Work Environment and Health among Swedish Livestock Workers

Christina Kolstrup
Faculty of Landscape Planning, Horticulture and Agricultural Science
Department of Work Science, Business Economics and Environmental Psychology
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Abstract

During the last decades, Swedish livestock farming has undergone considerable structural changes and technical development, which have influenced the work environment and health of the workers in several ways.

The general aim of the studies was to investigate the work environment and health among Swedish livestock workers on large modern dairy and pig farms. The studies were mainly based on questionnaires.

The results showed that the livestock workers reported high frequencies of musculoskeletal disorders (MSD), especially in the *upper extremities* and in the *back*, and especially among the females. Body height or repetitive work among dairy farm workers and awkward working postures or being exposed to dust among pig farm workers were identified as potential risk factors for MSD in the *upper extremities*. No risk factors were identified for MSD in the *back*.

Machine milking among the dairy farm workers and manual raking of manure among the pig farm workers were the most time-consuming work tasks and the tasks with the highest rated physical work strain (PWS). Milking in a rotary system was found to be demanding with respect to high values of velocities and repetitiveness and almost no time for rest for hands/wrists, which might be contributing factors for the development of symptoms and injuries in the hands.

The livestock workers assessed their psychosocial work environment and mental health as good, although the quality of leadership, feedback and social support was experienced as being slightly poorer on dairy farms compared to pig farms. No psychosocial risk factors were identified for MSD.

Dairy farm workers working with healthy cows had poorer physical and mental health than those working with less healthy dairy cows.

The livestock workers were contented with their psychosocial work environment; however, they reported high frequencies of MSD. The prevalence of MSD seemed to be associated with the physical rather than the psychosocial work environment.

Keywords: Musculoskeletal Disorders, Psychosocial Work Environment, Physical Work Environment, Farm Workers, Physical Health, Mental Health, Animal Health, Questionnaire, Dairy Production, Pig Production.

Author's address: Christina Kolstrup, Department of Work Science, Business Economics & Environmental Psychology (AEM), Swedish University of Agricultural Sciences (SLU), P.O. Box 88, SE-230 53 Alnarp, Sweden. *E-mail:* christina.kolstrup@ltj.slu.se.

To Carsten, Caare & Camilla
– and Enya

Contents

List of Publications

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

I Kolstrup, C., Stål, M., Pinzke, S. & Lundqvist, P. 2006. Ache, Pain, and Discomfort: The Reward for Working with Many Cows and Sows? *Journal of Agromedicine*, 11⁄2, pp. 45-55.

II Stål, M., Pinzke, S., Hansson, G-Å. & Kolstrup, C. 2003. Highly Repetitive Work Operations in a Modern Milking System. A Case Study of Wrist Positions and Movements in a Rotary System, *Annals of Agricultural and Environmental Medicine*, 10, pp. 67-72.

III Kolstrup, C., Lundqvist, P. & Pinzke, S. 2008. Psychosocial Work Environment among Employed Swedish Dairy and Pig Farm Workers, Accepted for publication in *Journal of Agromedicine*, 13⁄1, (In press).

IV Kolstrup, C. & Hultgren, J. 2008. Is the Health of Swedish Dairy Cows Associated with the Health of the Dairy Farm Workers? Submitted.

My contributions to the papers included in this thesis are:

I Planning of the study in collaboration with my co-authors. Responsible for sampling and data collection, analyzing the data, and for writing the paper.

II Took part in planning the study and data collection.

III Planning of the study in collaboration with my co-authors. Responsible for sampling and data collection, analyzing the data, and for writing the paper.

IV Planning of the study in collaboration with my co-author. Performed sampling, data collection and analyzing the data in collaboration with my co-author. Responsible for writing the paper.

Abbreviations, Terms and Definitions

Abbreviations are used as follows in this thesis:

APA	The Swedish Animal Protection Act (1988:534)
AVS	Average Score
BMI	Body Mass Index
BSE	Bovine Spongiform Encephalopathy
BST	Biostatistical Theory of Health (Boorse, 1977)
CI	Confidence Interval
COPSOQ	Copenhagen Psychosocial Questionnaire
CR-Scale	Category Rating Scale
ILO	International Labour Organisation
IR	Animal Disease Incidence Rate
GNP	Gross National Product
HTH	Holistic Theory of Health (Nordenfelt, 2001; 2007)
MPF	Mean Power Frequency
MSD	Musculoskeletal Disorders
ODTS	Organic Dust Toxic Syndrome
OR	Odds Ratio
PHY	Physical Health Score
PSY	Mental Health Score
PWS	Physical Work Strain Index
SD	Standard Deviation
TOT	Physical and Mental Health Score
USDA	United States Department of Agriculture
WA	Provision for Working with Animals (2008:xx)
WEA	The Swedish Work Environment Act (1977:1160)
WHO	World Health Organisation
WMSD	Work-Related Musculoskeletal Disorders

Terms and definitions are used as follows in this thesis:

