t-test was used for the variables time spent in the risk zone, job strain and attitudes to cows and working with cows.

Correlations were used to find associations between variables. For consistency, all correlations were calculated using Spearman's correlation coefficient.

The significance threshold used was $P \leq 0.05$ in Papers III and V, while $P \leq 0.01$ was used in Paper IV to decrease the risk of Type I errors, *i.e.* incorrect rejection of the null hypothesis due to the large number of variables resulting in many statistical comparisons.

6 Results

In this section, a summary of the results from Papers I-V is presented. More detailed results can be found in each individual paper.

6.1 Literature review (Paper I)

Paper I summarised the state of the art as regards research on injuries related to handling of dairy cattle, with special emphasis on human behaviour and facility design as risk factors. A presumed novel approach was the inclusion of references on animal welfare science. Human-animal interactions are important in relation to safety, but research on the safety aspect of human-animal interactions is limited. However, the knowledge gained from studies on human-animal interactions in relation to animal welfare and productivity can also be useful when considering handler safety. An example is the model of human-animal interactions proposed by Hemsworth (2003), describing the sequential relationship between the attitudes and behaviour of the handler and the animal response. Since animal fear also affects risk and safety of the handler, it could be added to 'Cow productivity & welfare' in the last stage of the process illustrated in *Figure 7*.

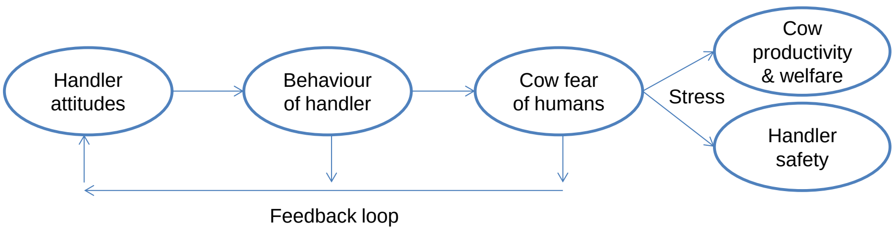

Figure 7. Model of human-animal interactions with the added circle of handler safety. Modified from original source: Hemsworth (2003).

A conclusion drawn from the review in Paper I is that studies that address potential risk factors often are based upon case reports or systematic reviews of medical records, insurance claims, or fatality statistics. These approaches provide valuable information on apparent causes, circumstances and consequences. However, it may be difficult to reach a deeper understanding of the underlying factors and causal relationships preceding the injury-producing event through such data. Furthermore, studies especially addressing risk factors related to injuries associated with animal handling in agriculture are still relatively limited in number, despite the repeated reporting of high frequencies of these injuries. It is possible that the risk factors related to dairy cattle handling differ from the risk factors in other agricultural contexts because of the specific work tasks and the interaction and close contact with cattle associated with dairy farming.

6.2 Swedish dairy farmers' perceptions of risks and safety related to cattle handling (Paper II)

In Paper II, a qualitative study was carried out to investigate Swedish dairy farmers' own experience of animal-related occupational injuries, as well as their perceptions and attitudes towards such injuries, including risk and safety issues and prevention measures.

Three main themes that have an impact on risk and safety when handling cattle were identified by the farmers; the handler, the cattle and the facilities. These three themes are all in interaction with each other and influence the potential risk of any work task (*Figure 8*). This corresponds to the epidemiological model of injury causation, where the cause of injury is described as a combination of interacting forces from the host (handler), the vector (cattle) and the environment (handling facilities).

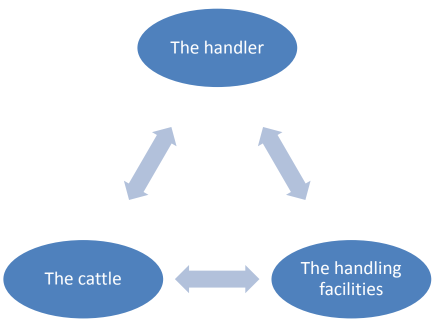

Figure 8. Schematic image of the three main themes with an impact on risk and safety during dairy cattle handling.

6.2.1 The handler

All farmers interviewed shared the belief that the people handling the animals have a major impact on the safety, and that the behaviour of the handler is the main cause of cattle-related injuries. Handling cattle calmly and patiently was thought to be the most important factor in avoiding injuries. Cows were described as mirrors of the person handling them, *e.g.* they easily become stressed if the handler is stressed. One farmer described it thus:

> "You have to have respect and be on the same level as the animal and then move quietly, talk just like you talk to a person I'd say. You should... you shouldn't shout and scream and so on. Then the cows will get scared and you can't have that. And then always stay close and not show any fear when you are handling the animals, because they will sense that too. They are not so foolish as not to take advantage of that in different ways, I think. So you have to be gentle, but at the same time decisive [...] no matter what, it's you who's in charge." [*male, aged 32*]

Skill was thought to be related to safety because a skilled handler is able to read and understand the cattle and predict their reactions in different situations, and is thereby able to stay one step ahead. According to the farmers, skill is improved through knowledge, experience and practice.

The farmers believed that some people are risk-takers by nature. The amount of risk a person is willing to take was believed to be affected by personality, age, experience and knowledge. Several of the farmers felt they had become more careful with age and one farmer thought that risk-taking decreased with experience gained.

6.2.2 The cattle

The farmers also stated that the cattle themselves affect the risk related to their handling. Aspects such as the cattle's age, sex, emotional status, temperament, hormonal status, and previous experience of being handled were brought up as relevant. For example, handling of bulls, cows in heat, cows with calf at foot and fearful or aroused individuals were pointed out as carrying a higher risk. In relation to fearful or aroused cattle, the handling situation was mentioned as important. Novel situations, situations that disrupt the normal routines or when cows get separated from the herd are contexts where dairy cattle may be fearful and react in unexpected ways.

6.2.3 The handling facilities

The facilities were considered by the farmers to be of importance for their safety when handling the cattle. The farmers believed that some injuries are preventable by designing and providing facilities that are as safe as possible, for example by taking measures against slippery floors, providing equipment to restrain cows when needed, and designing transfer alleys that enable cow movement and provide an escape route for the handler.

All farmers interviewed had experience of changing their housing system from a tether system to loose housing with cubicles. The change was generally considered positive for the safety of the handler, mainly because of the improved milking systems. A female farmer gave a vivid description of her experience of pipeline milking:

> "A much heavier job and you were more unbalanced. You had to squat and that, and get down on your knees. And I mean if they [the cows] kicked you, you would end up under the belly of another cow and then they'd get scared." [*female, aged 49*]

A majority of the farmers believed loose housing with cubicles to be a safer system than the tether system, even though loose housing involves work among loose cows. The perceived safety was mainly explained by the fact that farmers found the cows to be much calmer in loose housing. Furthermore, farmers considered the loose housing system to be better designed for handling dairy cows as a herd compared with the tether system. However, some farmers also acknowledged the increased exposure entailed in handling loose cows.

6.2.4 Attitudes to risk and to injury prevention

The farmers seemed to be aware of, and concerned about, the hazards associated with handling cattle. However, they also acknowledged that safety practices were easily forgotten or not prioritised. Thus, a conclusion was that unsafe practices were not mainly a consequence of reckless behaviour, but a calculated risk the farmers were willing to take due to other benefits (*e.g.* saving time).

One important aspect regarding attitudes to injury prevention is farmers' perception of whether or not they are in control of their own safety. We found two main views; one was that injuries are impossible to avoid because "if it's going to happen, it will happen" [*male, aged 39*], and the other was that one can control hazards and thereby prevent injuries. Most of the farmers interviewed believed that it is possible to prevent most injuries, but that there will always be some events that are impossible to foresee. The farmers described a perceived lack of control when working with cattle, mainly due to the animals' unpredictability. One farmer related:

> "They're living creatures, live animals, which really means that anything can happen." [*male, aged 52*]

6.3 Attitudes, stress and behaviour (Paper III)

Paper III examined how stress, handler attitudes and behaviour affect risk and safety during handling of dairy cows. The participating farms were visited on two occasions representing different stress levels, when cows were being moved to milking (low stress) and to hoof trimming (high stress). *Table 3* summarises the hypotheses and corresponding results found in the study.

Table 3. *Hypotheses in Paper III and corresponding results. Text in red italics indicates that the result did not support the hypothesis.*

	Hypothesis	Results
Interactions	Handlers use more moderately forceful and forceful interactions, spend more time in the risk zone and have a higher frequency of risk situations and incidents when moving cows to hoof trimming than to milking.	Larger proportions of moderately forceful and forceful interactions were used when moving cows to hoof trimming. A larger percentage of time was spent in the risk zone when moving to hoof trimming. Higher frequency of risk situations and incidents was observed when moving cows to hoof trimming.
Heart rate	There is a higher increase in cow heart rate when cows are being moved to hoof trimming rather than to milking. The handler's heart rate is higher when moving cows to hoof trimming than when moving them to milking.	Cow heart rate increased more when cows were being moved to hoof trimming. *Handler heart rate was higher when moving cows to milking.*
Stress and energy	The perceived stress levels are higher when moving cows to hoof trimming than when moving them to milking. A high stress level or low energy level is related to a high number of risk situations and incidents.	*There were no differences in perceived stress levels between moving to hoof trimming and to milking.* *Energy level was positively correlated with frequency of risk situations when moving cows to milking.* *No correlations were found between risk situations or incidents and stress and energy levels when moving cows to hoof trimming.*
Locus of control	Handlers with a lower safety locus of control score (*i.e.* externals) spend more time in the risk zone and have more observed risk situations and incidents.	*There were no differences in time spent in the risk zone or frequency of risk situations and incidents between internals and externals.* *No correlations were found between safety locus of control score and time in the risk zone, risk situations or incidents.*

	Hypothesis	Results
Job strain	Handlers with a higher job strain score have a higher perceived stress level and a lower energy level, which is related to a higher number of risk situations and incidents.	*No correlation was found between job strain and stress.* Job strain was negatively correlated with energy level when moving cows to hoof trimming. *No correlation was found between job strain and risk situations.* Job strain was positively correlated with frequency of incidents when moving cows to hoof trimming.
Attitude to risk	Handlers categorised as risk accepting spend more time in the risk zone and have a higher number of risk situations and incidents than those categorised as risk averse.	*Frequency of risk situations was higher for handlers categorised as risk averse than risk accepting.* *There were no differences in time spent in the risk zone or frequency of incidents between risk averse and risk accepting handlers.*
Attitude to cows	Handlers with a more negative attitude use more moderately forceful and forceful interactions, have cows with a higher heart rate and have more observed risk situations and incidents.	A negative correlation was found between positive attitude to cows and forceful interactions when moving cows to milking. A positive correlation was found between negative attitude to cows and cow heart rate when moving cows to milking. *No correlations were found between attitudes and frequency of risk situations and incidents.*

6.3.1 Handler behaviour

Risk situations and incidents were more frequent when moving cows to hoof trimming than to milking. When moving cows to milking there were no observed incidents, while risk situations were only observed on two farms. When moving cows to hoof trimming, risk situations were observed on all farms and incidents were observed on all farms except two. Furthermore, the percentage of time the handler spent in the risk zone was significantly higher when moving cows to hoof trimming than when moving them to milking. Larger proportions of gentle, moderately forceful and forceful interactions were used when moving cows to hoof trimming than when moving them to milking.

6.3.2 Stress

The handlers generally had a low perceived stress level and a high perceived energy level when moving cows to milking and to hoof trimming. There were no significant differences in perceived stress and energy levels between moving cows to milking and hoof trimming.

Cow heart rate increased significantly more from the base value when cows were being moved to hoof trimming than to milking. However, handler heart rate was higher when moving cows to milking. No correlations were found between handler or cow heart rate and the proportions of gentle, moderately forceful and forceful interactions.

Job strain was used as a measure of work stress generally, *i.e.* not related to the specific work tasks studied. Job strain ranged from 0.56 to 1.37, and was positively correlated with frequency of incidents at hoof trimming, as shown in *Figure 10*. No significant correlation was found between job strain and perceived stress and energy levels.

6.3.3 Attitudes

Safety locus of control and attitudes to risk

Safety locus of control score is a measure of an individual's beliefs about injury causation and whether one is in control of one's own safety. A high positive score indicates an internal safety locus of control, while a low negative score indicates an external locus of control. The safety locus of control score ranged from -7 to 3, where half of the handlers scored below zero and half scored above.

Attitude to risk was measured using a five-item questionnaire, with the respondents sorted into 'risk accepting' or 'risk averse' depending on the answers. Five handlers were found to be risk accepting and seven were found to be risk averse.

There were no differences between those categorised as externals and internals or those categorised as risk accepting and risk averse regarding handler-cow interactions, frequencies of risk situations and incidents, percentage of time spent in the risk zone and job strain. Furthermore, risk attitude score and safety locus of control score showed no significant correlations with age, experience, herd size, handler-cow interactions, job strain, time spent in the risk zone and incidents.

Attitudes to cows and working with cows

The results did not show any direct correlation between attitudes to cows and working with cows and frequency of risk situations and incidents. Furthermore, there was no clear overall association between interactions and attitudes, although there was a negative correlation between positive attitudes to cows and the use of forceful interactions when moving cows to milking. In addition, cow heart rate was positively correlated with the handler's negative attitude score to cows. No correlations between interactions or heart rates and attitudes were found when moving cows to hoof trimming.

6.3.4 Summary of correlations

Figures 9 and *10* illustrate the relationships found between variables in relation to risk situations when moving cows to milking and incidents when moving cows to hoof trimming, respectively.

When moving cows to milking, observed risk situations were only correlated with the perceived energy level of the handler (*Figure 9*). When moving cows to hoof trimming (*Figure 10*), frequency of incidents was correlated with job strain, cow heart rate and time spent in the risk zone. The time spent in the risk zone was positively correlated with job strain, age, and experience. A more detailed description of the correlations, as well as correlation coefficients and *P*-values, can be found in Paper III.

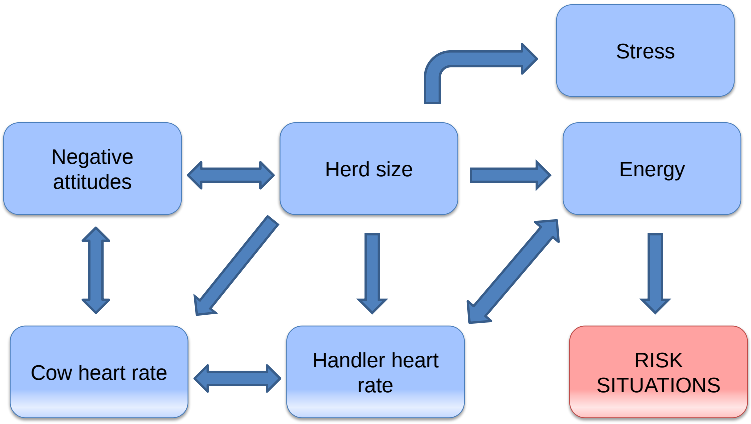

Figure 9. Positive correlations (arrows; $P < 0.05$) between variables related to risk situations per minute when moving cows to milking. Direction of arrows suggests causal relationship.

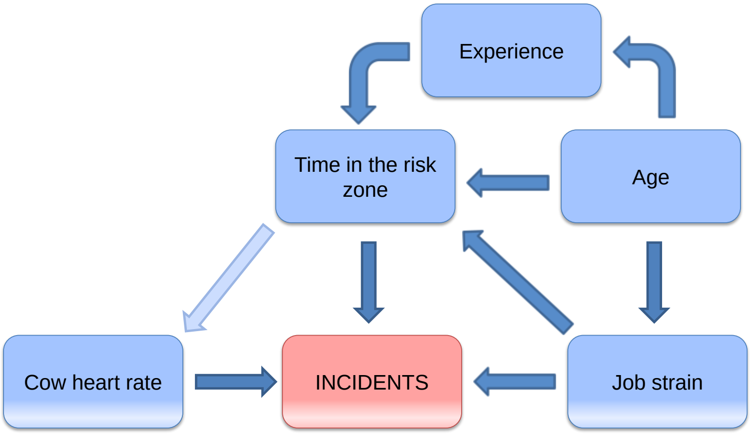

Figure 10. Positive correlations (solid arrows = $P < 0.05$; shaded arrow = $P < 0.10$) between variables related to incidents per minute when moving cows to hoof trimming. Direction of arrows suggests causal relationship.

6.4 Human-animal interactions (Paper IV)

Paper IV, which is associated with Paper III, studied the effects of the stressfulness of a situation on cow-handler interactions and handler safety by comparing moving of cows to routine milking (low stress) and to hoof trimming (high stress).