Ache and pain	Unpleasant sensory and emotional experiences associated with actual or potential tissue damage
Agriculture	The science or art of cultivating the soil, producing crops, and raising livestock (Murphy, 1992)
Any body part	A cluster consisting of perceived MSD in at least one of the following body parts: shoulders, elbows, hands/wrists, hips, knees, feet, neck, upper back and lower back
Back	A cluster consisting of perceived MSD in at least one of the following body parts: neck, upper back and lower back
Discomfort	Physical or mental distress (Hagberg *et al.*, 1997)
Disease	A disorder that can be assigned to a diagnostic category. It usually has a distinct clinical course and often a distinct aetiology (Last, 2001; Hagberg *et al.*, 1997)
Disorders	Descriptor for perceived symptoms, problems, aches, pains and discomforts for pathological entities in which the functions of an organ or the body system are disturbed or abnormal (Last, 2001; Hagberg *et al.*, 1997)
Farmers	Self-employed farmers, farm owners
Farming	The practice of agriculture (Murphy, 1992)
Fatigue	Incapacity to continue strenuous physical or mental work at the same rate as previously (Hagberg *et al.*, 1997)
Injury	Acute harm or damage to the body caused by an external agent such as physical, mechanical, chemical, thermal, or other environmental factors (WHO, 2001)
Health	A state of complete physical, mental and social well-being and not merely the absence of disease or infirmity (WHO, 1946; 2005)
Large livestock farms	More than 100 dairy cows or more than 200 sows
Livestock	Dairy cows and sows including their offspring
Lower extremities	A cluster consisting of perceived MSD in at least one of the following body parts: hips, knees and feet
Mental health	A state of well-being in which the individual realizes his or her own abilities, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to his or her community (WHO, 2005; 2008)
Modern farms	Newly build or renovated livestock barns within the last 10 years with sophisticated technical equipment and advanced machinery
Morbidity	The incidence or prevalence of a disease or of all diseases in a population (Medical Dictionary, 2008)
Prevalence	The number of events, e.g. of a given disorders or conditions, in a given population at a designated time (Last, 2001)
Small livestock farms	Less than 100 dairy cows or less than 200 sows

Upper extremities	A cluster consisting of perceived MSD in at least one of the following body parts: shoulders, elbows and hands/wrists
Vitality	Feeling vigour, having a lot of energy, not feeling exhausted & tired
Workers	Employed and paid farm and livestock workers (do not include unpaid family members)
Zoonos	Transmittable infections from farm animals to humans

Background

Livestock farming is a world wide occupation producing milk, meat and other products for human consumption and constitutes 4% of the world's gross national product (GNP) (Economy Watch, 2008; Kasnakoglu, 2004). On a global level, around 40% of the total work force is engaged in agriculture (ILO, 2004).

Structural and Technical Development in Livestock Farming

The structure of livestock farming differs between and within countries from small family farms with a small amount of livestock for own production or sale, to huge commercial farms with thousands of livestock producing large amounts of farm products per farm (EUROSTAT, 2007; Statistics Sweden, 2006; USDA, 2002). In the European countries, the trend of diversity in farm size is evident, livestock farms become fewer in number but larger in both acre and herd sizes (EUROSTAT, 2007).

In Sweden 2005, agriculture constituted around 0.5% of the GNP and occupied about 174 000 people including farmers, family members and workers (65% males and 35% females), which is about 4% of the total Swedish working force (Statistics Sweden, 2006). During the last two decades, there have been major structural changes in Swedish livestock production. From 1985 to 2006, the number of dairy and pig farms decreased considerably by 77% and 88%, respectively; in 2007, there were 8027 dairy farms and 2414 pig farms in Sweden. During the same period the livestock herds have become larger and the mean herd size has increased from 18 to 51 dairy cows and from 18 to 116 sows. In Sweden, livestock farms with a herd size of more than 100 dairy cows or more than 200 sows are considered large farms (Swedish Dairy Association, 2008; Statistics

Sweden, 2006). The biggest farms in Sweden have about 1300 dairy cows and 1100 sows.

Although the amount of produced milk has decreased by 17%, the milk yield per dairy cow increased by 40% during the period 1985-2006 (Swedish Dairy Association, 2008). In addition, the number of produced piglets per sow per year has increased by 14% during the same 20 year period (PIGWIN, 2008).

Yet, there are still a lot of small family-owned farms and in Sweden an increasing interest and demand for organic farm products from local farms and sold at the local grocery with farm trademarks has created a niche for smaller farms (Center for sustainable agriculture, 2008; Nielsen, 2007; Swedish Board of Agriculture, 2003).

Family-owned farms still dominate in Sweden. In 2005, around 87% of the people engaged in agriculture worked on family farms and almost 33% spent more than 50% of their time working with farming. About 20% of the farmers were older than 65 years whereas 6% were younger than 35 years (Statistics Sweden, 2006). The expansion from small family farms to larger farms has implied that farmers can no longer tend and manage the livestock themselves and employed and paid workers have become essential (Hadley *et al.*, 2002).

Along with the structural changes in livestock farming there has been considerable technical development resulting in new production systems and devices. In Sweden, farms with a large number of livestock usually have newly built or barns renovated within the last 10 years, sophisticated technical equipment and advanced machinery. These farms typically have loose-housing barns with technical well-equipped parlour or rotary milking systems (e.g. light-weight clusters, automatic cluster removers, adjustable floors in the parlours, computers with information regarding animal health and performance), or in some cases automatic milking robots for the dairy cows, machines for feeding, manual raking of manure and strewing of litter. The pig barns often comprise several sectioned barns for farrowing sows, weaned piglets and growing-finishing pigs, computerised and automatic feeding, manual raking of manure into the culverts and advanced ventilation systems, dust-reducing devices and robots for automatic washing of the pig pens (Hedlund, 2008; Olsson & Ascard, 2008; Sällvik & Dolby, 2008; Swedish Board of Agriculture, 2007; Benfalk *et al.*, 2005; Oostra, 2005; Stål & Englund, 2005; Flygare & Isacson, 2003; Pinzke, 2003; Olsson *et al.*, 1993). This development has made the farms more efficient and easier to manage (Flygare & Isacson, 2003; Hadley *et al.*, 2002; Lundqvist, 1996), and has also helped to reduce the workload among the livestock workers (Stål *et*

al., 2003; Nevala-Puranen *et al.*, 1996; Nevala-Puranen *et al.*, 1993). The daily work tasks for the workers on farms with a large number of livestock have become more specialized and imply that the farm workers spend more time on specific and fewer work tasks compared to the work carried out on small farms with fewer animals (Hedlund, 2008; Stål & Englund, 2005; Pinzke, 2003).