6.4.1 Cow-handler interactions

When moving cows to milking, a higher proportion of acoustic interactions and a lower proportion of visual interactions were used than when moving cows to hoof trimming. The only interaction that occurred with a significantly higher frequency when moving cows to milking was short-duration tactile interaction with an object using low force. All farms shared the routine of cleaning the cubicles at the same time as collecting cows to milking and of often using the hand-held manure scraper to direct the cows. The median value of the frequencies for talking with short duration and noise were higher at milking than hoof trimming, although the differences were not statistically significant.

More interactions per cow were used by the handler when cows were moved to hoof trimming than to milking. The tactile interactions without an object that were used more frequently during moving to hoof trimming were short-duration petting and long-duration contact using low force. The tactile interactions with an object that were used more frequently were of short duration with low force and long duration with moderate force. Tail twisting was also used more frequently when moving cows to hoof trimming than to milking. Waving was the visual interaction found to be used with a higher frequency when moving cows to hoof trimming. No significant differences were found for the frequencies of interactions categorised as acoustic, but there was a tendency ($P < 0.05$) for a higher frequency of loud talking for a long duration and of shouting at hoof trimming.

6.4.2 Cow behaviour

When being moved to hoof trimming, the cows showed a greater variety of different behaviours per cow than when being moved to milking, and they showed more behaviour indicative of averseness and fear, *i.e.* freezing, balking and resisting. Such behaviour was only rarely or never observed at milking. The behaviours with a higher frequency when cows were moved to milking were cow stopping but starting walking directly after contact by the handler and cow getting up from a lying position on request by the handler.

6.4.3 Incidents and risk situations

Paper III showed that the frequency of incidents and risk situations per minute was higher when cows were being moved to hoof trimming than to milking. The frequency of risk situations when moving cows to milking ranged from none to 0.05 per minute (median 0.00), while risk situations when moving cows to hoof trimming ranged from 0.6 to 1.7 per minute (median 1.0). No incidents were observed at milking, while the frequency of incidents ranged from none to 0.1 per minute (median 0.03) when cows were moved to hoof trimming. No events that resulted in injuries to the handler were observed within the study. In Paper IV, the association between incidents and handler-cow interactions when moving cows to hoof trimming were investigated.

A few correlations were found between handler interactions and incidents per cow and minute when moving cows to hoof trimming. Pulling on the neck strap or halter was positively correlated with the handler being head butted (r = 0.74, $P < 0.01$). Long-duration forceful tactile interaction with an object (*e.g.* a stick) was positively correlated with the handler being kicked (r = 0.76, $P <$ 0.01). Short-duration forceful tactile interaction with an object was positively correlated with the handler being pushed or run over by a resisting cow (r = 0.72, $P < 0.01$). The handler being run over/pushed by a resisting cow was also positively correlated with the handler talking with long duration to cows quietly or in a conversational tone (r = 0.83, $P < 0.001$). It is also worth noting that there was a tendency ($P < 0.05$) for a positive correlation between the handler being kicked and the frequency of loud talking with short duration (r = 0.64), loud talking with long duration (r = 0.69) and shouting (r = 0.58).

6.5 Handling facility design (Paper V)

Paper V is associated with Papers III and IV and studied the interaction between handler, cow and handling facility in order to identify associations between the design of the handling facility and handler safety. The moving of cows to milking represented a familiar environment for the cows, while moving them to hoof trimming represented an unfamiliar environment and an aversive procedure. The design of the handling facility may have a significant influence on the cows' behaviour, especially during aversive procedures, which consequently affects the ease of handling, handler safety and the stress levels for both the handler and the dairy cows. The aim in Paper V was not so much to compare the two situations as to study the associations within each context specifically.

6.5.1 Milking

The collection of cows for milking worked quite well on all farms, with only minor disruptions in cow flow. Four farms used a transfer alley to the waiting pen for milking, four farms had the waiting pen in direct connection with the cubicle area, and four farms used a section of the cubicle area as a waiting pen. One of the farms using the cubicle area as a waiting pen had a transfer alley between the waiting pen and the parlour, while the other three had the parlour in direct connection with the cubicle area. A more detailed description of handling facility characteristics at milking can be found in Paper V.

Handling facility characteristics identified for statistical analysis when cows were moved to milking were length of the transfer alley, size of the waiting pen (and if it was too small for all cows to be there at the same time), different floor levels, different flooring, other distractions (*i.e.* transfer alley passing other cow groups or calves), bottlenecks (*i.e.* narrowing of the passageway) and sharp (90º) bends. The most important correlations between these handling facility characteristics and handler-cow interactions, risk exposure of the handler, cow heart rate and cow behaviours when moving cows to milking are summarised below.

The farms with larger herd sizes used a transfer alley (range 14-50 m) to move cows to milking, and the length of the transfer alley was positively correlated with herd size (r = 0.67, P = 0.016). A common problem for the farms with larger herd sizes was that the waiting pen was too small for the number of cows, so some cows had to wait in the transfer alley. Furthermore, the transfer alley sometimes lacked escape routes for the handler. There was a tendency for a positive correlation between length of the transfer alley and time spent in the risk zone (r = 0.55, P = 0.065). One probable reason for this relationship is that it was not possible for the handler to move along the transfer alley without walking among the cows. The length of the transfer alley was positively correlated with the frequency of the cow behaviour stopping (type c), *i.e.* where the handler had to interact repeatedly to get the cow to start walking (r = 0.66, P = 0.019). There was also a tendency for a positive correlation between moderately forceful interactions and length of transfer alley (r = 0.53, P = 0.076). A reason for these correlations could be that the handler was interacting with the cows in the back of the herd, even though those cows could not walk forward because other cows at the front of the herd were blocking the way. Thus, the handler possibly increased the force of interactions instead of making the cows in the front of the herd move first.

Possible causes of interruptions in cow flow when moving cows to milking, as identified in the documentation of handling facilities, were high steps, narrow passages (bottlenecks), sharp bends, small waiting pens and the transfer alley passing calves or other cow groups (other distractions). However, none of these were found to be correlated with cow behaviours indicating interruptions in cow flow. There was a positive correlation between the proportions of visual interactions and different types of flooring along the way to milking (r = 0.62, P = 0.033), as well as risk situations and different types of flooring (r = 0.63, P = 0.028). Thus, this might be an indication of increased difficulty in moving the cows, even though no clear association to any specific cow behaviour could be found.

Cow heart rate was positively correlated with the presence of a bottleneck (narrow passage) on the way to milking (r = 0.60, P = 0.048). The farm with the highest cow heart rate increase of all farms studied had a very narrow entrance to the waiting pen for milking, and also had the largest herd size. The farm with the lowest cow heart rate increase, however, also had a narrow passage, namely the 14 m long transfer alley from the area used as waiting pen to the parlour. The low cow heart rate in this case may be explained by the fact that the bottleneck did not cause crowding, because cows were not driven through the alley all at once but were allowed to walk at their own pace and in smaller groups.

6.5.2 Hoof trimming

When moving cows to hoof trimming, one or a few cows at a time were collected from the group and moved into a smaller waiting pen from where a single-file alley of varying length (range 3-30 m) led to the trimming chute. Some farms did not use a waiting pen, but moved the cows straight into the single-file alley. Half the farms placed the trimming chute in a scrape/slatted floor alley in the cubicle area (*Figure 11*). Three farms used a transfer alley in connection with the cubicle area, and one of these had a stationary transfer alley specifically designed for hoof trimming and other treatments (*Figure 12*). Two farms used one side of the milking parlour as a transfer alley, with the trimming chute placed in connection with the return alley from the parlour. One farm had placed the trimming chute outdoors, on the way to pasture. A more detailed description of handling facility characteristics at hoof trimming can be found in Paper V.

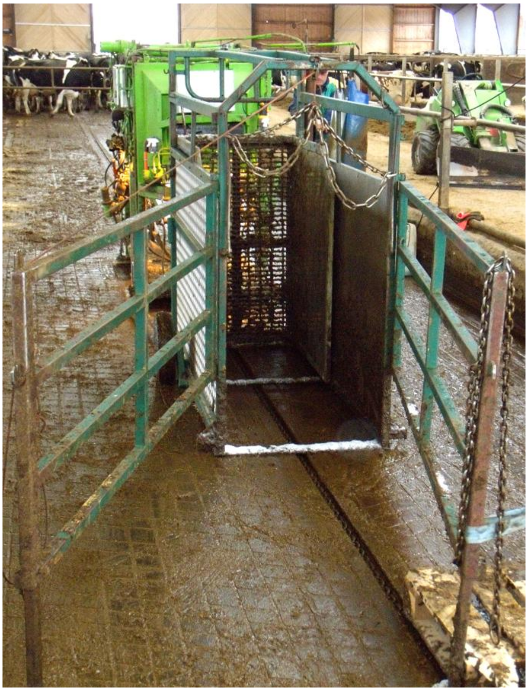

Figure 11. Mobile single-file alley and trimming chute placed in a scrape alley.

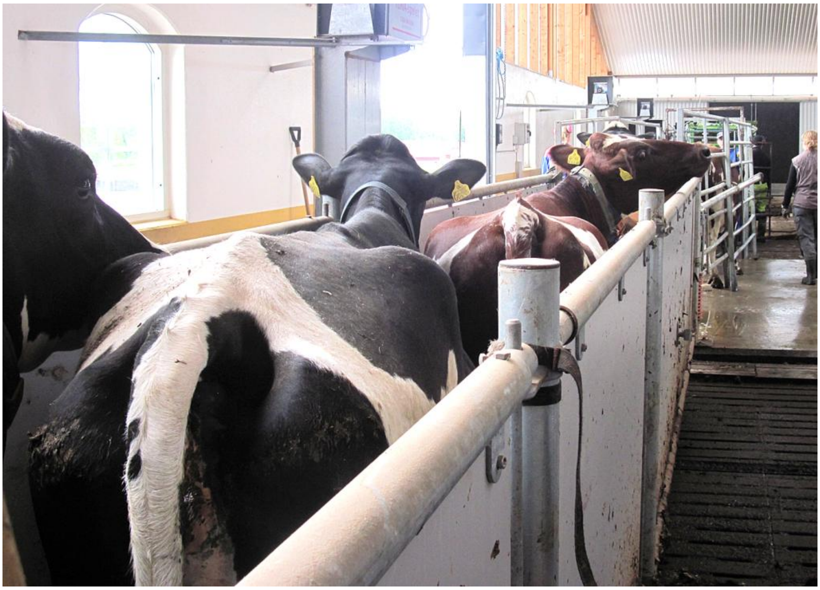

Figure 12. Stationary single-file transfer alley leading to the trimming chute. (Photo: Sofia Åström).

Handling facility characteristics identified for statistical analysis when cows were being moved to hoof trimming were length of the single-file transfer alley leading to the chute, use of a waiting pen before the alley, different floor levels, different flooring, sharp (90^0) bends and 'corners' (*i.e.* a place, usually a corner or cubicle, where cows were often seen standing or crowding to avoid the handler). The most important correlations found between handling facility characteristics when moving cows to hoof trimming and handler-cow interactions, risk exposure of the handler, cow heart rate and cow behaviours are summarised below.

On nine farms, the cows had to pass through a sharp bend on the way to the trimming chute. There was a positive correlation between balking (type c[3]) and cows having to move through a sharp (90º) bend on the way to the trimming chute (r = 0.64, P = 0.025). Furthermore, a positive correlation was found between a sharp bend and frequency of stopping (type c[4]) was found (r = 0.59, P = 0.046). The frequency of risk situations was significantly higher when the handling facility had a sharp bend than when there were no sharp bends (P < 0.05), which is most likely explained by the increased frequency of balking (type c[3]).

3. Cow stops balking only after contact by handler
4. Cow stops and does not start to walk again despite contact by handler

The seven farms that used a waiting pen for collecting cows to hoof trimming had a higher frequency of resisting (types a[5] and c[6]) than farms that did not use a waiting pen (P < 0.05). In the waiting pen, cows were often observed attempting to go back the way they came, while the trimming chute was situated in the opposite direction, creating a lot of resistance by the cows. A negative correlation was found between use of a waiting pen and frequency of stopping, of both type b[7] (r = -0.81, P = 0.001) and type c[4] (r = -0.86, P < 0.001). The frequency of incidents and risk situations was significantly higher when the farm used a waiting pen compared with when no waiting pen was used (P < 0.05). The cows could not be moved from the waiting pen to the transfer alley without the handler being inside the waiting pen, which increased the exposure to the animals. This in combination with cows being stressed and showing a high frequency of resistance probably caused the high rate of incidents.

Once the cows were in the single-file transfer alley there was no possibility for them to turn around, so farms with long transfer alleys (20-30 m) and no waiting pen consequently had low frequencies of resistance behaviours. This is also the probable explanation for why there was a negative correlation between resisting type b[8] (r = -0.74, P = 0.005) and type c[6] (r = -0.67, P = 0.017), and length of the transfer alley. Instead of resisting, cows avoided going forward mainly by stopping, as length of alley was positively correlated with cows stopping (type b[7]; r = 0.85, P = 0.001) and stopping (type c[4]; r = 0.80, P = 0.002). Thus, a long transfer alley does not necessarily mean that it is easier to move the cows, as cows show different avoidance behaviours depending on what the facility design permits them to perform.

No significant correlations were found between handling facility characteristics and time spent in the risk zone. However, the farm with the stationary transfer alley (and the longest alley) had the lowest percentage of time spent in the risk zone and even though the frequency of risk situations was relatively high, no incidents were observed. The cows could be handled from outside the alley, thereby always keeping a protective barrier between cows and handler.

The only correlation found between cow heart rate and handling facility characteristics was a negative correlation with the length of the transfer alley (r = -0.71, P = 0.020). The farm with the longest transfer alley of all farms

5. Cow tries to pass between handler and wall/interior/other cow, but does not complete
6. Cow passes between handler and wall/interior/other cow and hits the handler
7. Cow stops but starts to walk again directly after contact by handler
8. Cow passes between handler and wall/interior/other cow, no contact with handler

studied had the lowest mean heart rate increase of all farms. This finding may be related to the negative correlation between frequency of resisting and length of alley, as mentioned above, since physical activity affects heart rate. Supporting this is the fact that the frequencies of other behaviours indicating fear, *e.g.* freezing (type c[9]) and balking (type b[10] and c[3]), were among the highest on the two farms with the longest transfer alleys. However to be certain of the interpretation, some complementary variables, *e.g.* stress hormones, would need to be measured.

There were problems with slippery floors and cows were observed slipping on all farms when being moved to hoof trimming. All farms except two had a concrete floor in the waiting pen and transfer alley. The risk of slipping increases when the cows are resisting and struggling to get away from the situation, which was probably the reason for the tendency for a positive correlation between use of a waiting pen and slipping (type b[11]) and the tendency for a negative correlation between length of transfer alley and slipping (type b[11]).

6.5.3 Questionnaire and interviews

Based on the findings from the behavioural observations, a clear difference between the handlers' thoughts on handling facility design between milking and hoof trimming would have been expected. For example, higher agreement with the statements "*The cows often slip during handling*" and "*The design of the transfer alley obstructs safe handling and smooth movement of the cows*" was expected at hoof trimming. However, no significant differences were found and the handlers generally believed the handling facilities for both milking and hoof trimming were well designed, although they did reflect on some shortcomings in design and possible improvements.

Most handlers thought the design of their transfer alley was good from the cow's perspective, which is not really in keeping with the observations made directly on the farms, especially during the hoof trimming procedure. Some handlers seemed to be unaware or underestimated how much the cows were slipping during handling, as the frequency of observed slips by the cows during handling was not found to be correlated with the handler's experience of cows slipping during handling. Furthermore, there were some discrepancies between the answers the handlers gave in the questionnaire and what they said during the interviews. For example, only two handlers agreed or partly agreed with the

9. Cow freezes and does not start to walk again despite contact by handler
10. Cow stops balking voluntarily or because of interior/other cows
11. One or both knees or hooks in contact with floor

statement that the design of the transfer alley obstructs safe handling and smooth movement of the cows while moving them to hoof trimming, even though all handlers said they had noticed specific places where the cows often stopped and their explanations were commonly related to facility characteristics. Only five of the handlers said they felt they were exposed to risk when moving cows to hoof trimming, even though incidents were observed on nearly all farms, and some of the handlers also seemed to overestimate their possibilities to escape from the cows if needed.

7 Discussion

In this section, aspects of methodology and the main results in the thesis are discussed.

7.1 Methodological considerations

Both quantitative and qualitative methods were used in Papers II-V. The combination of different methods and their systematic application to successively deepen the understanding of the research topic strengthens the validity of the results presented in this thesis. Furthermore, the interdisciplinary approach is a strong point and essential for being able to grasp the complexity of the subject.