Swedish Dairy Farming

Sweden has about 388 000 dairy cows of which 35% are housed on farms with more than 75 cows per herd (Statistics Sweden, 2006). Loose-housing barns with cubicles, parlour, rotary or automatic milking systems are more and more often seen in dairy barns and 41% of the Swedish dairy cows are housed in these systems (Figures 1 and 2) (Swedish Dairy Association, 2007).

Figure 1. Loose-housing barns with cubicles.

Figure 2. Milking in a parallel parlour.

However, the traditional tethering system with dairy cows tied up, and with pipeline milking is still the most common (Figures 3 and 4) (Swedish Dairy Association, 2007).

Figure 3. Tethering system with cows tied up.

Figure 4. Milking in a tethering system.

In the parlour and rotary milking systems the milking equipment is stationary and the cows walk to the parlour or on to the rotating platform (carousel). The workers stand in a ditch (about 0.8-0.9 m. below the milking platform) and milking is performed in an upright standing position. In the tethering system, the workers have to carry or pull all the equipment along a rail to the cows. Milking in this system often involves bent and awkward working postures (Stål *et al.*, 1999; Nevala-Puranen *et al.*, 1996; Nevala-Puranen *et al.*, 1993; Lundqvist, 1988b).

The new automatic milking systems replace the twice-daily manual milking task. In April 2008, approximately 420 Swedish dairy farms had automatic milking systems and about 50% of these farms had 2 milking units per farm. The capacity of the automatic milking system is about 60 dairy cows milked per day, implying that a herd of 120 dairy cows requires 2 milking units. Today, only 8 large dairy farms in Sweden have 3 or 4 milking units per farm (Larsson, 2008).

The capacity of the milking systems varies depending on the number of cows, milking units, design of the barn, working routines, work pace, and the behaviour and udder health of the cows (Hedlund, 2008; Jakobsson, 2000; Stål *et al.*, 2000; Stål *et al.*, 1999). The workers on large dairy farms usually work full-time in the barns (40 hours per week) and work according to a rolling timetable which normally involves one or two milking shifts per day (Pinzke, 2003). About one third of the workers are females (Statistics Sweden, 2005; Pinzke, 2003). Depending on the size of the parlour or rotary milking system, usually one or two workers carry out the milking of the cows and each milking shift usually lasts a couple of hours (Hansen, 1999). Besides machine milking, the workers carry out several other work tasks, such as tending calves and young cattle, manual raking of manure from cubicles, strewing of litter, feeding, performing artificial insemination, daily supervision, possible treatment of sick animals and computer registration of data regarding livestock performance and health. Several of the work tasks such as strewing of litter in cubicles, cleaning of alleys and feeding of roughage are usually done with machines (Hedlund, 2008; Gustafsson, 2005).

Swedish Pig Farming

There are around 1.7 million pigs in Sweden, and 184 000 of these are sows for breeding of piglets. Sixty-four per cent of the sows are housed on pig farms with a herd size of more than 200 (Statistics Sweden, 2006). Pig farming in Sweden can be divided into three production categories: One

category comprises just sows and piglets and the piglets are sold off to farms specializing in growing-finishing pigs (category two). The third category is a combination of the two production systems, named integrated pig production (Olsson & Ascard, 2008; Gustafsson & Lundqvist, 2003; Olsson *et al.*, 1993). The number of farms with sows and specialized production of piglets amounts to approximately 1600 farms (although this figure is somewhat uncertain) which corresponds to 66% of the total number of Swedish pig farms (Statistics Sweden, 2006).

Large Swedish pig farms usually have sows and piglets sectioned into several farrowing (figures 5 and 6), gestations (Figure 7) and weaning units (Figure 8). Almost all large pig farms practice a principle of "all-in-all-out", where groups of pigs are moved between different sections depending on the pigs' production status (gestation, farrowing or weaning). The sections are carefully cleaned and washed before new groups enter them. The reason for sectioning is to minimize the possible spread of infections among the animals (Swedish Animal Welfare Agency, 2007; Olsson *et al.*, 1993).

Figure 5. Farrowing section with sows.

Figure 6. Pig pen in the farrowing section.

Figure 7. Gestation section.

Figure 8. Weaning section.

Pig farm workers in Sweden often work full-time (40 hours per week) in the barns and according to a rolling timetable. However, unlike the dairy farm workers, they do not have early mornings or late evenings at work (Stål & Englund, 2005).

Work tasks in farrowing, weaning and gestation sections can be roughly divided into daily, weekly or monthly performed work tasks, however, this depends on the number of sows and working routines on the farms. Manual raking of manure from pig pens, strewing of litter, supervision of animals and technical equipment, possible treatment of sick animals and computer registration of livestock data are work tasks conducted on a daily basis. Work tasks performed on a more periodic basis are gelding of piglets, earmarking, vaccination, relocation of pigs, artificial insemination and cleaning of pig pens with a high pressure washer or automatic cleaning robot (Olsson & Ascard, 2008; Mattson *et al.*, 2004; Olsson *et al.*, 1993).