7.1.1 Sampling methods

Sampling methods differ for different types of research. Thus, Paper II, with a qualitative approach, and Papers III-V, with mainly a quantitative approach, differed in both the intent and the method of sampling.

In Paper II, purposive sampling (*i.e.* sample selection according to relevance to the study) was used to ensure that the data provided a range of perspectives to deepen the understanding. To maximise variation across the sample, we aimed for a heterogeneous sample in terms of age, gender, farm location, herd size and milking system. Random sampling is considered inappropriate for qualitative research, as key informants may be missed through the randomisation process (Endacott & Botti, 2007). Furthermore, in qualitative research it is assumed that the findings are context-specific and for that reason no attempt is made to generalise the findings (Petty *et al.*, 2012).

In quantitative research, the intent of sampling is to estimate or predict outcomes about a population based on the sample of that population. Therefore, it is important that the sample is representative of the population. To reduce the risk of selection bias, random sampling is preferred (Endacott & Botti, 2007). However, in Papers III-V random sampling was not practically achievable, as is common in field studies. Instead, a combination of purposive and convenience sampling was used, where location of the farm and time of the next hoof trimming influenced the selection. Non-random sampling may be a threat to the external validity, or generalisability, of the results (Cook & Campbell, 1979).

In the qualitative study and in the combined qualitative-quantitative study, dairy farms were identified through agricultural advisors (and hoof trimmers), which may have caused a sampling bias. As pointed out in Paper II, it is possible that the advisors suggested farmers they believed were willing to share their experiences. Since participation was voluntary, it is also a possibility that those farmers who agreed to participate were more concerned about safety. This is especially relevant for Papers III-V, where 28 farmers contacted did not fit the criteria in some way or declined to participate.

Women were generally under-represented in the studies, which should be kept in mind when interpreting the results. Previous studies have indicated that there may be a gender-specific difference in the perceptions and attitudes related to injury risks and safety in agriculture (Sorensen, 2009; Stave *et al.*, 2009; Dewar, 1996), even though research in this field is sparse (McCoy *et al.*, 2002). However, the actual gender representation in Swedish dairy farming is skewed, with only 6% of dairy farm businesses being owned by women (SJV, 2011a).

It is also worth noting that all participants in the studies were Swedish, even though an increasing number of workers in modern Swedish dairy farming, as in most EU countries today, are migrant workers (Schenker & Gunderson, 2013; SWEA, 2012). Migrant workers were not represented at all in this thesis and thus specific safety issues relating to their work situation, such as language barriers and cultural clashes, were not included.

7.1.2 Sample size

The sample size in Paper II was considered appropriate for the study design. An exploratory design allows the use of small samples that are chosen through a deliberative process (Brink & Wood, 1998, p. 320). All twelve interviews were conducted before the analysis began. During the analysis process, it was concluded that saturation was reached. Saturation means that no new information was gained during the last interviews, which is a confirmation of an adequate sample size (Endacott & Botti, 2007).

The relatively small sample size in Papers III-V is a limitation, especially when considering that the data were collected on commercial farms, where every farm is unique and the variance between farms may be fairly large. A larger sample size would have increased the validity of the study. Small sample size increases the risk of Type II errors, *i.e.* failure to detect a difference when a difference truly exists (Burmeister & Aitken, 2012; Endacott & Botti, 2007). Furthermore, the accuracy of estimates of correlation coefficients is low, because the magnitude of a correlation is rather unstable in small samples (Schönbrodt & Perugini, 2013). Thus, the results should be interpreted with some caution, even though several of the results found in Papers II-V are supported by findings in the literature.

7.1.3 Qualitative research design (Paper II)

The inductive process of qualitative research is well suited for achieving insight into individuals' thoughts, experiences and understanding of the issue in question (Creswell, 2007). The focus of Paper II was to get a complex and detailed understanding of the participants' perspective and thus a qualitative approach was appropriate.

How the interviews are performed is of paramount importance (Brink & Wood, 1998, p. 323). The interviewer's role is to guide the respondent through the topics of interest, but also to allow the respondent some freedom to cover the areas they find relevant. The interviewer needs to be attendant throughout the interview and follow up on any new tracks or loose ends. The interview procedure was refined through pilot testing, with valuable guidance and support by a researcher who was very familiar with the method. Emphasis was placed on establishing a relaxed atmosphere, where the participants could feel comfortable during interviews. The participants were very open in sharing their thoughts and experiences.

The issue of failure to recall injuries is also important to consider. This matter became apparent in Paper II, where most of the farmers interviewed initially failed to recall any injuries, while recalling several injuries after going into greater detail about their work. This highlights the importance of not rushing through the interview and of allowing the respondent to pursue lines of reasoning at the periphery of the topic of interest. It is also an indication that the use of questionnaires would most probably have resulted in a strong underestimation of the injury experiences.

The way in which qualitative research is evaluated is a contentious issue (Petty *et al.*, 2012), with some arguing that the same criteria as for quantitative research should be used, while others argue that different criteria are more relevant. Traditionally, evaluations of studies have centred on assessment of reliability and validity (Cook & Campbell, 1979). Several alternative terms and criteria have been suggested (Long & Johnson, 2000) specifically for qualitative research, but in this thesis the evaluation was based on the traditional terms. In Paper II, the specific criterion for the quality of qualitative research, namely credibility, was briefly discussed. Credibility corresponds to internal validity (Long & Johnson, 2000).

One weakness of qualitative research is its lack of replicability (Brink & Wood, 1998, p. 318). All researchers are selective in what they observe and what they report, so a certain effect of researcher bias will always be present. Furthermore, people continually change their beliefs and perceptions, which means that the same individual will not give the exact same answers if asked the same questions on another occasion. Thus, the uniqueness of human beings means that the research findings are unlikely to be replicated (Hayes, 2000), which implies that reliability is weak. Efforts were made to make the decision trail transparent in the publication and provide rich excerpts from the transcripts, allowing readers to compare the results with their own conclusions made from the information.

To ensure rigour in Paper II, peer debriefing was pursued on a continuous basis throughout the whole study. The analysis was conducted independently by two researchers and the analysis and conclusions were then discussed to ensure congruence between data and results. Furthermore, the findings were related to previous research in the field, both to support findings and to identify discrepancies. These measures strengthen the validity of the study. Respondent validation, *i.e.* checking the findings with the respondents, was not conducted, but could have been a way to further enhance validity.

7.1.4 Methods included in Papers III-V

The variables measured in Paper III-V were identified based on results from Paper II and previous research literature. The purpose of the investigations was to describe the relationships between variables and determine how they related to safety. Data collection was conducted on commercial dairy farms, which brought both weaknesses and strengths to the study. It allowed us to make our observations in a natural setting with minimum interference and no manipulation. However, such field studies in natural settings provide very low control over variables, so confounding bias may be a risk (Brink & Wood, 1998). Confounding occurs when a third variable interferes and distorts the association being studied between two other variables, because of a strong relationship with both of the other variables (Agresti & Franklin, 2013, p. 137). Confounding factors measured and included in the analysis were gender, age, experience of working with dairy cows, and herd size. There may still have been latent variables, not measured or controlled for, affecting the results.

The various behaviours to be observed were identified based on previous studies of cattle handling on dairy farms and slaughterhouses (Wiberg, 2012; Hemsworth *et al.*, 2011; Waiblinger *et al.*, 2002). Emphasis was placed on development of the inventory of human and cow behaviours and their definitions, and pilot testing of the observational method on farms before the true studies. This was an important step to ensure that the inventory of behaviours was complete and that each behaviour was distinct and well-defined, which strengthened the reliability of the study (Ostrov & Hart, 2012; Lehner, 1996, p. 212-214). The observations of handlers and cows were conducted by the same individuals on each farm, so inter-observer reliability was not an issue. No specific measures were taken to ensure intra-observer (*i.e.* within-observer) reliability across time or within a session.

A threat to validity in observational studies is bias caused by participant reactivity, which occurs when the individuals under study alter their behaviour due to the presence or influence of the observer (Ostrov & Hart, 2012). The consequence will be that the observed behaviour does not provide a true representation of the construct being measured. In the present study, the researchers' presence may have influenced the handlers to act in the way that they assumed was expected of them, which could have led *e.g.* to a more animal-friendly behaviour. It is likely that the researchers' presence would have affected each handler differently, with some being more affected than others. Furthermore, the cows may have reacted to our presence even though we strove for minimum disturbance by strategic stationing and remaining unobtrusive.

We only studied the cows being moved to milking and hoof trimming once on each farm, so we only obtained a single momentum measure in each setting and thus do not know how the data vary within-farm. Waiblinger *et al.* (2002) concluded that observation of one milking per farm (including collection of cows to milking and the actual milking) was sufficient due to a previously found high correlation (r = 0.84) in handler behaviour between two successive evening milkings. However, the variability in behaviour is probably higher during hoof trimming. To be aware of any abnormalities experienced by the handler, after each observation session the handler was asked if the handling was representative of an average milking/hoof trimming.

The handler's attitudes, perceived stress and energy level, job strain and thoughts on facility design were measured using questionnaires. The use of a questionnaire ensures that the questions are asked in exactly the same way of all participants. Questionnaires are dependent on self-reporting and do not give the researcher the opportunity to check the truthfulness of the answers. The Safety Locus of Control Scale and the Stress-Energy Questionnaire have been validated previously (Kjellberg & Wadman, 2002; Theorell *et al.*, 1988; Karasek, 1979). However, since the Safety Locus of Control Scale was initially designed for industrial employees, it was modified to be applicable to agriculture, which may have affected the validity (Glasscock *et al.*, 2006). The questionnaire on attitudes to cows and working with cows has been used in several studies and has repeatedly been shown to predict handler behaviour towards the cows. It was somewhat modified to fit the aim of Paper III in this thesis. The risk attitude questionnaire has only been used in a couple of previous studies, and its validity can be questioned, as discussed below. The questionnaire on handling facilities was designed for this study, and it should not be considered as assessing the concept of the handlers' view on facility design completely, but rather as covering some selected key questions. The questionnaire was complemented by a short structured interview, where the handler was allowed to explain more deeply and develop some of the answers given in the questionnaire. Thus, interviews were used instead of open-ended questions in the questionnaire, as we believed that this would increase the chance of getting a thorough and complete answer.

7.2 Discussion of results

The findings from Papers II-V are discussed below in relation to previous findings in the literature.

7.2.1 Risk perception and normalisation of risk

Understanding how farmers themselves assess their occupational risk and decide how to carry out tasks is essential for developing effective interventions. Inadequate awareness of injury risks among the farmers has been suggested as a reason for high injury rates, and consequently one prevention strategy is to increase awareness (DeRoo & Rautiainen, 2000). However, qualitative studies, including Paper II, often come to a different conclusion regarding the farmers' awareness of hazards (Lindahl *et al.*, 2012; Kallioniemi *et al.*, 2011; Green, 1999). The responses given in the interviews in Paper II indicated that Swedish dairy farmers are aware of the dangers of working with cattle. The farmers were able to identify specific hazards in different work activities and also what preventive measures to take to increase safety, although they also pointed out that it is impossible to eliminate all risks due to the unpredictability of the animals. However, while safety may be acknowledged by farmers as an important and relevant issue, in practice safety is often forgotten or not prioritised. Elkind (1993) found that many farmers perceive farming as dangerous, but that attitudes about the importance of the hazards with respect to their own life differed from knowledge of the hazards. Elkind (1993) also found that farmers who regularly take many safety precautions do not say that farming is any more or less dangerous than those who do nothing to protect their families and workers. Murphy (2003, p. 27-29) has described this as the farm safety-risk paradox, which refers to the often reported discrepancy between farmers' safety knowledge, values and practices.

A study by van Winsen *et al.* (2011) stated that farmers will make use of heuristics (*i.e.* rules of thumb) to form a perception of the risk, because it is too complicated to objectively calculate due to uncertainty. These heuristics are based on *e.g.* previous experience, personality, beliefs and culture (van Winsen *et al.*, 2011). People are also selective in the evidence they will accept and are more likely to see less risk in cases where they see benefits from the activity (Siegrist & Cvetkovich, 2000; Alhakami & Slovic, 1994). This is in accordance with the conclusion in Paper II that farmers are willing to take calculated risks to obtain benefits such as saving money or time. Another factor affecting risk perception is that people tend to think that events are more probable if they can recall an incident of its occurrence (Tversky & Kahneman, 1974).

Even though most of the farmers interviewed in Paper II had experience of animal-related injuries and near-misses, they seemed to have difficulty recalling them at first, unless the injury was very severe. The farmers took the view that injuries are a part of dairy farming and that minor injuries are not even worth mentioning. When near-misses and minor injuries are a part of everyday life on the farm, the farmer might cease to be emotionally affected by these events. The events then become normalised, leading to a future underestimation of the risks. An interesting consideration in relation to this issue is that some farmers in Paper II believed that experiencing injuries was necessary in order to avoid injuries in the future. Conversely, findings in our study indicate that it might have the opposite effect unless the farmer manages to stay aware, take notice and learn from these experiences. Normalisation of risk through repeated exposure with positive outcomes was also found in a qualitative study of risk perceptions in relation to tractor retrofitting among a group of farmers in New York (Sorensen *et al.*, 2008). Thus, habituation to risk seems not only to be related to animal handling in dairy farming, but a general phenomenon in the agricultural sector.

These phenomena, the habituation to risk and the farm safety-risk paradox, constitute a challenge to safety research and are important to consider when designing injury prevention programmes and interventions. The results presented in this thesis also highlight the strength of combining qualitative and quantitative research methods to reach a more complete understanding.

Furthermore, increased knowledge on how to make farmers acknowledge their personal susceptibility to injuries and how different factors interact to create a mismatch between what farmers say and what they do would be beneficial for the prevention of animal-related injuries and most likely also for the agricultural sector as a whole.

7.2.2 Stress

Stress is related to behavioural changes and there is most likely a correlation between physical or psychosocial levels of stress and behaviours that lead to agricultural injuries (Burns & Sullivan, 2000). Stress has been reported to be a contributing factor to injury risk in agriculture (Rautiainen *et al.*, 2004), while Glasscock *et al.* (2006) concluded that there is a correlation between measurements of both stressors and stress symptoms and occupational injuries in agriculture in general. Previously, interviews with focus groups of practising farmers in eastern Washington found that they thought stress was the primary cause of unsafe and unhealthy behaviour (Elkind & Cody-Salter, 1994). Similar results were found in Paper II, where the dairy farmers interviewed believed stress to be a major risk factor for injury.

Stress may be especially relevant in relation to animal handling because it can have an important effect on the behaviour and reaction of the animals. Many of the farmers interviewed had experienced their own stress being transmitted to the cows during handling. Such a connection between human and animal stress reactions has been shown in human-horse interactions (Keeling *et al.*, 2009). Boivin *et al.* (2001) describes the phenomenon as a double mirror where the handlers stress can be transmitted to the animal and the animal's stress can be similarly transmitted to the handler, thereby creating a vicious cycle.

Studies on stress in relation to injury risk during animal handling are limited. In a case-control study aiming to assess risk factors for animal-related injury among large-livestock farmers, stress was not found to be significantly associated with animal-related injury (Sprince *et al.*, 2003). In that study, stress was measured using a questionnaire which assessed a person's perceived stress over the previous month. However, in Paper II the farmers attributed the increased injury risks to particularly acute stressful situations rather than to more general overall stress, which may explain why Sprince *et al.* (2003) failed to find an association.

In Paper III, stress during the handling of cows to milking and to hoof trimming was measured in three ways, by the Karasek job strain model (Karasek, 1979), the Stress-Energy model (Kjellberg & Iwanowski, 1989) and heart rate measurements. The Stress-Energy model was used to measure the handlers' subjective stress level during the specific tasks of moving the cows, while the job strain model was used to relate to the work situation more generally. Both measures were contemporary, *i.e.* measured the handler's perceived stress at that specific moment, but job strain is likely to be more persistent over time, as it links to the structure of the job, while the Stress-Energy score measures a person's mood, which can change quickly.

Job strain was found to be positively correlated with observed incidents with physical contact between handler and cow that could have resulted in an injury, *e.g.* head butts and kicks, when moving cows to hoof trimming. Job strain in relation to injury risks in agriculture is an interesting issue which to our knowledge has not been studied previously in relation to animal handling. Since the causal relationship is not clear, future studies should aim at confirming causality between job strain and animal-related injuries (and other agricultural injuries) and at identifying the sources of job strain in dairy farming.

The results showed no difference in perceived stress or energy levels when moving cows to milking and to hoof trimming, and in general stress levels were low and energy levels were high. Thus, the effects of an acute stress related to a specific work task on injury risks could not be identified. It is interesting to note, however, that some handlers stated that they felt stressed during the observed handling, but the stress level according to the Stress-Energy model was below the neutral value (neither stressed nor calm). This may be an indication that the neutral value is actually lower for the agricultural population compared with the populations used for identifying the neutral values (Kjellberg & Iwanowski, 1989), or it may just show that the true neutral varies between individuals. It is also worth noting that a positive correlation was found between herd size and handlers' perceived stress and energy levels, independent of work task. Since there is a trend towards larger herd size not just in Sweden but in most countries (Douphrate *et al.*, 2013), the effects of this on occupational safety and health should be a high priority area in future research.

Our initial hypothesis was that handler heart rate would be higher during moving cows to hoof trimming than to milking because of stress, but since the perceived stress levels did not differ, no effects on heart rate could be shown. In fact, the results showed the opposite, *i.e.* handler heart rate was higher when moving cows to milking. The reason for this was probably that while moving cows to milking, the handlers cleaned the cubicles at the same time. Thus, the raised heart rate was not an indication of stress, but a consequence of physical activity. Moreover, moving cows to milking was a relatively short and intense activity, while moving cows to hoof trimming had a lower intensity over a longer period and involved lots of waiting time.

7.2.3 Safety locus of control

One important aspect, especially when discussing injury prevention, is farmers' perception of whether or not they are in control of their work environment, *i.e.* their locus of control. Locus of control is an important factor in relation to injury prevention, since it is correlated with beliefs regarding the effectiveness of safety precautions and the usefulness of expert advice (Elkind, 2007). The two main views on the ability to prevent animal-related injuries found in Paper II were consistent with the internal and external loci of control. The farmers generally expressed a more or less strong internal locus of control, referring to their own actions as a major cause of injuries and claiming that most injuries are preventable. However, at the same time the farmers seemed to feel some lack of control during animal handling, mainly due to the unpredictability of the animals' behaviour, in some cases with a trace of fatalism. The hypothesis that handlers with an internal locus of control would be associated with a lower level of risk exposure was therefore tested in Paper III, using the Safety Locus of Control Scale (Jones & Wuebker, 1985).

The results in Paper III, did not support this hypothesis, in line with Glasscock *et al.* (2006), although previous studies have consistently shown that the Safety Locus of Control Scale is able to measure safety consciousness and can differentiate between groups with varying injury histories in employees (Jones & Wuebker, 1993; Wuebker, 1986; Jones & Wuebker, 1985). However, the original questionnaire was developed for industrial employees and was later modified by Glasscock *et al*. (2006) to suit farmer populations, which may have affected the validity of the measure, as also pointed out by those authors. Furthermore, the previous studies related the results to injury histories, while in Paper III they were related to a momentary measure of the risk exposure during two specific work tasks involving animal handling. Thus, the findings may not be representative of the person's risk behaviour over a longer period, in other handling situations or during work tasks not involving animals, and do not give any indication of the person's injury history.

Paper III showed a negative correlation between Safety Locus of Control Score and the handler's perceived stress level at both milking and hoof trimming. This is in line with Elkind (2007), who stated that those with an external locus of control often feel that they lack control, which is a condition often related to stress. In addition, the handlers categorised as internals in Paper III were found to have a more positive attitude to cows and a belief that cows are less fearful compared with those categorised as externals, which could possibly also be explained by the higher feeling of control. Based on these results, safety locus of control may be indirectly involved in the safety specifically related to animal handling. However, additional studies are needed to confirm these findings.

7.2.4 Risk proneness and attitudes to risk

The farmers interviewed in Paper II believed that some people are risk-takers by nature. A meta-analysis of studies that used a sample of the general population found that there were more individuals with repetitive injuries than would be expected by chance (Visser *et al.*, 2007), possibly indicating that injury proneness as a personality feature does exist. Such clustering of injuries has been reported in agricultural populations too (Karttunen & Rautiainen, 2013b), but it is difficult to tell whether this clustering is due to personal risk factors or a higher exposure to risk independent of personal factors.

Another feature that can be related to increased injury rates is a person's risk attitude. People have different risk attitudes and this causes them to act differently in relation to a perceived risk, *i.e.* risk attitude partly influences risk behaviour (van Winsen *et al.*, 2011). Risk attitudes lie on a continuous scale between the two extremes risk accepting (or risk seeking) and risk averse. In Paper III, a risk attitude questionnaire (Sprince *et al.*, 2003) was used to differentiate between handlers who were risk accepting and handlers who were risk averse. The expected outcome was that those who had a high attitude score (*i.e.* risk accepting) would have a higher level of risk-taking when handling the cows. However, the results showed that the handlers categorised as risk averse actually encountered more risk situations during hoof trimming than those categorised as risk accepting. This finding was unexpected, although in keeping with Sprince *et al.* (2003), who in a case-control study did not find support for the hypothesis that attitude to risk is associated with animal-related injuries.

One possible explanation for the contradictory results found in Paper III is that the questionnaire used may not have been able to actually differentiate between risk accepting and risk averse. One could argue that one or two of the statements used (*e.g.* "*Farming is more dangerous than jobs in industry or manufacturing*") relate more to the person's risk perception than to risk attitudes. Although risk perception is a very important determinant for risk attitude (van Winsen *et al.*, 2011), it may be wrong to relate an agreement to this statement as contributory to a risk accepting attitude. Furthermore, we do not know whether the group disagreeing with the statement that they encounter a number of close calls during farm work actually encounter fewer close calls than those who agreed with the statement. Research has also demonstrated that risk attitudes are not necessarily stable or homogeneous across hazard types (Rohrmann, 2008; Weber *et al.*, 2002). Thus a questionnaire designed specifically for measuring risk attitudes in relation to cattle handling would have been more relevant.

In conclusion, risk attitude did not serve as a good indicator of injury risks during the handling of cows. This supports the views of Elkind (1993) and Murphy (1981), who question the impact of safety attitudes on behaviour. Nevertheless, it should be borne in mind that the studies included in this thesis only comprised a momentary measure of the risks taken by a person and may not be representative of that person's risk behaviour over a longer period or other handling situations. Furthermore, the validity of the measure could be questioned.

7.2.5 Moving dairy cattle - identified risk factors

The handling of dairy cattle was studied in two contexts, during collection and moving cows to milking and to hoof trimming. In Paper II, moving cows was a work task the farmers believed to be related to an increased injury risk, as has also been found in studies analysing injury data (Erkal *et al.*, 2008; Rasmussen *et al.*, 2000). The farmers also reported that activities that disrupt the daily routine, *e.g.* hoof trimming, can be stressful to the cows and make them more hazardous to handle. By observing these two handling situations, we were able to study how an aversive situation affected handler and cow behaviour and injury exposure to the handler. Furthermore, we were able to look for associations between injury risks and stress, attitudes, handler-cow interactions, cow behaviour and handling facility design. Even though the causal relationships are not clear, the discussion below focuses on how these associations can be explained based on knowledge from previous research.

Risk exposure during milking and hoof trimming

The injury risk (*i.e.* time spent in the risk zone and frequency of risk situations and incidents) to which the handler was exposed during handling was much higher when moving cows to the more averse hoof trimming procedure than to routine milking. Moving cows to milking involved relatively little time spent in the risk zone, no incidents and almost no risk situations. When moving cows to hoof trimming, the average frequency of incidents (physical contact between handler and cow that could have resulted in injury, *e.g.* head butts, kicks) observed per minute corresponded to a total number of 14 incidents in just one work day, assuming the handler works a full eight-hour day moving cows to hoof trimming. The handler with the highest frequency of observed incidents (0.1 per minute) when moving cows to hoof trimming would have almost 50 incidents in one day. Incidents were correlated with time spent in the risk zone, with the percentage of time spent in the risk zone being almost twice as high when moving cows to hoof trimming, making it a contributory cause to the high rate of incidents. In light of these findings, it is not surprising that the statistics show such high injury rates related to animal handling in dairy farming. Furthermore, when cows were moved to hoof trimming the handlers were often seen taking unnecessary risks when handling the cows. Such risk behaviours may result in an injury that could very easily have been prevented by the handler being better positioned during handling, by a better understanding of the cows' behaviour and responses and by better handling facility design.

The relatively low injury risks observed when cows were being moved to milking and the significant increase in injury risks when cows were being moved to hoof trimming supports the relevance of using these two situations to represent two levels of injury exposure to the handler, despite the fact that no difference in the handlers' perceived stress levels could be found.

Fearfulness in dairy cattle

Fearful and agitated animals are believed to be a major cause of animal handling injuries (Grandin, 1999). Dairy cattle, originating from prey-animals, have a capacity for fear which alters their behavioural responses to stimuli (MacKay *et al.*, 2014). Fear is a powerful aversive, emotional state (Boissy, 1995), and fear-related reactions in farm animals include stress responses, with diverse physiological and behavioural changes. Behavioural responses to aversive events vary and can even be contradictory, from active defence (attack, threat) to active avoidance (flight, escape) and immobility or movement inhibition (freezing) (Boissy, 1995). Other responses considered as indicators of fear include vocalisation, defecation, urination and increased heart rate and stress hormones (Boissy, 1995; Davis, 1992).

Humans can evoke fear in animals, and aversive handling in particular has been shown to increase cows' fear of humans (Rushen *et al.*, 1999; Munksgaard *et al.*, 1997). In animal welfare science, researchers have focused on understanding the factors that induce fear in farm animals in order to assess the human-animal relationship and improve animal welfare. Hemsworth *et al.* (2000) found a relationship between the handler's attitudes and behaviour and fear in dairy cows. Several studies have found that restless behaviour (flinch/step/kick responses) of cows during milking correlated positively with negative tactile or loud, harsh vocal interactions (Waiblinger *et al.*, 2002; Breuer *et al.*, 2000; Hemsworth *et al.*, 2000). Previous studies have also shown that rough and aversive handling of dairy cows can reduce milk yield

(Hemsworth *et al.*, 2002; Breuer *et al.*, 2000). Furthermore, poor handling during movement is thought to be a contributor to lameness (Breuer *et al.*, 1997; Hemsworth *et al.*, 1995; Chesterton *et al.*, 1989). Thus, aversive handling is not just a safety issue to the handler, but also has a negative impact on animal welfare, health and productivity.

Routine management procedures, *e.g.* dehorning, insemination, hoof trimming, herding and transportation, can elicit fear-related responses (Forkman *et al.*, 2007; Waiblinger *et al.*, 2004; Lewis & Hurnik, 1998). A novel situation can be a strong stressor and even if dairy cows are generally tranquil and docile, when situations occur that they perceive or remember as aversive they may become fearful and agitated and thereby hazardous to handle (Grandin, 1984). Lewis and Hurnik (1998) found that a new experience to a cow, generating fear, may be as aversive as a painful experience. Furthermore, they showed that cows that had painful hoof trims (on injured or diseased feet) were more reluctant to re-enter a headgate than cows which had experienced a normal hoof trim.

In this thesis, moving cows to hoof trimming was chosen to represent a procedure that could be aversive to the cows and could evoke fear-responses, creating a more hazardous handling situation. As expected, the results showed that cow heart rate was higher during moving to hoof trimming than to milking, possibly indicating a higher level of fear/stress at hoof trimming. One could argue that the higher heart rate at hoof trimming could be explained by increased physical activity. However, the changes in cow behaviour related to hoof trimming, where more fear responses were shown (*i.e.* resistance, balking, freezing), supported the assumed higher stress load at hoof trimming.

There was a wide variation in heart rate between cows, indicating individual differences in how the procedure was perceived by the cows. A wide difference in ease of handling between individual cows within farms was also evident in our personal notes from the field observations. Probable explanations are genetic differences between cows (Boissy *et al.*, 2005) and previous experiences (Lewis & Hurnik, 1998). As temperament is a heritable trait (reviewed by Boissy *et al.*, 2005; Dickson *et al.*, 1970), breeding is a good way to improve the herd in this respect in the long term by selecting bulls with a good disposition and culling bad-tempered cows. Furthermore, since aversive procedures are impossible to avoid completely in modern dairy production, there is a need to make these procedures as less unpleasant as possible for the cows.

Our initial hypothesis was that the use of forceful interactions when handling the cows would increase cow heart rate due to raised stress and fear levels, but we failed to find correlations between the frequency of moderately forceful or forceful interactions by the handler and cow heart rate. One explanation could be that cow heart rate and interactions were measured on herd level, which means that we were unable to relate the heart rate of individual cows directly to the interactions that specific cow experienced.

Human-cow interactions

Paper II indicated that the handlers' behaviour might be the main factor influencing the risk of injury during cattle handling. The element most frequently mentioned by the farmers interviewed was the importance of always being calm and gentle when handling the animals. Similarly, a qualitative study of safety and animal handling practices among women dairy farmers in Finland concluded that one important aspect of working safely when handling cattle is trust and a positive relationship between cattle and handler (Kallioniemi *et al.*, 2011). Furthermore, our interviewees admitted that in stressful situations it is easy to lose patience with the cows and then handle them too roughly. Handler-cow interactions were therefore recorded in the observational study (Paper IV) to determine how the aversive hoof trimming would affect the handlers' behaviour and thereby influence safety.

At milking, cows were commonly moved as a herd and they were quite easily moved using few interactions, consisting mainly of non-forceful tactile interactions, whistling and talking. The common routine was to clean the cubicles at the same time, and the manure scraper was often gently used to get cows to stand and move. As expected, the cows showed no behavioural signs of stress, fear or resistance. Cows were allowed to move at their own pace, and the cow heart rate only rose slightly from the baseline, indicating little, if any, perceived stress by the cows.

Moving cows to hoof trimming involved a greater proportion of tactile and visual interactions, as well as moderately forceful and forceful interactions, compared with moving cows to milking. This was expected and was most likely due to the fearfulness of the cows, which made them more challenging to handle, but it was unexpected to see the amount of force some of the handlers used in their interactions with the cows. A desire to be time-efficient and to get as many cows through the trimming chute as possible per day may cause handlers to use force when cows move too slowly or resist moving forward. A lack of knowledge and skill in animal handling is another probable reason.

The proportion of gentle interactions used was also larger during moving to hoof trimming than to milking, probably with the aim of calming nervous cows. This strategy was probably effective, as indicated by the negative correlation between the frequency of risk situations and the proportion of gentle interactions found in Paper III. It is known that gentle handling causes dairy cows to be less fearful and easier to manage (Hemsworth *et al.*, 1996; Boissy & Bouissou, 1988). Waiblinger *et al.* (2004) concluded that stress reactions in cows can be reduced by previous positive handling, as well as by providing positive, gentle interactions during an aversive situation, thereby reducing the risk of injury during such procedures. This was more recently supported by Schmied *et al.* (2010), who found a stress-reducing effect of stroking (lower heart rate and less restless behaviour) during an aversive procedure (rectal palpation). Repeated stroking of dairy cows has been suggested as a way to improve human-animal relationships and routine handling of dairy cattle (Schmied *et al.*, 2008). However, it has also been shown that people differ in their potential to calm cows (Waiblinger *et al.*, 2004) and the characteristics responsible for these differences are not yet known.

One aspect that became clear during the observation study was the difficulty in interpreting different interactions, since we could not be sure how the cows perceived them. For example, shouting may not appear to be a very forceful interaction in comparison with repeated forceful beating with a stick or twisting a cow’s tail. However, Pajor *et al.* (2003; 2000) compared different treatments that are often used when moving cows and concluded that shouting may be perceived by cows as aversive as the use of an electric prod. Furthermore, Waynert *et al.* (1999) found that sound of humans shouting and of metal clanging evoked responses indicative of fear in beef cattle, based on elevated heart rate and increased movement, and shouting in particular appeared to be more alarming. Pajor *et al.* (2000) also found that tail twisting and hitting cows on the rump with an open hand was not perceived as more aversive than a control group receiving no handling.

This difficulty of categorising the interactions may help explain why we did not find the expected correlations between proportions of moderately forceful or forceful interactions and risk situations or incidents. In addition, whether the handler was in risk zone or not when interacting forcefully with the cows was of crucial importance for the outcome. However, when correlating each interaction individually to incidents, some interesting associations were found. Pulling the neck strap or halter was positively correlated with the handler being head butted, which is probably a consequence of them being in the risk zone close to the cow’s head while interacting. Forceful tactile interactions with an object were positively correlated with incidents where the handler was kicked, run over or pushed by a cow, which are most likely indications of fear responses by the cows. No correlations were found between tail twisting or forceful hitting without an object and incidents, which supports previous findings that these interactions are not strongly fear-inducing (Pajor *et al.*, 2000). In keeping with Pajor *et al.* (2003) and Waynert *et al.* (1999), there was a tendency for a positive correlation between shouting/talking loudly and incidents where the handler was kicked by a cow. A more unexpected finding was that talking to cows quietly or in conversational tone for a long duration was positively correlated with incidents where the cow resisted and ran over or pushed the handler, since previous studies have indicated that quiet talking may decrease fear (Breuer *et al.*, 2000; Seabrook, 1984). However, correlations do not indicate any causal relationships, so this result could be due to chance or to the handler talking more to the cows because of their obvious stress behaviour.