Swedish Legislation

Sweden has protection acts, and appurtenant ordinance and provisions regulating the working environment for both people and animals. In the near future (June 2008) a new provision is likely to be decreed (Referral WA, 2008) with specific focus on working with animals (Provision WA, 2008).

Work Environment Act (WEA)

Working conditions for people is regulated by the Swedish Work Environment Act (WEA, 1977) and appurtenant provisions (Provisions WEA, 2008) with the purpose to prevent ill-health and injuries at work and generally achieve a good work environment. The legislations state that the working environment shall be satisfactory with regard to the nature of the work and social and technical progress in the community. Working conditions shall be adapted to people's different physical and mental aptitudes. The workers shall be given the opportunity to participate in the design of his/her own working situation and in processes of change and development affecting her/his own work.

Technology, work organisation and job content shall be designed in such a way that the workers are not subjected to physical or mental strain which can lead to ill-health or injuries. Types of wages and the distribution of working hours shall also be taken into account in this connection.

Closely controlled or restricted work shall be avoided or limited. Efforts shall be made to ensure that work provides opportunities for variety, social contact and co-operation, as well as coherence between different tasks.

Furthermore, efforts shall be made to ensure that working conditions provide opportunities for personal and vocational development, as well as for self-determination and professional responsibility (Provisions WEA, 2008; WEA, 1977).

Animal Protection Act (APA)

The Swedish Animal Protection Act (APA, 1988), and appurtenant ordinance (Ordinance APA, 1988) and provisions (Provisions APA, 2008) apply to the welfare of domestic animals and other animals kept in captivity. These legislations state that animals shall be treated well and be protected from unnecessary suffering and disease. If animals get sick or injured they shall be provided with the necessary care without delay. Furthermore, they shall be provided with sufficient food, water, adequate care and treatment. Stables and other premises shall provide animals with adequate space and shelter, and they shall be kept clean. Animals that are bred and kept for the production of food, wool, skins or furs shall be kept and handled in a good environment for animals and in such a way as to promote their health and allow natural behaviour.

According to legislation it is not permitted to use growth hormones or antibiotics as growth promotion or for preventive purposes, or to use heat synchronisation of heifers. It is forbidden to keep sows tied up or have full slatted floors in the pens. The legislations also state that dairy cows are required to be on pasture during the summer period. The lying area for dairy cows must be comfortable with bedding material or other adequate material. Pigs must have access to straw in the pens which makes, for example manual raking of manure both a time-consuming as well as laborious job. In addition, animal welfare must be taken into consideration regarding the assessment of existing and the introduction of new production systems and technology (Provisions APA, 2008; APA, 1988; Ordinance APA, 1988).

Provision for Working with Animals (WA)

According to the Swedish Official Statistics approximately 400 work-related injuries in agriculture, of which 50% were related to working with domestic animals, were reported in 2004 (Swedish Work Environment Authority, 2006a). A study conducted by the Swedish University of Agricultural Sciences and Statistics Sweden showed that only 8% of the actual work-related injuries (70% related to domestic animals) emerged from the official statistics of occupational injuries (Pinzke & Lundqvist, 2007).

To reduce and prevent these injuries a referral for a new provision, Working with Animals (Provision WA, 2008), is being prepared for decree in June 2008 (Referral WA, 2008). The provision concerns general requirements regarding working with animals and specific rules for working with certain types of animals that imply a risk for injuries and ill-health for the workers. The provision makes demands on the design of farm buildings and equipment, the acquirement of knowledge about animal behaviour, information about and instructions on the implications of working with animals. Furthermore, the provision comprises several measures for avoiding injuries in relation to specific work tasks such as relocation of animals, treatment of animals and specific risks involved with working with dairy cows, cattle, horses and pigs (Provision WA, 2008).

The provisions of WEA and APA are issued by two different authorities, the Swedish Work Environment Authority and the Swedish Board of Agriculture, with very little coordination and evaluation before introducing them. The provisions do not always go hand in hand, and at times the Animal Protection legislation has been in conflict with the Work Environment legislation, for example the ban of caged laying hens (Lundqvist, 2006). A coordination of the legislation would be beneficial and the introduction of the provision for Working with Animals will probably contribute to an improved work environment and welfare for both animals and humans.

The structural and technical development in Swedish livestock farming has probably contributed to a reduced work load, which most likely has had a positive effect on the health of the livestock farmers and workers. The work environment in livestock farming should be such that farmers and workers can work and remain in the occupation throughout their entire working life, without jeopardizing their health. A safe and healthy work environment is also important if the occupation is to be attractive as a work place for the younger generation.

This thesis focuses on the work environment and health among employed male and female livestock workers (in the following text referred to as workers), working on dairy and pig farms (in the following text also named livestock farms), with newly built or renovated barns within the last 10 years, with sophisticated technical equipment and advanced machinery (in the following named modern farms), and with mean herd sizes larger than 100 cows and 200 sows (in the following named large farms).

Introduction

Work Environment

A good work environment can be defined as a place where work can be performed by any person productively during a normal working day and working life without causing physical or mental ill-health (Pinzke, 1999b). Work environment as a concept includes several work factors in a work place which may affect the individual. These factors comprise physical (e.g. vibration, dust and awkward working postures), chemical (e.g. solvents and gases), biological (e.g. zoonoses), as well as psychosocial factors (e.g. work demands, social relations at work and job satisfaction) (Donham & Thelin, 2006; Bohgard *et al.*, 1997; Langley *et al.*, 1997; WEA, 1977). In livestock farming, the animals are also an important work environmental factor that may affect the safety and health of the workers.

This thesis focuses on some aspects of the physical and psychosocial work environment. The animals themselves are also considered as a work environmental factor in this thesis.

Physical Work Environment

Agriculture is one of the three most hazardous sectors in the world (the other two are mining and construction). The International Labour Organisation estimates that of 335 000 fatal work-related accidents a year worldwide, some 170 000 involve agricultural workers. Several more of the world's agricultural workers suffer serious injury in workplace accidents caused by machinery, chemicals and animals (ILO, 2004; ILO, 1999). In 2006, 12.8 fatal injuries per 100 000 workers occurred within Swedish agriculture compared to 1.6 for all occupations (Swedish Work Environment Authority, 2008).

The sector comprises several different branches such as production of crops and raising of livestock, which include a diversity of work tasks. Farmers and farm workers are exposed to a variety of the above-mentioned work factors or hazards (e.g. injuries caused by machines and animals), which can affect their safety and health (Rautiainen & Reynolds, 2002; Lundqvist, 2000; Gustafsson, 1997; Murphy, 1992; Dosman & Cockcroft, 1989).

Physical Work Load in Dairy Barns

It is well-known that working with dairy farming, and milking in particular, is physically demanding and associated with difficult working postures and movements (Stål *et al.*, 2000; Lundqvist *et al.*, 1997; Ahonen *et al.*, 1990; Arborelius *et al.*, 1986).

Results from a study of working postures in different milking systems revealed that milking in tethering systems involved unacceptable working postures during 38% of the working time and 9% in loose-housing systems with parlour milking (Lundqvist, 1988b). Installation of a milking rail in tethering systems improved the work postures, and the twisted back postures decreased from 29% to 11% (Nevala-Puranen *et al.*, 1993). Further improvements of work postures were observed when the milking parlours were introduced, which were shown in a study by Nevala-Puranen (1996). The dairy farmers worked with a straight back for 85% of the time and with the arms under shoulder level for 76% of the time in the milking parlours.

Several studies have shown that milking in parlours is physically strenuous for the upper extremities and especially among females (Pinzke *et al.*, 2001; Stål *et al.*, 2000; Stål *et al.*, 1999; Stål *et al.*, 1996). A study using electromyography showed that milking in loose-housing systems with parlours was associated with lower muscle peak loads in the biceps, flexor and extensor muscles in the forearm compared to milking in tethering systems (Stål *et al.*, 2000). However, the static muscle load was higher and the relative duration of muscular rest was lower in parlours than in tethering systems.

Work tasks such as premilking, attaching the teat cups and drying the dairy cow's udder were found to be the most physically demanding for the hands/wrists during milking in parlour systems and especially among females (Pinzke *et al.*, 2001). However, a study among dairy farmers working with an average herd size of 45 cows in loose-housing systems with parlour milking and milking shifts lasting two hours showed that milking was light work with respect to heart rate, work posture and perceived exertion. (Perkiö-Mäkelä & Hentila, 2005)

Physical Work Load in Pig Barns

Working with pigs is regarded as a strenuous job, involving exposure to organic dust, heavy work tasks performed repetitively or for several hours a day. This has been shown to be associated with disorders in the musculoskeletal system (Stål & Englund, 2005; Gustafsson & Lundqvist, 2003; Hartman *et al.*, 1999; Nyström, 1997; Christensen *et al.*, 1992). An observational study of pig farmers revealed that more than 50% of the working time was spent in a bent position which, in the long run, may cause MSD (Hartman *et al.*, 2000). Christensen *et al* (1992) found among Danish pig farmers that the high degree of low back pain could be explained by the large amount of manual material handling in combination with difficult working postures.

Organic dust in the pig barns is a major risk factor for the health of farmers and farm workers and might cause various acute and chronic respiratory diseases (Kirkhorn & Schenker, 2002; Donham, 2000). Farmers and farm workers who are exposed to high concentrations of organic dust in the air in combination with heavy work loads involving high pulmonary ventilation, have an increased risk for respiratory symptoms and diseases (Christensen *et al.*, 1992).

Psychosocial Work Environment

The term psychosocial work environment is a multidimensional concept describing various psychosocial aspects of the work environment. No precise definition of the concept appears to exist. However, the psychosocial work environment can be defined as the psychological and social interactions between individuals and the environment at work (Westlander, 1978).

A good psychosocial work environment can be characterized as the individual's possibility to have control over his or her work situation, positive work and social relationships with superiors and colleagues, stimulation from the work, and an adequate physical and mental work load (Rubenowitz, 1984).

Two well-known theoretical models have been suggested to explain the relation between psychosocial work stressors and health, the *Demand-Control* model by Karasek and Theorell (1990) and the *Effort-Reward* imbalance model by Siegrist (1996). The *Demand-Control* model is based on the psychological demands at work, the use of skills and the work task control, and their effect on health. High work demands can endanger the worker's health, but a high degree of control is considered to reduce this risk (Karasek & Theorell, 1990). In the *Effort-Reward* imbalance model a high degree of effort (for example, high job demands and/or a considerable individual need

for control) in combination with low reward (for example low job status, low esteem and/or low pay) are regarded as particularly stressful and detrimental to the health (Siegrist, 1996).