Handler attitude to cows and working with cows

Handler attitude to cows and working with cows was included in this thesis because of the reported causal relationship between handler attitude/behaviour and fear in dairy cattle. Thus, handler attitude could be related to safety, since fearful animals are more difficult and hazardous to handle (Boivin *et al.*, 2003).

However, the results did not show any correlation between attitudes to cows and working with cows and risk situations and incidents. In addition, there was no overall association between handler-cow interactions and attitudes, although we did find a negative correlation between positive attitudes and the use of forceful interactions when moving cows to milking. Breuer *et al.* (2000) showed that a composite attitude score (high score representing positive attitudes), based on questions about patting and talking to cows and ease of movement of cows, was negatively correlated with the use of negative tactile interactions such as slaps, pushes and blows in connection with milking. Hemsworth *et al.* (2000) found that positive beliefs about the general characteristics of cows were associated with the use of more positive interactions and less negative interactions by the handler when moving cows to milking. In Paper III, similar results as in previous studies were found when associated with a similar situation (milking), but not for hoof trimming. This might imply that more research is needed to better understand the significance of attitudes on handler behaviour by studying cattle handling in various situations.

It is worth noting that a higher perceived stress level by the handler was related to a belief that cows are fearful of humans and that positive attitudes to cows were related to a lower perceived stress level (consistent at both milking and hoof trimming). It is possible that a positive attitude to cows is associated with higher job satisfaction and thereby also to a lower perceived stress level. In addition, we found that employees had more negative attitudes to cows than farm owners did, which may be linked to job satisfaction too. Maller *et al.*

(2005) found that positive beliefs by dairy farmers about cow behaviour were correlated with farmers positively reporting on working in the dairy and the characteristics of the job, which appeared to be related to job satisfaction. Similar findings on job satisfaction have been reported in relation to attitudes to pigs among handlers in large commercial piggeries (Coleman *et al.*, 1998). Research on the role of job satisfaction specifically in agricultural safety is limited (Clay *et al.*, 2014), but job dissatisfaction has been found to be positively associated with occupational injury in a general occupational study, in which farming was included (Dembe *et al.*, 2004).

The handling facilities

It is well known that the design of the handling facilities affects cattle behaviour, ease of handling and handler safety (Grandin & Deesing, 2008). However, studies on handling facility design and its effects on these issues are limited in the context of dairy cattle handling in work tasks specific to dairy production. The moving of cows to milking has been studied from an animal welfare and production point of view (Waiblinger *et al.*, 2006; Breuer *et al.*, 2000; Hemsworth *et al.*, 2000), but in these studies little, if any, attention has been paid to facility design or handler safety.

Better designed facilities could contribute to the prevention of a number of injuries (Casey *et al.*, 1997), and there has been continuous development of new housing systems to improve efficiency, working environment and animal welfare. In Paper II, the farmers were very positive about the development of modern systems of housing and milking. Milking in a parlour was perceived as safer than the more traditional pipeline milking in tether systems, confirming findings by Wagner *et al.* (2001). Gustafsson (1997) concluded that the comfortable working postures, protective railings around the cow and concentrated work station with short walking distances provided by the parlour contribute to the less hazardous working situation in parlour milking. Similarly, Karttunen and Rautiainen (2013a) found higher odds of injury claims relating to dairy farming couples with a conventional stanchion barn (tether system) than those with loose housing.

Boivin *et al.* (2003) argue that modern husbandry systems and modern biotechnology have strongly distorted the social contact between humans and animals. In Paper II, the farmers perceived that their relationship with the animals grew stronger in automatic milking systems than in the manual milking systems. The major argument was that automatic milking provided the opportunity for more quality time with the cows, like grooming or just being around the cows and observing them, which was considered positive from a safety point of view because the cows became calmer around the handler.

Thus, the problem is perhaps not so much the biotechnology itself, but the fact that dairy production has become concentrated to fewer and larger farms and many dairy farmers work alone, handling large groups of animals and devoting only a limited amount of time to the care of each individual animal (Gustafsson, 1997). Rushen *et al.* (1999) also argue that labour-saving technology often replaces positive contact with the cows, *e.g.* feeding, while aversive tasks like restraint and transport still require human intervention, leading to a risk that the animals' natural fear of humans will be reinforced. Balancing these aversive tasks with daily positive interactions has the potential to increase safety and to improve animal welfare.

The best way to enable calm handling when moving cows is to design the handling facilities to minimise interruptions in cow flow. Even though the collection and moving of cows to milking worked smoothly on most farms included in this thesis, the results indicate that longer transfer alleys to milking were associated with an increased frequency of cows stopping, requiring repeated interactions to start them moving again. Thus, placing the milking parlour strategically to minimise the distance the cows have to walk to milking is recommended. However, long transfer alleys to milking may be unavoidable when designing houses for large herds or when expanding an existing house, and then optimal design of the transfer alley is of importance. Longer transfer alleys also caused some handling difficulties and increased injury risk exposure to the handler, since the handler could not walk along the alley without being among the cows. A passageway for the handler beside the transfer alley would eliminate this problem. The relatively few associations found between facility design and cow behaviour are most likely due to the fact that the cows were familiar with the route to the parlour. One might expect cows moving through the facility for the first time to show more behavioural responses.

More significant correlations were found between facility characteristics and cow behaviour when cows were being moved to hoof trimming. All farms used a single-file alley of varying length to line up a few cows in front of the trimming chute. A relatively long alley, sharp bends and the use of a waiting pen had the strongest influence on cow behaviour. From a handler safety perspective, using a long transfer alley and no waiting pen was associated with a low frequency of incidents. However, when interpreting these results there is a need to relate them to the handling procedures. The use of a waiting pen is not necessarily related to higher risk exposure, but the fact that the handlers were in the pen with the cows was the reason for the high rate of incidents. Thus, if the waiting pens can be designed in such a way that the cows can be handled from the outside the pen, the risks will be reduced. Similarly, the use of a transfer alley will be a safe way of handling the cows as long as the handler remains outside the alley. Thus, the key factor is to keep a barrier between the handler and the cows when handling cows that are agitated and stressed.

A general problem seen on more or less all farms was cows slipping during handling, both when being moved to milking and to hoof trimming, although more frequently at hoof trimming. Answers from the questionnaire and interviews indicated, with a few exceptions, that the handlers were not fully aware of this and consequently prevention measures are unlikely to be introduced. Slippery floors increase the risk of injury for both handler and cows. According to Layde *et al.* (1996), falls on slippery floors by handlers are one of the most common injuries experienced within animal facilities. With this in mind, slippery floors are most likely an even greater issue for the cows, because they are more sensitive to low floor friction than humans are (Phillips & Morris, 2000). A majority of the farms had concrete flooring, although concrete often does not provide enough friction to allow natural locomotion behaviour for cattle, especially when coated with manure (Phillips & Morris, 2000). Rubberised surfaces are more preferable, since studies have shown that cows walking on rubber slip less, take longer fewer strides and increase the speed of walking (Rushen & de Passillé, 2006; Telezhenko & Bergsten, 2005). Furthermore, when given a choice cows prefer to stand and walk on soft rubber flooring rather than on concrete floors (Telezhenko *et al.*, 2007). Manure increases slipperiness on both concrete and rubber floors (Rushen & de Passillé, 2006), and thus regular removal of manure from the transfer alley and waiting pen is necessary.

The interviews in Paper II revealed that the work environment and safety issues were not prioritised by the farmers when designing a new cow house. This was further illustrated in Paper V, where planning for how the hoof trimming procedure was to be carried out was found to be neglected when most new facilities were being designed. The interviewees in Paper II reasoned that a design focused on improving animal welfare would improve both the work environment and safety. However, the design of a system from a welfare perspective is only part of the solution, since cows may be under stress even in a well-designed system if they cannot develop a good relationship with humans (Albright & Fulwider, 2007). Thus, design of the facilities has an impact on safety, but from a safety point of view good design cannot compensate for bad stockmanship.

7.2.6 Associations between identified risk factors and injury risk exposure

The correlations found between different variables as presented in *Figures 9* and *10* are discussed below.

Risk situations when moving cows to milking were only correlated with the perceived energy level of the handler, even though the handling facilities also had an effect on safety, as previously discussed. A possible explanation for the correlation with perceived energy is that a high energy level (feeling active, effective and focused) might be interrelated to haste (*i.e.* a desire to act or move rapidly without necessarily being stressed), and haste is believed to generate a risk of injury (Kallioniemi *et al.*, 2011; Rautiainen *et al.*, 2004). Risk situations when moving cows to hoof trimming did not show the same correlation with perceived energy as when moving to milking. The different results related to milking and hoof trimming indicate that the risks of injury and the underlying causes are dependent on situation, as was expected.

Incidents when moving cows to hoof trimming were primarily correlated with time spent in the risk zone, cow heart rate and job strain. The handler naturally has to be within reaching distance (risk zone) of a cow to be affected by its actions. Therefore, the closer the proximity between handler and cow, the greater the risk of the handler being injured in the event of an unexpected response or reaction by the cow (McCurdy & Carroll, 2000). The time spent in the risk zone most likely depends on the design of the handling facilities, handling technique, handler behaviour, whether individual cows or a group are moved, the cows' willingness to move and the flight zone of the cows. The results also showed that time spent in the risk zone was positively correlated with job strain, age and experience. Older and more experienced handlers have possibly become accustomed to the hazards related to their work, as discussed in section 7.2.1.

For intensively kept dairy cows, the flight zone is small (often close to zero), so the handler presumably has to be close to them to get them to move. Because risk zone was so clearly related to incidents, an effective way to reduce incidents would be to make sure the handler does not have to be in close proximity to cows in situations where the cows may be fearful or unwilling. This highlights the importance of designing handling facilities that enable the handler to work the cows from outside the transfer alley or waiting pen, which was often not fulfilled on the farms studied. The design of the handling facilities had an impact on safety and specific handling facility characteristics, such as length of the transfer alley and the use of a waiting pen, were directly related to incidents.

The positive correlation found between average cow heart rate increase and frequency of incidents when moving cows to hoof trimming confirms previous statements that cow fear/stress is a risk factor for injuries (Grandin, 1999). Furthermore, there was a tendency for a correlation between average cow heart rate and the percentage of time spent in the risk zone by the handler. An increased time spent in the risk zone might be a consequence of cows being more difficult to move (because of the higher fear level) or the cows might feel more pressured and pushed when the handler is in close proximity, resulting in a higher heart rate.

7.3 General discussion and practical implications

This thesis demonstrates that many factors contribute to the occurrence of animal-related injuries in dairy farming and that such injuries result from a complex interplay of multiple risk factors. Although the studies performed were correlational, *i.e.* we were not able to show causality, and the results needs to be confirmed by more extensive research, it was possible to create an embryo of a model to illustrate how the different factors influencing safety relate to each other (*Figures 9* and *10*).

The observations made when cows were being moved to milking and hoof trimming confirmed what has previously mainly been presumed from practical experiences, *i.e.* that hoof trimming is perceived as fear-inducing by the cows, resulting in them showing more resistance and handlers becoming more forceful in their handling, consequently increasing the injury risks. Thus this is not altogether new knowledge, but what was eye-opening was the high rate of incidents observed when cows were being moved to hoof trimming. It is most likely that other aversive procedures, *e.g.* loading and transportation, involve similar injury risks. These results demonstrate a need for changes in the way aversive procedures are performed on dairy farms in order to improve handler safety, but also animal welfare, ease of handling and efficiency.

The results presented in this thesis support the need for training of handlers, as inappropriate handling techniques, including forceful interactions, were commonly used during hoof trimming. This is in keeping with previous studies focusing on animal-related injuries in agriculture, where training in livestock handling is suggested as one prevention strategy (Langley & Morrow, 2010; Casey *et al.*, 1997). Furthermore, the Swedish Provision for Work with Animals (PWA, 2008) clearly states that the employer is responsible for ensuring that employees handling animals have sufficient knowledge of the behaviour and expected responses of the animals with which they are working. How well farmers comply with these regulations is not fully known.

Reviews on farm safety interventions have concluded that educational interventions provide very vague or no evidence of being an effective prevention strategy (Rautiainen *et al.*, 2008; DeRoo & Rautiainen, 2000). However, none of these focused on education specifically in livestock handling and dedicated educational efforts, for example in animal handling, may be more effective than general safety education and would most likely also be easier to evaluate. A cognitive-behavioural intervention procedure designed to improve the attitude and behaviour of handlers toward cows resulted in lower use of negative tactile interactions by handlers and lower levels of fear of humans by cows (Hemsworth *et al.*, 2002). Similar results have been found for employees and animals in the pig industry (Hemsworth *et al.*, 1994). Those studies did not focus on safety, but assuming that the modification of *Figure 7* is accurate (as the results of Paper III indicate), a reduced fear response by the cows will reduce injury risks to the handler. This indicates that training of handlers should not only focus on technical competence and practical skills, but should also be designed to target other areas, such as improving attitudes and perceptual skills.

Another possible solution to reduce fear is to prepare the cows better to cope with aversive procedures by training them, thereby reducing their level of fear in such situations. For example, it is possible to train zoo animals to comply with unpleasant procedures, such as injections or blood sampling, by positive reinforcement of wanted behaviour (Young & Cipreste, 2004). Training and familiarisation of dairy heifers with the milking procedure and environment has been found to have positive effects on their behavioural responses (Bremner, 1997) and distress displayed (Sutherland & Huddart, 2012) during milking in the first week of lactation. Using similar techniques, it should be possible to train cattle to accept aversive procedures, for example to willingly enter a trimming chute. If this type of training, through relatively little effort, can result in improved efficiency, improved animal welfare and, not least, handler safety, it might be motivating to dairy farmers. This is an interesting area for future research and behavioural modification using positive reinforcement is already an active area of research with companion animals, especially dogs (Fukuzawa & Hayashi, 2013; Rooney & Cowan, 2011; Hiby *et al.*, 2004).

The results presented in this thesis also show that the handling facilities have an effect on safety, both by influencing cow behaviour and thus cow flow and ease of handling and by the extent to which they enable handlers to interact with the cows without being exposed to injury risks. The results illustrated that planning for how the hoof trimming procedure was to be carried out was neglected when most new facilities were being designed. Furthermore, there were some indications that the handlers were underestimating some risks related to the handling facilities and believed the handling facilities to be well-designed, even though several deficiencies were observed. This implies that hoof trimming has received very little attention by the farmers or farm building advisors designing new dairy houses. There is clearly a need to disseminate knowledge on designing an optimal handling facility for hoof trimming and other aversive procedures, both regarding mobile systems in existing houses and stationary systems in new houses. Applied research should focus on the positive effects of implementing a good handling facility not only from a handler safety perspective, but also from an animal welfare, animal performance and farm economics perspective.

According to the Swedish Animal Protection Ordinance (APO, 1988), a new cow house must go through a preliminary examination from an animal protection and animal health perspective. However, no such examination is needed regarding the work environment and safety of the humans, even though the Work Environment Act (WEA, 1977) states that the employer must ensure that employees are not placed at risk of ill-health or injury and the Provision for Work with Animals (PWA, 2008) specifies that animal handling facilities should provide sufficient safety for the worker. Since the results in this thesis indicate that farmers do not prioritise work safety when planning a new dairy farm building, there is possibly a need to include a pre-examination from the work environment perspective too. This would send clear signals to both farmers and advisors designing new buildings that this is an important issue which should not be overlooked.

To conclude, the many factors involved and their complex interplay mean that prevention strategies must work on multiple levels to be successful. This is one possible explanation for why it has proven so difficult to demonstrate the effectiveness of an isolated intervention to reduce injuries. The prevention strategies discussed above are not new or unique in any way, but the results show that these strategies target only some of the risk factors identified. Other factors are perhaps more difficult to aim for in interventions, *e.g.* the farm safety-risk paradox or psychosocial factors such as job strain, and need more research for clarification. The results of this thesis point to the need for interdisciplinary research and multi-targeted prevention strategies, but the findings presented here will hopefully act as a springboard to future studies and intervention designs.