Psychosocial Work Environment in Farming

Several studies of the psychosocial work environment have been conducted, however, these have focused mainly on farmers, and very few on farm workers. Some international studies have shown that farmers experience high demands at work and lack of control concerning unpredictability of the weather, low commodity of prices, increasing expenses, high debt load (Wallis, 2006; Walker *et al.*, 1986), difficulties balancing work and family responsibilities (CASA-ACSA, 2005; Walker & Walker, 1987), and new legislations, the amount of paper work and media criticism (Booth & Lloyd, 1999).

In a Swedish study, Lundqvist (1988a) found that younger dairy farmers between 30 and 40 years of age, worked for longer hours, experienced a greater work intensity, were more concerned about unfavourable prices and high interest rates than dairy farmers older than 45 years of age. In addition, they were more concerned about the lack of spare time and felt it was difficult to handle conflicting demands and expectations from work and family. In a study among farmers affiliated with the Swedish Occupational Health Organization, Thelin found that although male farmers experienced high work demands, they had a large degree of stimulation from and control over their work situation as well (Thelin, 1998). However, they felt more insecure about their working conditions (Holmberg *et al.*, 2004).

A study conducted among Danish farm workers showed that there was a difference between how the farmers, managers and farm workers assessed their psychosocial work environment (CASA, 2005). The farmers had higher work demands and more influence over their work situation than the farm workers, which also Thelin (1998) found. Both the farmers, managers and the farm workers were very contented with their work, believed their work was meaningful and felt they had an important role to fill as farm workers.

Animal Health

Animals may have a negative impact on human health, in the form of zoonoses (such as viruses, bacteria and parasites), allergies (skin epithelium and hair), infections (from scratches and bites) and injuries caused by kicks and crushing (Donham & Thelin, 2006; Langley *et al.*, 1997; Plaut *et al.*, 1996; Dosman & Cockcroft, 1989).

Working with animals may also be beneficial. Several researchers have studied and discussed the topic of human health benefits of domestic animals (Bokkers, 2006; Podberscek *et al.*, 2000; Beck & Meyers, 1996; Anderson *et al.*, 1992; Levinson, 1964), human attitude and behaviour towards animals and the effect of these on animal behaviour, performance and welfare (Hemsworth *et al.*, 2000; Hemsworth & Coleman, 1998; Seabrook, 1984; Seabrook, 1972). However, none of these concerned the effect of farm animals´ health on livestock workers´ health and well-being in a work setting.

Evidence is found in research that supports the benefits of animal companionship for various segments of the population, especially children, the elderly, the socially isolated and the disabled (Jennings, 1997; Beck & Meyers, 1996). The psychiatrist Boris Levinson (1964) was the first to describe that emotionally disturbed children, who experienced difficulties in their relationships with people, related more easily or quickly to animals (Bokkers, 2006).

Studies have also indicated that animal companionship is associated with better physical health among humans (Raina *et al.*, 1999; Serpell, 1991; Friedmann *et al.*, 1980). Anderson *et al* (1992) found that pet owners had lower values of several well-known risk factors for the development of cardiovascular disease, such as blood pressure and plasma triglyceride, than people without pets. Besides the physical health benefits, animal companionship may also be beneficial for mental health, for example by decreasing symptoms of stress, anxiety, loneliness and depression (Barker *et al.*, 2003; Raina *et al.*, 1999). Results from two qualitative studies suggested that contact or working with farm animals had a positive therapeutic effect among children in a residential treatment centre (Mallon, 1994) and among people with mental disorders (Berget, 2006).

As in human medicine, the concept of health and disease is also essential in veterinarian medicine. Yet, a review of 500 veterinarian textbooks showed that the concepts were rarely explicitly defined and among the definitions of health, the following were found: normality, biological function, homeostasis, physical and psychological well-being and productivity including reproduction (Gunnarsson, 2006).

In this thesis dairy cows´ health is conceptualized as the presence of diseases and operationalized by incidence rates of veterinary-treated cases of eight common clinical diagnosis groups among dairy cows (Andersson, 1988; Emanuelson, 1988).

Individual Factors

Individual factors such as age, gender, body height and weight, lifestyle factors such as physical exercise, smoking and alcohol habits, number of years in the occupation, former work environmental exposure, competing diseases and hereditary characters, may also be of importance regarding if, how, when and to what extent the health of an individual is affected by the work environment (Edling *et al.*, 2003; Hagberg *et al.*, 1997; Wilson & Corlett, 1995).

Health

The definition and conception of health is widely discussed and many definitions exist; however, just a few will be drawn in the following. Christopher Boorse (1977), professor of philosophy of science, presented the Biostatistical Theory of Health (BST), which states that *health is identical with the absence of disease*. Furthermore, disease was defined as *statistically abnormal bodily functions and conditions which affect the individual's reproduction and survival* (Boorse, 1977). This, in fact, implies that an individual experiencing diffuse pains and aches in the body can be diagnosed as healthy, if the condition does not correspond to a defined disease, and the condition will consequently be considered as normal (Wester, 2007).

A Swedish professor of philosophy of medicine and health care, Lennart Nordenfelt (2001; 2007), considers that an individual's *capability to achieve* is essential for his or her health. Nordenfelt defines health in a wide sense as *the physical and mental conditions which bring an individual capable of achieving vital goals under understood or accepted prerequisites*. He named the theory, the Holistic Theory of Health (HTH) (Nordenfelt, 2007; Nordenfelt, 2001). According to this author, an individual's vital goals are his or her most essential goals in life, and more than just survival.