8 Conclusions

This thesis provided some preliminary insights into the mechanisms behind animal-related injuries in dairy farming. The main findings were:

- Swedish dairy farmers were aware of the injury risks related to animal-handling, but also took the view that injury risks are part of dairy farming, so safety was often forgotten or not prioritised. The farmers took calculated risks in order to save time or money.
- The dairy farmers believed that most injuries can be prevented, but that there will always be some injuries which are impossible to foresee. They sometimes perceived themselves as lacking control during animal handling due to the unpredictability of the animals' behaviour and responses.
- The dairy farmers pointed out three main themes believed to have an impact on risks and safety: the handler, the cattle and the handling facilities.
- Moving cows in an aversive situation (*i.e.* hoof trimming) was associated with a high frequency of incidents (physical contact between handler and cow that could have resulted in an injury, *e.g.* kicking or head butting). Risk situations and incidents were significantly more frequent when moving cows to hoof trimming than to milking.
- The percentage of time spent in the risk zone (the area around the cow where the handler could be hit by the cow's head or hind legs) was higher when cows were being moved to hoof trimming than to milking.
- Moving cows to hoof trimming involved higher frequencies of fear responses by the cows (freezing, balking, resisting), and more forceful interactions by the handler compared with moving cows to milking.
- When moving cows to milking, risk situations were positively correlated with the perceived energy level of the handler. Injury risks were also

associated with specific handling facility characteristics, including slippery floors and long transfer alleys to the waiting pen where the handler had no option but to walk among the cows.

- When moving cows to hoof trimming;
  - Cow heart rate increase was positively correlated with incidents, indicating that fear in cows is a risk factor for injury.
  - The time spent in the risk zone was positively correlated with incidents, *i.e.* close proximity to the cows during aversive procedures increases injury risks.
  - Job strain was positively correlated with incidents, which indicates that a high perceived stress load due to high job demands combined with low control may be a risk factor for injury.
  - Some handler-cow interactions (*e.g.* forceful tactile interactions with an object and pulling neck strap or halter) were positively correlated with incidents where the handler was kicked, head butted or run over by a cow and thus the behaviour and handling techniques of the handler affect safety.
  - Specific handling facility characteristics were associated with injury risks, where the key factor appeared to be whether it was possible to keep a barrier between handler and cows when moving the cows.
- Safety locus of control and risk attitudes did not serve as good indicators of injury risks during moving cows to milking and hoof trimming. The limitations in methods make it impossible to draw any far-reaching conclusions based on these results, but the results indicate that other variables have more impact on safety.
- There were indications that handler attitudes to cows had an effect on handler behaviour and cow stress/fear. There was a negative correlation between positive attitudes to cow characteristics and the use of forceful interactions, and a positive correlation between negative attitudes to cows and cow heart rate when moving cows to milking. Such correlations were not found when cows were being moved to hoof trimming. Handler attitude to cows and working with cows was not correlated with risk situations or incidents.
- The results highlight a need for changes in the way aversive procedures are performed on dairy farms so as to increase handler safety, but also improve animal welfare, ease of handling and efficiency.

- In conclusion, this thesis shows that many factors contribute to the occurrence of animal-related injuries in dairy farming and that injuries result from a complex interplay of multiple risk factors. This indicates a need for future interdisciplinary research and multi-targeted prevention strategies.

9 Future research

Limited data are available on the efficacy of specific preventive approaches, so future research on animal-related injuries in agriculture should include evaluations of interventions to reduce injuries. In order to identify effective prevention strategies, knowledge of underlying risk factors is essential. This thesis provides a basis for such knowledge, but the results need to be confirmed and extended to other handling situations, and causal relationships need to be established by more extensive research. For example, longitudinal studies are needed to confirm whether the identified potential risk factors are associated with animal-related injuries over a longer period of time.
Future research should also examine these aspects:

- The habituation to risk and the farm safety-risk paradox is a challenge to safety research. Studies on how to make farmers acknowledge their personal susceptibility to injury and the factors that interact creating the mismatch between what farmers say and do would be beneficial. Why do farmers decide to take deliberate risks and how can this kind of risk-taking be prevented?
- The possible causal relationship between acute worker stress and injuries during animal handling needs to be further investigated.
- The psychosocial work environment (including job strain) in relation to occupational injury in dairy farming is an interesting issue for future research. Studies should aim at confirming causality between job strain and animal-related injury and look into the sources of job strain in dairy farming. Furthermore, the possibility to decrease job strain by organisational changes on the farm should be investigated.
- There are indications that safety on dairy farms can be improved by training farmers and their employees in animal handling. Studies addressing the effectiveness in such training in reducing worker injuries are needed.

Furthermore, how to design such a training programme and how to make farmers and their employees motivated to attend training and acknowledge a need to improve their handling skills are important issues.

- This thesis revealed a need to improve the handling facilities on dairy farms for moving cows in a safe way, especially to hoof trimming. What is a good design of transfer alleys and waiting pens to enable good cow flow and easy and safe handling in aversive situations? Applied research should focus on the positive effects of implementing a good handling facility not only from a handler safety perspective, but also from the animal welfare, animal performance and farm economics perspective. The knowledge needs to be disseminated to farmers, farm building designers and advisors.
- Fear of humans in cattle seems to be associated with an increased risk of occupational injury. Thus, research should focus on how to minimise fear, especially during aversive procedures such as hoof trimming. For example, behavioural modification using positive reinforcement is an interesting area in relation to handling of dairy cattle.
- In Sweden, dairy cows are raised in conditions that make them very accustomed to being close to humans and to being handled, which probably affects the way they react to handling and to different handling situations. Studies and dissemination of knowledge on best practices in animal handling on dairy farms under these conditions, especially in relation to aversive management procedures, focusing on improving safety, effectiveness, and animal welfare, would be very valuable and helpful to the farmers and their employees.
- The current trend is for increasing herd size on dairy farms. Since larger herd size and thereby also increased mechanisation may increase cows' fear of humans, the effect of this development on occupational injuries should be investigated.

10 Svensk sammanfattning

Jordbruket tillhör de farligaste branscherna i arbetslivet och enligt svensk arbetsskadestatistik är det flerdubbelt större olycksfallsrisk att arbeta i jordbruket jämfört med de flesta andra yrken. Olyckor med djur och maskiner samt fallolyckor är de tre vanligaste skadeorsakerna. Djurrelaterade arbets-olyckor utgör uppskattningsvis en fjärdedel av det totala antalet olyckor i det svenska jordbruket och i genomsnitt sker ett dödsfall per år vid hantering av nötkreatur.

Företag med mjölkproduktion verkar vara särskilt drabbat av olycksskador. Arbetet omfattar många olika och vitt skilda arbetsuppgifter som exempelvis hantering av stora maskiner, mjölkning och övrig hantering och skötsel av djur, underhåll och reparation av maskiner och byggnader, samt administrativt arbete. Det dagliga arbetet innebär också åtskilliga stressfaktorer, varav många är svåra att kontrollera för, såsom väderförhållanden, maskinhaverier, ekonomiska bekymmer och förändringar i lagar och förordningar. Arbetet innefattar ofta även en hög fysisk arbetsbelastning, långa arbetsdagar och mycket ensamarbete. Arbete med djur är det arbete som lantbrukarna själva ser som det mest riskabla och djurrelaterade olyckor är också en av de vanligaste skadehändelserna på mjölkgårdar. I mjölkproduktionen hanteras djuren ofta och i en nära kontakt med dem. Olyckor inträffar främst vid mjölkning och förflyttning av djur, där skador framför allt uppkommer genom spark, tramp, slag och klämning. Skador orsakade av nötkreatur är ofta allvarliga med lång sjukfrånvaro.

Syftet med denna avhandling var att ge en fördjupad kunskap om och förståelse för de bakomliggande faktorerna till varför olyckor sker vid hantering av nötkreatur i mjölkproduktionen. Flera olika metoder, både kvalitativa och kvantitativa, användes för att belysa ett antal aspekter av risk och säkerhet i djurhanteringen, såsom djupintervjuer med mjölkproducenter, beteendestudier och hjärtfrekvensmätningar av djurskötare och kor under rutinmässiga arbetsuppgifter (drivning av kor till mjölkning samt till klövverkning), dokumentation av miljön (t.ex. drivgångar, inredning) samt frågeformulär som omfattade bland annat attityder och upplevd stress i arbetet. All datainsamling genomfördes på kommersiella svenska mjölkgårdar.

Resultat från djupintervjuerna visade att svenska mjölkproducenter är medvetna om farorna att arbeta med nötkreatur. Även om säkerhet ansågs vara en viktig och relevant fråga menade lantbrukarna att risker och säkerhet ofta glöms bort eller prioriteras ner. Det framkom också att de väljer att ta medvetna risker om det innebär att de kan spara tid eller kostnader. Lantbrukarna ansåg att de flesta djurrelaterade olyckor kan förebyggas, men också att det alltid kommer att finnas olycksförlopp som är omöjliga att förutse och därmed förhindras. De uttryckte en ibland upplevd brist på kontroll vid djurhanteringen på grund av att det alltid finns ett visst mått av oförutsägbarhet i djurens beteende och reaktioner.

Vid drivning till mjölkning observerades inga incidenter och endast några få risksituationer. Drivningen fungerade generellt sett bra på alla gårdar, med lugn hantering och endast ett fåtal stopp i djurflödet. Resultatet visade en positiv korrelation mellan risksituationer och skötarens upplevda energinivå. En ökad skaderisk kopplades också till specifika miljöfaktorer, som hala golv och drivningsgångar till samlingsfållan utan möjlighet att hantera djuren eller förflytta sig utmed gången utan att vara inne bland djuren.

Vid drivning av kor till klövverkning (som kan upplevas som obehaglig och stressande för korna) observerades en högre frekvens av incidenter (fysisk kontakt mellan skötare och ko som kunde ha resulterat i skada, t.ex. spark eller stångning) jämfört med vid drivning till mjölkning. Skötaren uppehöll sig också en större andel av den observerade tiden i kornas ”riskzon”, d.v.s. inom träffavstånd för spark eller stångning, vid klövverkning. Vid drivning till klövverkning observerades högre frekvenser av beteenden som indikerar rädsla hos korna och de hade också en högre hjärtfrekvens än vid mjölkning. Skötaren använde en större andel kraftfulla interaktioner vid drivning till klövverkning, som exempelvis hårda slag och svansvridningar.

Följande variabler var positivt korrelerade till incidenter vid drivning till klövverkning:

- Kornas relativa hjärtfrekvens, vilket tyder på att rädsla/stress hos korna är en riskfaktor för olyckor.
- Andel tid skötaren uppehöll sig i kornas riskzon, vilket inte så förvånande visar på att närheten till korna under hanteringen påverkar risken.
- Att skötaren upplever höga krav i arbetet i kombination med låg kontroll (job strain) kan öka olycksrisken.

- Några beteenden hos skötaren var kopplade till en ökad olycksrisk, som exempelvis kraftfulla slag med redskap (t.ex. gödselskrapa, grind) och drag i nackrem eller grimma, vilket visar att skötarens hanteringsteknik påverkar säkerheten.
- Skaderisker var också kopplade till vissa specifika miljöfaktorer, där den viktigaste övergripande faktorn verkade vara om det var möjligt att skilja skötare och djur åt med någon typ av barriär under hanteringen, t.ex. grindar.

Sammanfattningsvis visar denna avhandling att risk och säkerhet vid hantering av nötkreatur i mjölkproduktionen påverkas av ett komplext samspel mellan många faktorer relaterade till människa, djur och miljö. En del av de riskfaktorer som identifierats här är relativt uppenbara och kan styrkas av tidigare forskning medan andra behöver verifieras och studeras mer ingående. Tydligt är behovet av tvärvetenskaplig forskning för att inte ha en för snäv ingång och därmed missa viktiga samverkande faktorer. För att förebygga djurrelaterade olyckor finns ingen enskild lösning utan det krävs en kombination av insatser för att nå framgång. Förhoppningen är att denna avhandling kan utgöra en inspirationskälla och språngbräda till utformningen av framtida interventioner och förebyggande insatser.

References

Agresti, A. & Franklin, C. (2013). *Statistics. The art and science of learning from data*. 3rd ed. Boston: Pearson Education, Inc.

Alavanja, M.C.R., Sprince, N.L., Oliver, E., Whitten, P.S., Lynch, C.F., Gillette, P.P., Logsden-Sacket, N. & Zwerling, C. (2001). Nested case-control analysis of high pesticide exposure events from the agricultural health study. *American Journal of Industrial Medicine* 39, 557-563.

Albright, J.L. & Fulwider, W.K. (2007). Dairy cattle behaviour, facilities, handling, transport, automation and well-being. In: Grandin, T. (Ed.) *Livestock handling and transport*. 3rd ed. Cambridge: CAB International, pp. 109-133.

Alhakami, A.S. & Slovic, P. (1994). A psychological study of the inverse relationship between perceived risk and perceived benefit. *Risk Analysis* 14, 1085-1096.

Allen, P.B., Field, W.E. & Frick, M.J. (1995). Assessment of work-related injury risk for farmers and ranchers with physical disabilities. *Journal of Agricultural Safety and Health* 1(2), 71-81.

APO (1988). *Djurskyddsförordning* [Animal Protection Ordinance]. Stockholm, Sweden. (SFS 1988:539). Available from: http://www.riksdagen.se/sv/Dokument-Lagar/Lagar/Svenskforfattningssamling/Djurskyddsforordning-1988539_sfs-1988-539/ [Accessed 16-09-2013]. (In Swedish).

Baker, S.P., O'Neill, B., Ginsburg, M.J. & Guohua, L.I. (1992). *The injury fact book*. 2nd ed. New York: Oxford University Press.

Bijur, P.E. (1995). What's in a name? Comments on the use of the terms 'accident' and 'injury'. *Injury Prevention* 1, 9-11.

Boissy, A. (1995). Fear and fearfulness in animals. *The Quarterly Review of Biology* 70(2), 165-191.

Boissy, A. & Bouissou, M.F. (1988). Effects of Early Handling on Heifers' Subsequent Reactivity to Humans and to Unfamiliar Situations. *Applied Animal Behaviour Science* 20(3-4), 259-273.

Boissy, A., Fisher, A.D., Bouix, J., Hinch, G.N. & Le Neidre, P. (2005). Genetics of fear in ruminant livestock. *Livestock Production Science* 93, 23-32.

Boivin, X., Lensink, B.J. & Veissier, I. (2001). The farmer and the animal: a double mirror. In: Hovi, M. & Bouilhol, M. (Eds.) *Human-animal relationship: stockmanship and housing in organic livestock systems.* Proceedings of the Third NAHWOA Workshop, 21-24 October 2000, France, pp. 7-15.

Boivin, X., Lensink, J., Tallet, C. & Veissier, I. (2003). Stockmanship and farm animal welfare. *Animal Welfare* 12(4), 479-492.

Boyle, D., Gerberich, S.G., Gibson, R.W., Maldonado, G., Robinson, R.A., Martin, F., Renier, C. & Amandus, H. (1997). Injury from dairy cattle activities. *Epidemiology* 8(1), 37-41.

Bremner, K.J. (1997). Behaviour of dairy heifers during adaption to milking. *Proceedings of the New Zealand Society of Animal Production* 57, 105-108.

Breuer, K., Hemsworth, P.H., Barnett, J.L., Matthews, L.R. & Coleman, G.J. (2000). Behavioural response to humans and the productivity of commercial dairy cows. *Applied Animal Behaviour Science* 66(4), 273-288.

Breuer, K., Hemsworth, P.H. & Coleman, G.J. (1997). The influence of handling on the behavior and productivity of lactating heifers. In: Hemsworth, P.H., Špinka, M. & Kostal, L. (Eds.), *Proceedings of the 31st International Congress of the International Society for Applied Ethology*, Prague, Czech Republic, pp. 39.

Brink, P.J. & Wood, M.J. (Eds.) (1998). *Advanced design in nursing research*. Thousand Oaks: SAGE Publications, Inc.

Brison, R.J. & Pickett, C.W.L. (1992). Nonfatal Farm Injuries on 117 Eastern Ontario Beef and Dairy Farms: A One-Year Study. *American Journal of Industrial Medicine* 21(5), 623-636.

Burmeister, E. & Aitken, L.M. (2012). Sample size: How many is enough? *Australian Critical Care* 25, 271-274.

Burns, R. & Sullivan, P. (2000). Perceptions of danger, risk taking, and outcomes in a remote community. *Environment and Behavior* 32(1), 32-71.

Carstensen, O., Lauritsen, J. & Rasmussen, K. (1995). The West-Jutland study on prevention of farm accidents, phase 1: A study of work specific factors in 257 hospital-treated agricultural injuries. *Journal of Agricultural Safety and Health* 1(4), 231-239.

Casey, G.M., Grant, A.M., Roerig, D.S., Boyd, J., Hill, M., London, M., Gelberg, K.H., Hallman, E. & Pollock, J. (1997). Farm Worker Injuries Associated with Cows. *AAOHN Journal* 45(9), 447-450.