The World Health Organisation (WHO) defines health as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity (WHO, 2005; WHO, 1946). The ambition was to encompass the health definition of WHO, however this thesis merely covers a fraction of it.

Health of Livestock Farmers and Workers

Farming is associated with several occupational related injuries, diseases and disorders and some of the most common are injuries caused by animals, chemical handling or machines, giving rise to hearing loss, respiratory and

skin diseases and MSD (Donham & Thelin, 2006; Kirkhorn & Schenker, 2002; Rautiainen & Reynolds, 2002; Lundqvist, 2000; Gustafsson, 1997; Murphy, 1992). Yet, Swedish studies have shown lower mortality and morbidity rates among farmers compared to rural and urban referents regarding cardiovascular disease and mental diseases (Stiernström et al., 2001; Thelin, 1991).

To operationalize the health of livestock workers, this thesis covers just some of several important physical aspects, such as the prevalence of MSD*, discomfort from the work environment relating to health, and psychosocial aspects, such as well-known risk factors and symptoms for mental health.*

Musculoskeletal Disorders (MSD)

The term musculoskeletal disorders (MSD) are an umbrella for disorders and diseases in the musculoskeletal system including muscles, joints, tendons, ligaments and bones. Work-related musculoskeletal disorders (WMSD) are a descriptor for disorders and diseases of the musculoskeletal system having a proven or hypothetical work-related causal component (Hagberg *et al.*, 1997). It is assumed that repeated efforts (e.g. movements and postures), static work, continuous loading of the tissue structures or lack of recovery time, trigger or cause a pathological process that then manifests itself as a WMSD (Hagberg *et al.*, 1997).

In the literature MSD are also referred to as overexertion/overuse injuries, cumulative trauma disorders, repetitive strain injuries, and sprains and strains (Lessenger, 2006; Hagberg *et al.*, 1997; Langley *et al.*, 1997; Murphy, 1992). MSD can be classified into two categories: as a result of acute injuries and as a result of cumulative trauma. Acute injuries result from one-time trauma, for example slipping, kicks from animals and other single events, and cumulative trauma develops from repeated exposure of a stressor. The acute conditions are normally not incorporated into the term MSD (Davis & Kotowski, 2007; Lessenger, 2006) and are not included in this thesis either. Moreover, MSD is used as a descriptor for perceived symptoms, problems, ache, pain and discomfort in the musculoskeletal system in this thesis.

MSD is considered to be multifactorial and besides physical work load, other factors, for example, psychosocial work environment, mental ill-health, competing diseases and leisure time, probably contribute to the aetiology of MSD as well (Nisell & Vingård, 1992).

The neutral term musculoskeletal disorder is used in this thesis since the magnitude of causality from work exposures in relation to exposure during leisure time is difficult to establish and sometimes questioned (Hansson, 2001).

Prevalence of MSD

In Sweden, MSD are commonly reported in the general population, are more common among blue-collar workers than white-collar workers and are more common among females (Arvidsson *et al.*, 2006; Swedish Work Environment Authority, 2006c; Treaster & Burr, 2004; Walker-Bone *et al.*, 2004; Gummesson *et al.*, 2003; Bergman *et al.*, 2001; Nordander *et al.*, 1999). In the age group 25-34 years of age, about 52% of the general male and 67% of the female Swedish population reported 2007 that they regularly suffered from ache and pain, and 8% and 17%, respectively, suffered from major pain (Statistics Sweden, 2008). Approximately, one million workers (24% of the total Swedish working force) reported work-related disorders in 2006 and about 600 000 of these were related to physical disorders (Swedish Work Environment Authority, 2006b).

Several national and international studies have shown that farming is a physically demanding occupation with work tasks that can cause MSD; this is frequently reported among farmers and farm workers (Davis & Kotowski, 2007; Gomez *et al.*, 2003; Holmberg *et al.*, 2002; Walker-Bone & Palmer, 2002). According to the Swedish Work Environment Authority 69 % of the reported occupational diseases among people engaged in Swedish farming were related to the musculoskeletal system compared to 55% for all occupations (Swedish Work Environment Authority, 2008).

MSD in Dairy Farming

MSD are common among dairy farmers, and especially in the lower back, shoulders, hands/wrists and knees (Hartman *et al.*, 2006; Gomez *et al.*, 2003; Pinzke, 2003; Lower *et al.*, 1996; Stål *et al.*, 1996; Hildebrandt, 1995; Manninen *et al.*, 1995).

In a study conducted among 3000 Swedish dairy farmers including 1000 females, 82% of the males and 86% of the females reported MSD in some part of the body 12 months prior to the study. MSD were most frequent in the shoulder (49%), neck (35%), and hands/wrists (35%) among females, and in the lower back (55%) and knees (41%) among the males (Gustafsson *et al.*, 1994). The corresponding frequency of MSD in some body part (84%) was found in a study of 161 Swedish female dairy farmers (Stål *et al.*, 1996).

Results from a study of 1465 dairy farmers active in 1988 and of 686 active farmers in Skåne (the southernmost province of Sweden) in 2002, showed that 83% of males and 90% of females in 2002 reported some kind of MSD. This was an increase compared to the 81% males and 84% females who reported some kind of MSD in 1988. The most significant change in MSD prevalence among both the male and the female dairy farmers was an

increase in the shoulder, neck and in the hands/wrists. Among the males in 2002, MSD were most frequently reported in the lower back (54%), shoulders (44%) and knees (38%). The females reported MSD most frequently in the shoulders (56%), lower back (47%) and hands/wrists (46%) (Pinzke, 2003).