Chesterton, R.N., Pfeiffer, D.U., Morris, R.S. & Tanner, C.M. (1989). Environmental and behavioural factors affecting the prevalence of foot lameness in New Zealand dairy herds - a case control study. *New Zealand Veterinary Journal* 37, 135-142.

Clay, L., Treharne, G.J., Hay-Smith, E.J.C. & Milosavljevic, S. (2014). Is workplace satisfaction associated with self-reported quad bike loss of control events among farm workers in New Zealand? *Applied Ergonomics* 45(3), 496-502.

Coleman, G.J., Hemsworth, P.H. & Hay, M. (1998). Predicting stockperson behaviour towards pigs from attitudinal and job-related variables and empathy. *Applied Animal Behaviour Science* 58(1-2), 63-75.

Cook, T.D. & Campbell, D.T. (1979). *Quasi-experimentation. Design and analysis issues for field settings*. Boston: Houghton Mifflin Company.

Creswell, J.W. (2007). *Qualitative Inquiry & Research Design: Choosing Among Five Approaches*. 2nd ed. Thousand Oaks: Sage Publications.

Davis, M. (1992). The role of the amygdala in fear and anxiety. *Annual Review of Neuroscience* 15, 353-375.

Dembe, A.E., Erickson, J.B. & Delbos, R. (2004). Predictors of work-related injuries and illnesses: national survey findings. *Journal of Occupational and Environmental Hygiene* 1, 542-550.

DeRoo, L.A. & Rautiainen, R.H. (2000). A systematic review of farm safety interventions. *American Journal of Preventive Medicine* 18(4), 51-62.

Dewar, D.M. (1996). Farm health safety issues: Do men and women differ in their perceptions? *AAOHN Journal* 44(8), 391-401.

Dickson, D.P., Barr, G.R., Johnson, L.P. & Wieckert, D.A. (1970). Social dominance and temperament of Holstein cows. *Journal of Dairy Science* 53, 904-907.

Douphrate, D.I., Hagevoort, G.R., Nonnenmann, M.W., Lunner Kolstrup, C., Reynolds, S.J., Jakob, M. & Kinsel, M. (2013). The dairy industry: A brief description of production practices, trends, and farm characteristics around the world. *Journal of Agromedicine* 18(3), 187-197.

Douphrate, D.I., Rosecrance, J.C., Stallones, L., Reynolds, S.J. & Gilkey, D.P. (2009). Livestock-handling injuries in agriculture: an analysis of Colorado workers' compensation data. *American Journal of Industrial Medicine* 52(5), 391-407.

Douphrate, D.I., Rosecrance, J.C. & Wahl, G. (2006). Workers' compensation experience of Colorado agriculture workers, 2000-2004. *American Journal of Industrial Medicine* 49(11), 900-910.

Doyle, Y. & Conroy, R. (1988). A one year survey of accidents on Irish farms and their medical outcome. *Journal of Occupational Accidents* 10(3), 199-208.

Elkind, P.D. (1993). Correspondence between knowledge, attitudes, and behavior in farm health and safety practices. *Journal of Safety Research* 24(3), 171-179.

Elkind, P.D. (2007). Perceptions of Risk, Stressors, and Locus of Control Influence Intentions to Practice Safety Behaviors in Agriculture. *Journal of Agromedicine* 12(4), 7 - 25.

Elkind, P.D. & Cody-Salter, H. (1994). Farm Stressors: The Hazards of Agrarian Life. *Annals of Agricultural and Environmental Medicine* 1, 23-27.

Endacott, R. & Botti, M. (2007). Clinical research 3: Sample selection. *Accident and Emergency Nursing* 15, 234-238.

Erkal, S., Gerberich, S.G., Ryan, A.D., Renier, C.M. & Alexander, B.H. (2008). Animal-related injuries: A population-based study of a five-state region in the upper midwest: Regional rural injury study II. *Journal of Safety Research* 39(4), 351-363.

Eurostat (2013). European Statistical System [database]. Luxembourg: Statistical office of the European Union. Available from : http://epp.eurostat.ec.europa.eu/portal/page/portal/agriculture/introduction [Accessed 16-10-2013]

Forkman, B., Boissy, A., Maunier-Salaün, M.-C., Canali, E. & Jones, R.B. (2007). A critical review of fear tests used on cattle, pigs, sheep, poultry and horses. *Physiology & Behavior* 92, 340-374.

Fukuzawa, M. & Hayashi, N. (2013). Comparison of 3 different reinforcements of learning in dogs (*Canis familiaris*). *Journal of Veterinary Behaviour* 8(4), 221-224.

Glasscock, D.J., Rasmussen, K., Carstensen, O. & Hansen, O.N. (2006). Psychosocial factors and safety behaviour as predictors of accidental work injuries in farming. *Work and Stress* 20(2), 173-189.

Gordon, J.E. (1949). The epidemiology of accidents. *American Journal of Public Health* 39, 504-515.

Grandin, T. (1984). Reduce stress of handling to improve productivity of livestock. *Veterinary Medicine & Small Animal Clinician* 79(6), 827-831.

Grandin, T. (1999). Safe handling of large animals. *Occupational Medicine-State of the Art Reviews* 14(2), 195-212.

Grandin, T. & Deesing, M. (2008). *Humane livestock handling*. North Adams: Storey Publishing.

Green, K.L. (1999). Farm health and safety: rural couples' beliefs and practices. *Journal of Agricultural Safety and Health* 5(1), 83-96.

Gustafsson, B. (1997). The health and safety of workers in a confined animal system. *Livestock Production Science* 49(2), 191-202.

Haddon, W. (1973). Energy damage and the ten countermeasure strategies. *Journal of Trauma* 13, 321-331.

Haddon, W. (1980). Advances in the epidemiology of injuries as a basis for public policy. *Public Health Reports* 95(5), 411-421.

Hartman, E., Frankena, K., Vrielink, H., Nielen, M., Metz, J.H.M. & Huirne, R.B.M. (2004). Risk factors associated with sick leave due to work-related injuries in Dutch farmers: an exploratory case-control study. *Safety Science* 42(9), 807-823.

HaSPA (2012). *Models of causation: safety*. (The Core Body of Knowledge for Generalist OHS Professionals). Tullamarine: Safety Institute of Australia. Available from: http://www.ohsbok.org/downloads/32%20Models%20of%20Causation%20Safety.pdf [Accessed 20-09-2013].

Hayes, N. (2000). *Doing Psychological Research*. Buckingham: Open University Press.

Hedlund, S. (2008). *Arbetsåtgång i mjölkproduktion beroende på besättnings-storlek samt mekaniserings- och automatiseringsgrad* [Working time in

dairy production depending on herd size and level of mechanization]. (LTJ-report 2008:2). Alnarp:Swedish University of Agricultural Sciences. (In Swedish with English summary).
Heinrich, H.W. (1931). *Industrial accident pevention: A scientific approach*. New York: McGraw-Hill.
Hemsworth, P.H. (2003). Human-animal interactions in livestock production. *Applied Animal Behaviour Science* 81(3), 185-198.
Hemsworth, P.H., Barnett, J.L., Beveridge, L. & Matthews, L.R. (1995). The welfare of extensively managed dairy cattle: A review. *Applied Animal Behaviour Science* 42, 161-182.
Hemsworth, P.H., Coleman, G.J. & Barnett, J.L. (1994). Improving the attitude and behavior of stockpersons towards pigs and the consequences on the behavior and reproductive-performance of commercial pigs. *Applied Animal Behaviour Science* 39(3-4), 349-362.
Hemsworth, P.H., Coleman, G.J., Barnett, J.L. & Borg, S. (2000). Relationships between human-animal interactions and productivity of commercial dairy cows. *Journal of Animal Science* 78(11), 2821-2831.
Hemsworth, P.H., Coleman, G.J., Barnett, J.L., Borg, S. & Dowling, S. (2002). The effects of cognitive behavioral intervention on the attitude and behavior of stockpersons and the behavior and productivity of commercial dairy cows. *Journal of Animal Science* 80(1), 68-78.
Hemsworth, P.H., Price, E.O. & Borgwardt, R. (1996). Behavioural responses of domestic pigs and cattle to humans and novel stimuli. *Applied Animal Behaviour Science* 50(1), 43-56.
Hemsworth, P.H., Rice, M., Karlen, M.G., Calleja, L., Barnett, J.L., Nash, J. & Coleman, G.J. (2011). Human-animal interactions at abattoirs: Relationships between handling and animal stress in sheep and cattle. *Applied Animal Behaviour Science* 135, 24-33.
Hiby, E.F., Rooney, N.J. & Bradshaw, J.W.S. (2004). Dog training methods: their use, effectiveness and interaction with behaviour and welfare. *Animal Welfare* 13(1), 63-69.
Hoskin, A.F. & Miller, T.A. (1979). Farm accident surveys - 21-state summary with emphasis on animal-related injuries. *Journal of Safety Research* 11(1), 2-13.
IAPA (2007). *Glossary of Occupational Health & Safety Terms*. Ontario: Industrial Accident Prevention Association. Available from: http://www.iapa.ca/pdf/iapa_glossary.pdf [Accessed 18-09-2013].
ISA (2013). Informationssystemet om arbetsskador [database]. Stockholm: Swedish Work Environment Authority.
Jones, J.W. & Wuebker, L.J. (1985). Development and validation of the safety locus of control scale. *Perceptual and Motor Skills* 61, 151-161.
Jones, J.W. & Wuebker, L.J. (1993). Safety locus of control and employees' accidents. *Journal of Business and Psychology* 7(4), 449-457.

Kallioniemi, M.K., Raussi, S.M., Rautiainen, R.H. & Kymäläinen, H.R. (2011). Safety and animal handling practices among women dairy operators. *Journal of Agricultural Safety and Health* 17(1), 63-78.

Karasek, R.A. (1979). Job demands, job decision latitude, and mental strain: implications for job redesign. *Administrative Science Quarterly* 24(2), 285-308.

Karttunen, J.P. (2014). *Clustering of occupational injuries, diseases, and disability in Finnish farmers - an opportunity for targeted prevention.* Diss. Helsinki:University of Helsinki.

Karttunen, J.P. & Rautiainen, R.H. (2013a). Characteristics of and risk factors for compensated occupational injury and disease claims in dairy farming: a case-control study. *Journal of Agricultural Safety and Health* 19(3), 191-206.

Karttunen, J.P. & Rautiainen, R.H. (2013b). Distribution and characteristics of occupational injuries and diseases among farmers: a retrospective analysis of workers' compensation claims. *American Journal of Industrial Medicine* 56, 856-869.

Keeling, L.J., Jonare, L. & Lanneborn, L. (2009). Investigating horse-human interactions: The effect of a nervous human. *The Veterinary Journal* 181, 70-71.

Kjellberg, A. & Iwanowski, S. (1989). *Stress/energi-formuläret: utveckling av en metod för skattning av sinnesstämning i arbetet* [The Stress-Energy Questionnaire: Development of an instrument for measuring mood at work]. (Undersökningsrapport 1989:26). Solna: National Institute of Occupational Health. (In Swedish).

Kjellberg, A. & Wadman, C. (2002). *Subjektiv stress och dess samband med psykosociala förhållanden och besvär. En prövning av Stress-Energi-modellen* [Subjective stress and its relation to psychosocial work conditions and health complaints. A test of the Stress-Energy model]. (Arbete och Hälsa 2002:12). Stockholm: National Institute for Working Life. (In Swedish with English summary).

Langley, L.R. & Morrow, W.E.M. (2010). Livestock Handling - Minimizing Worker Injuries. *Journal of Agromedicine* 15, 226-235.

Layde, P.M., Nordstrom, D.L., Stueland, D., Wittman, L.B., Follen, M.A. & Olson, K.A. (1996). Animal-related occupational injuries in farm residents. *Journal of Agricultural Safety and Health* 2(1), 27-37.

Lehner, P.N. (1996). *Handbook of ethological methods*. 2nd ed. Cambridge: Cambridge University Press.

Lewis, N.J. & Hurnik, J.F. (1998). The effect of some common management practices on the ease of handling of dairy cows. *Applied Animal Behaviour Science* 58(3-4), 213-220.

Lindahl, C., Lundqvist, P. & Lindahl Norberg, A. (2012). Swedish Dairy Farmers' Perceptions of Animal-Related Injuries. *Journal of Agromedicine* 17(4), 364-376.

Loimer, H. & Guarnieri, M. (1996). Accidents and the act of God: A history of the term. *American Journal of Public Health* 86(1), 101-107.

Long, T. & Johnson, M. (2000). Rigour, reliability and validity in qualitative research. *Clinical Effectiveness in Nursing* 4, 30-37.

LRF (2012). *Grön konkurrenskraft - produktivitetsutveckling i Sverige och i våra konkurrentländer*. Stockholm: LRF Konsult. Available from: http://www.lrf.se/PageFiles/94102/Gro%CC%88n_Konkurrenskraft.pdf [Accessed: 10-11-2013]. (In Swedish).

MacKay, J.R.D., Haskell, M.J., Deag, J.M. & van Reenen, K. (2014). Fear responses to novelty in testing environments are related to day-to-day activity in the home environment in dairy cattle. *Applied Animal Behaviour Science* 152, 7-16.

Maller, C.J., Hemsworth, P.H., Ng, K.T., Jongman, E.J., Coleman, G.J. & Arnold, N.A. (2005). The relationships between characteristics of milking sheds and the attitudes to dairy cows, working conditions, and quality of life of dairy farmers. *Australian Journal of Agricultural Research* 56(4), 363-372.

McCoy, C.A., Carruth, A.K. & Reed, D.B. (2002). Women in agriculture: Risks for occupational injury within the context of gendered role. *Journal of Agricultural Safety and Health* 8(1), 37-50.

McCurdy, S.A. & Carroll, D.J. (2000). Agricultural injury. *American Journal of Industrial Medicine* 38(4), 463-480.

Munksgaard, L., De Passillé, A.M., Rushen, J., Thodberg, K. & Jensen, M.B. (1997). Discrimination of People by Dairy Cows Based on Handling. *Journal of Dairy Science* 80(6), 1106-1112.

Murphy, D.J. (1981). Farm safety attitudes and accident involvement. *Accident Analysis and Prevention* 13(4), 331-337.

Murphy, D.J. (2003). *Looking Beneath the Surface of Agricultural Safety and Health*. St. Joseph: American Society of Agricultural Engineers.

Neira, J. & Bosque, L. (2004). The word "accident": no chance, no error, no destiny. *Prehospital and Disaster Medicine* 19(3), 187-189.

Nordstrom, D.L., Layde, P.M., Olsen, K.A., Stueland, O., Brandt, L. & Rollen, M.A. (1995). Incidence of farm-work-related acute injury in a defined population. *American Journal of Industrial Medicine* 28, 551-564.

Ostrov, J.M. & Hart, E.J. (2012). Observational methods. In: Little, T.D. (Ed.) *Oxford Handbook of Quantitative Methods*. New York: Oxford University Press, pp. 285-303.

Pajor, E.A., Rushen, J. & De Passillé, A.M.B. (2000). Aversion learning techniques to evaluate dairy cattle handling practices. *Applied Animal Behaviour Science* 69(2), 89-102.

Pajor, E.A., Rushen, J. & de Passillé, A.M.B. (2003). Dairy cattle's choice of handling treatments in a Y-maze. *Applied Animal Behaviour Science* 80(2), 93-107.

Petty, N.J., Thomson, O.P. & Stew, G. (2012). Ready for a paradigm shift? Part 2: Introducing qualitative research methodologie and methods. *Manual Therapy* 17, 378-384.

Phillips, C.J.C. & Morris, I.D. (2000). The locomotion of dairy cows on concrete floors that are dry, wet, or covered with a slurry of excreta. *Journal of Dairy Science* 83, 1767-1772.

Pinzke, S. & Lundqvist, P. (2007). Occupational accidents in Swedish agriculture. *Agricultural Engineering Research* 13(5), 159-165.

Pless, I.B. & Hagel, B.E. (2005). Injury prevention: a glossary of terms. *Journal of Epidemiology & Community Health* 59, 182-185.

Pratt, D.S., Marvel, L.H., Darrow, D., Stallones, L., May, J.J. & Jenkins, P. (1992). The Dangers of Dairy Farming - The Injury Experience of 600 Workers Followed for 2 Years. *American Journal of Industrial Medicine* 21(5), 637-650.

PWA (2008). *Arbete med djur* [Provision for Work with Animals]. Stockholm, Sweden. (AFS 2008:17). Available from: http://www.av.se/dokument/afs/afs2008_17.pdf [Accessed 16-09-2013]. (In Swedish).

Rasmussen, K., Carstensen, O. & Lauritsen, J.M. (2000). Incidence of unintentional injuries in farming based on one year of weekly registration in Danish farms. *American Journal of Industrial Medicine* 38, 82-89.

Rautiainen, R.H., Lange, J.L., Hodne, C.J., Schneiders, S. & Donham, K.J. (2004). Injuries in the Iowa certified safe farm study. *Journal of Agricultural Safety and Health* 10(1), 51-63.

Rautiainen, R.H., Lehtola, M.M., Day, L.M., Schonstein, E., Suutarinen, J., Salminen, S. & Verbeek, J. (2008). *Interventions for preventing injuries in the agricultural industry (Review).* (Cochrane Database of Systematic Reviews 2008, Issue 1). The Cochrane Collaboration, John Wiley & Sons, Ltd.

Reason, J.T. (2008). *The human contribution: unsafe acts, accidents and heroic recoveries*. Farnham: Ashgate Publishing Ltd.

Ridley, J. & Channing, J. (1999). *Safety at work*. 5th ed. Oxford: Taylor & Francis Ltd.

Rohrmann, B. (2008). *Risk perception, risk attitude, risk communication, risk management: a conceptual appraisal.* The International Emergency Management Society 15th Annual Conference, 17-19 June, 2008, Prague, Czech Republic. Available from: http://tiems.info/dmdocuments/events/TIEMS_2008_Bernd_Rohrmann_Keynote.pdf [Accessed 10-02- 2014].

Rooney, N.J. & Cowan, S. (2011). Training methods and owner-dog interactions: Links with dog behaviour and learning ability. *Applied Animal Behaviour Science* 132, 169-177.

Runyan, C.W. (2003). Introduction: Back to the future - revisiting Haddon's conceptualization of injury epidemiology and prevention. *Epidemiologic Reviews* 25, 60-64.

Rushen, J. & De Passillé, A.M.B. (2006). Effects of roughness and compressibility of flooring on cow locomotion. *Journal of Dairy Science* 89, 2965-2972.

Rushen, J., Taylor, A.A. & De Passillé, A.M. (1999). Domestic animals' fear of humans and its effect on their welfare. *Applied Animal Behaviour Science* 65, 285-303.

SCB (1986). *Yearbook of agricultural statistics 1986*. Stockholm: Statistics Sweden.

SCB (1990). *Yearbook of agricultural statistics 1990*. Stockholm: Statistics Sweden.

SCB (1995). *Yearbook of agricultural statistics 1995*. Stockholm: Statistics Sweden.

SCB (2000). *Yearbook of agricultural statistics 2000*. Stockholm: Statistics Sweden.

SCB (2005). *Yearbook of agricultural statistics 2005*. Stockholm: Statistics Sweden.

SCB (2010). *Yearbook of agricultural statistics 2010*. Stockholm: Statistics Sweden.

SCB (2013). *Yearbook of agricultural statistics 2013*. Stockholm: Statistics Sweden.

Schenker, M. & Gunderson, P. (2013). Occupational health in the dairy industry needs to focus on immigrant workers, the new normal. *Journal of Agromedicine* 18, 184-186.

Schmied, C., Boivin, X., Scala, S. & Waiblinger, S. (2010). Effect of previous stroking on reactions to a veterinary procedure Behaviour and heart rate of dairy cows. *Interaction Studies* 11(3), 467-481.

Schmied, C., Waiblinger, S., Scharl, T., Leisch, F. & Boivin, X. (2008). Stroking of different body regions by a human: effects on behaviour and heart rate of dairy cows. *Applied Animal Behaviour Science* 109, 25-38.

Schönbrodt, F.D. & Perugini, M. (2013). At what sample size do correlations stabilize? *Journal of Research in Personality* 47, 609-612.

Seabrook, M.F. (1984). The psychological interaction between the stockman and his animals and its influence on performance of pigs and dairy cows. *Veterinary Record* 115, 84-87.

Siegrist, M. & Cvetkovich, G. (2000). Perception of hazards: The role of social trust and knowledge. *Risk Analysis* 20(5), 713-720.

SJV (2011a). *Jordbruksföretag och företagare 2010* [Agricultural holdings and holders in 2010]. (Statistiska meddelanden JO 34 SM 1101). Jönköping: Swedish Board of Agriculture. Available from: https://www.jordbruksverket.se/webdav/files/SJV/Amnesomraden/Statistik,%20fakta/Foretag%20och%20foretagare/JO34/JO34SM1101/JO34SM1101_ikortadrag.htm [Accessed 11-10-2013]. (In Swedish with English summary).

SJV (2011b). *Heltidsjordbruket i Sverige 2010* [Full-time farming in Sweden 2010]. (Statistiska meddelanden JO 65 SM 1101). Jönköping: Swedish Board of Agriculture. Available from: https://www.jordbruksverket.se/webdav/files/SJV/Amnesomraden/Statistik,%20fakta/Foretag%20och%20foretaga re/JO65/JO65SM1101/JO065SM1101_omstatistiken.htm [Accessed 11-10-2013]. (In Swedish with English summary).

Sorensen, J.A., May, J.J., Paap, K., Purschwitz, M.A. & Emmelin, M. (2008). Encouraging Farmers to Retrofit Tractors: A Qualitative Analysis of Risk Perceptions Among a Group of High-Risk Farmers in New York. *Journal of Agricultural Safety and Health* 14(1), 105-117.

Sorensen, J.T. (2009). *Social Marketing for Injury Prevention. Changing risk perceptions and safety-related behaviors among New York farmers.* Diss. Umeå:Umeå University.

Sprince, N.L., Park, H., Zwerling, C., Lynch, C.F., Whitten, P.S., Thu, K., Burmeister, L.F., Gillette, P.P. & Alavanja, M.C.R. (2003). Risk Factors for Animal-related Injury Among Iowa Large-livestock Farmers: A Case-control Study Nested in the Agricultural Health Study. *The Journal of Rural Health* 19(2), 165-173.

Stave, C., Zachau, G., Löve, J. & Dellve, L. (2009). *Lantbrukares syn på risker och säkerhet i arbetsmiljön - ett genusperspektiv*. (Rapport från Arbets- och miljömedicin nr 125). Göteborg: Göteborgs Universitet. (In Swedish).

Sutherland, M.A. & Huddart, F.J. (2012). The effect of training first-lactation heifers to the milking parlor on the behavioral reactivity to humans and the physiological and behavioral responses to milking and productivity. *Journal of Dairy Science* 95, 6983-6993.

SWEA (2009). *Jordbruk*. (Korta arbetsskadefakta nr 2). Stockholm: Swedish Work Environment Authority. Available from: http://www.av.se/dokument/statistik/sf/Af_2009_02.pdf [Accessed 12-12-2013]. (In Swedish).

SWEA (2012). *Migrantarbete inom den gröna näringen. Kunskapsöversikt*. (Rapport 2012:14). Stockholm: Swedish Work Environment Authority. Available from: http://www.av.se/dokument/aktuellt/kunskapsoversikt/RAP2012_14.pdf [Accessed 10-11-2013]. (In Swedish).

Telezhenko, E. & Bergsten, C. (2005). Influence of floor type on the locomotion of dairy cows. *Applied Animal Behaviour Science* 93, 183-197.

Telezhenko, E., Lidfors, L. & Bergsten, C. (2007). Dairy cow preferences for soft or hard flooring when standing and walking. *Journal of Dairy Science* 90, 3716-3724.

Theorell, T., Perski, A., Akerstedt, T., Sigala, F., Ahlberg-Hulten, G., Svensson, J. & Eneroth, P. (1988). Changes in job strain in relation to changes in physiological state. A longitudinal study. *Scandinavian Journal of Work Environment & Health* 14(3), 189-196.

Tversky, A. & Kahneman, D. (1974). Judgement under uncertainty: heuristics and biases. *Science* 185(4157), 1124-1131.

Wagner, A., Palmer, R.W., Bewley, J. & Jackson-Smith, D.B. (2001). Producer satisfaction, efficiency, and investment cost factors of different milking systems. *Journal of Dairy Science* 84, 1890-1898.

Waiblinger, S., Boivin, X., Pedersen, V., Tosi, M.V., Janczak, A.M., Visser, E.K. & Jones, R.B. (2006). Assessing the human-animal relationship in farmed species: A critical review. *Applied Animal Behaviour Science* 101(3-4), 185-242.

Waiblinger, S., Menke, C. & Coleman, G. (2002). The relationship between attitudes, personal characteristics and behaviour of stockpeople and subsequent behaviour and production of dairy cows. *Applied Animal Behaviour Science* 79(3), 195-219.

Waiblinger, S., Menke, C., Korff, J. & Bucher, A. (2004). Previous handling and gentle interactions affect behaviour and heart rate of dairy cows during a veterinary procedure. *Applied Animal Behaviour Science* 85(1-2), 31-42.

Waller, J.A. (1992). Injuries to farmers and farm families in a dairy state. *Journal of Occupational and Environmental Medicine* 34(4), 414-421.

van Winsen, F., Wauters, E., Lauwers, L., de Mey, Y., van Passel, S. & Vancauteren, M. (2011). *Combining risk perception and risk attitude: A comprehensive individual risk behaviour model*. EAAE 2011 International Congress, 30 August-2 September, Zürich, Switzerland. Available from: http://ageconsearch.umn.edu/bitstream/115749/2/Winsen_Frankwin_214.pdf [Accessed 10-02-2014].

Watts, M. & Meisel, E.M. (2011). Cattle associated trauma - A one year prospective stydy of all injuries. *Injury* 42, 1084-1087.

Waynert, D.F., Stookey, J.M., Schwartzkopf-Genswein, K.S., Watts, J.M. & Waltz, C.S. (1999). The response of beef cattle to noise during handling. *Applied Animal Behaviour Science* 62, 27-42.

WEA (1977). *Arbetsmiljölagen* [Work Environment Act]. Stockholm, Sweden. (SFS 1977:1160). Available from: http://www.riksdagen.se/sv/Dokument-Lagar/Lagar/Svenskforfattningssamling/Arbetsmiljolag-19771160_sfs-1977-1160/ [Accessed 16-09-2013]. (In Swedish).

Weber, E.U., Blais, A.-R. & Betz, N.E. (2002). A domain-specific risk-attitude scale: measuring risk perceptions and risk behaviors. *Journal of Behavioral Decision Making* 15, 263-290.

WHO (1989). *Manifesto for safe communities. Safety - A universal concern and responsibility for all.* First World Conference on Accident and Injury Prevention. Available from: http://www.ki.se/csp/pdf/Manifesto.pdf [Accessed 21-09-2013].

WHO (1998). *Safety and safety promotion: conceptual and operational aspects*. World Health Organisation. Available from: http://www.ki.se/csp/pdf/Books/promo_en.pdf [Accessed 21-09-2013].

WHO (2001). *Injury surveillance guidelines*. World Health Organisation. Available from: http://whqlibdoc.who.int/publications/2001/9241591331.pdf [Accessed 21-09-2013].

Wiberg, S. (2012). *Slaughter - not only about animals. An interdisiplinary study of handling of cattle at slaughter.* Lic. Skara:Swedish University of Agricultural Sciences.

Visser, E., Pijl, Y.J., Stolk, R.P., Neeleman, J. & Rosmalen, J.G.M. (2007). Accident proneness, does it exist? A review and meta-analysis. *Accident Analysis and Prevention* 39, 556-564.

Wuebker, L.J. (1986). Safety locus of control as a predictor of industrial accidents and injuries. *Journal of Business and Psychology* 1, 19-30.

Young, R.J. & Cipreste, C.F. (2004). Applying animal learning theory: training captive animals to comply with veterinary and husbandry procedures. *Animal Welfare* 13, 225-232.

Zhou, C. & Roseman, J.M. (1994). Agricultural injuries among a population-based sample of farm operators in Alabama. *American Journal of Industrial Medicine* 25(3), 385-402.

Acknowledgements

The SLO foundation (administered by the Royal Swedish Academy of Agriculture and Forestry), the Swedish Farmers' Foundation for Agricultural Research (SLF), the Swedish University of Agricultural Sciences and JTI - Swedish Institute of Agricultural and Environmental Engineering are all greatly acknowledged for the support and funding that made this thesis possible.

This work could not have been done without the kind support and encouragement of many important people. I would particularly like to thank:

Professor *Peter Lundqvist*, my main supervisor, for your positive energy, enthusiasm and encouragement. Thank you for believing in me and giving me the freedom to choose the direction of this work, making the project very personal.

Associate Professor *Stefan Pinzke*, my assistant supervisor, for all your help with the statistics, good input on my writing and your eye for detail. You are a very warm person with a good bit of humour!

Associate Professor *Eva Salomon*, my assistant supervisor, for your support, valuable comments, quick responses and for cheering me up in times of doubt and disbelief. You made the work during the final months a bit easier.

Professor *Linda Keeling*, for all your enthusiasm, support and guidance, and for sharing your knowledge and time. You greatly improved the quality of this work and I admire your scientific knowledge and skill. I have learned a lot from you and you have been, and will continue to be, a great source of inspiration for me!

Associate Professor *Annika Lindahl Norberg*, for all the valuable support during my first study. Without your help that study would not have been nearly as good as it turned out. All my knowledge of qualitative methodology I got from you. I really enjoyed working with you!

Associate Professor *Anders Herlin*, for constructive comments that contributed to improving the papers.

Dr. *Jan-Eric Englund*, for guiding me through the statistical challenges of my data and for patiently answering all my possible and impossible questions regarding statistics.

Sofia Åström, for all the hard work helping me collect data. Without you this study would not have been possible. Thank you for getting up at 4 a.m. for the privilege of standing in an ice-cold draughty barn for seven hours, for eternalising the time when I managed to put ethanol into a diesel car, for singing along with "Du måste flytta på dig" during our long drives, for always smiling and for your never ending positive energy. I wish you all the best in your future working career!

All the farmers and farm workers who participated in my studies, for your hospitality and for generously sharing your time, thoughts and knowledge. Without you, this thesis would not have been possible.

Christel Benfalk, because you are the reason I got the chance to do this PhD degree in the first place.

Mary McAfee, for accurately amending and improving my English writing and always responding quickly to my confused questions regarding the English language.

All my colleges at AEM, for your welcoming and friendly spirit and for making me feel at home whenever I came to visit in Alnarp and as "one of the gang" during the various conference trips together.

All my colleges at JTI, for being very helpful, supporting me and cheering me up throughout my PhD studies. "JTI-andan" is very much alive and makes it worth coming to work every day! Special thanks to: *Martin*, for your patience with my Excel-related questions and for always finding the time for a chat; *Anna*, for your genuine commitment to my work during the last months and sharing my ups and downs; *Erik*, for finally solving the title issue and for patiently trying to answer my tricky English questions; *Niklas*, for company during lunch-break dog-walks; *Anders R*, for always making me smile.

My dear friends, for just being you, and for always being there when I need you the most, sharing good times and bad times. Thank you for your company during lunches, dinners, fika, movie nights, aikido and iaido practice, travel, horse riding and much, much more. You gave me the energy to go back to work!

My parents, *Sussi* and *Kalle*, for believing in me, supporting me unconditionally and always encouraging me in whatever path I've decided to follow. I hope you know that you are the best parents one can have!

Kenneth, for being the kindest brother one can have. You have a beautiful family and I am proud to be your sister!

My beloved *Tao*, for making sure I took the breaks I needed in my work. During our walks some of the best ideas were born.

Daniel, the light of my life. Thank you for putting up with me, for not complaining when I had to work on holidays and weekends, for fattening me up with your delicious cooking and for being my very best friend.

Acta Universitatis Agriculturae Sueciae
Doctoral Thesis No. 2014:23

Dairy cattle are frequently cited as a major source of injuries on dairy farms. This thesis provides a deeper understanding of the underlying factors relating to risks of injury in dairy cattle handling. On-farm investigations showed that many factors contribute to the occurrence of animal-related injuries in dairy farming and that injuries result from a complex interplay of multiple risk factors. These findings indicate a need for future interdisciplinary research and multi-targeted prevention strategies.

Cecilia Lindahl received her postgraduate education at the Department of Work Science, Business Economics and Environmental Psychology, Swedish University of Agricultural Sciences (SLU), Alnarp. She received her Master of Science degree in Agriculture at SLU, Uppsala.

Acta Universitatis Agriculturae Sueciae presents doctoral theses from the Swedish University of Agricultural Sciences (SLU).

SLU generates knowledge for the sustainable use of biological natural resources. Research, education, extension, as well as environmental monitoring and assessment are used to achieve this goal.

Online publication of thesis summary: http://epsilon.slu.se/eindex.html

ISSN 1652-6880

ISBN (print version) 978-91-576-7994-9

ISBN (electronic version) 978-91-576-7995-6