MSD in Pig Farming

Fewer studies have been conducted regarding the impact of the work load on MSD in pig farming. Christensen *et al* (1992) found that the most frequently reported prevalence of MSD was in the lower back (60%), neck (32%) and in the shoulders (20%) among Danish pig farmers. Among Dutch pig farmers the prevalence of MSD was most frequent in the lower back (62%), neck (30%), elbows and hands/wrists (20%) and in the knees (17%) (Hildebrandt, 1995).

In Sweden, a small study of pig farm workers showed that the prevalence of MSD mainly was located to the shoulders (40%), lower back (42%) and neck (33%) 12 months prior to the study (Nyström, 1997). Stål & Englund (2005) found high frequencies of MSD among 288 Swedish pig farmers working in herds with more than 100 sows. Among the 202 males in the study, 83% reported some kind of musculoskeletal problems, mainly in the upper extremities. Ninety-two percent of the 86 female pig farmers reported MSD, especially in the shoulders (30%) and in the hands/wrists (53%).

Several studies and reviews have concluded that there are significant associations between MSD and factors related to the psychosocial work environment, and this especially regarding high work demands, low job control, lack of social support and low job satisfaction (Ariens *et al.*, 2001; Hoogendoorn *et al.*, 2000; Bongers *et al.*, 1993). Furthermore, physically demanding work, such as an intensified work load, monotonous and repetitive work tasks combined with psychosocial factors, such as time pressure, overtime, low control and low job satisfaction have been found as possibly predisposing for upper extremity disorders (Bongers *et al.*, 2002).

Mental Health

The term mental health is difficult to define and several definitions of the concept exist (Wikipedia, 2008; Nordenfelt, 2001; Jahoda, 1980). WHO describes mental health as a state of well-being in which the individual realizes his or her own abilities, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to his or her community (WHO, 2008; WHO, 2005).

Stress factors as a consequence of a poor psychosocial work environment might constitute an adverse effect on the both physical and mental health, well-being and the quality of life of the individual (Siegrist, 1996; Karasek &

Theorell, 1990). In Sweden, mental stressors are the most common cause of work-related disorders among females and the second most common among males (Swedish Work Environment Authority, 2006b).

In this thesis the term mental health is exemplified and operationalized in different ways by the subjects' apprehension of discomforting psychosocial factors and symptoms for mental health and vitality.

Mental Health in Farming

Several studies have investigated the mental health, and symptoms of stress and depression among farmers (Wallis, 2006; Fraser *et al.*, 2005; Gregoire, 2002; Thelin *et al.*, 2000; Booth & Lloyd, 1999; Stallones *et al.*, 1995; Lundqvist, 1988a; Walker & Walker, 1987). In a review, Fraser *et al* (2005) concluded that male and female farmers, as well as farm workers, were faced with a number of stressors relating to the physical environment, the structure of farming and uncertainties associated with it, which were suggested to be detrimental to their mental health.

Wallis (2006) found that Australian dairy farmers, despite their raised level of control, had a very high degree of stress symptoms caused primarily by external factors, such as environmental and globalization demands, along with high work demands and low social support. The outbreaks of bovine spongiform encephalopathy (BSE) and foot and mouth epidemics in the United Kingdom during the nineties were acute and extreme examples of farming crises which lead to mental ill-health and depression among a large number of farmers (Gregoire, 2002).

Lundqvist (1988a) found that young Swedish dairy farmers (30-40 years) felt the work was hectic, tied and risky, and were more anxious than their older counterparts (more than 45 years of age). However, they appreciated seeing the results of their work and their independence. Other studies among Swedish farmers have proved low mortality and morbidity regarding different mental diseases (not specified) (Stiernström *et al.*, 2001; Thelin, 1991).

Aims of the Thesis

The general aim of this thesis is to:
Investigate the work environment and health among Swedish livestock workers on large modern dairy and pig farms and to identify possible effects of the work environment on their health.

The specific aims of the included papers were to:

- Investigate the prevalence of perceived symptoms of MSD (Paper I).
- Identify physical work environmental risk factors in the development of MSD (Paper I).
- Quantify the wrist positions and movements among dairy farm workers working in a rotary milking system and compare the results with tethering and loose housing milking parlour systems (Paper II).
- Investigate the psychosocial work environment and mental health (Paper III).
- Identify risk factors associated with the psychosocial work environment in the development of MSD (Paper III).
- Investigate possible associations between the health of the dairy cows and that of the dairy farm workers (Paper IV).

Hypotheses of the Thesis

The general hypothesis of this thesis is:
The structural and technical development in Swedish livestock farming has contributed to a reduced work load, resulting in a positive effect on the livestock workers´ health.

The specific hypotheses of the included papers were:
- The prevalence of perceived symptoms of MSD has decreased (Paper I).
- Risk factors in the development of MSD are associated with the physical work environment (Paper I).
- Working in a rotary milking system is less physically demanding for the hands and wrists among dairy farm workers compared to working in tethering and loose housing milking parlour systems (Paper II).
- Livestock workers assess their psychosocial work environment and mental health as good (Paper III).
- Risk factors in the development of MSD are associated with the psychosocial work environment (Paper III).
- Dairy farm workers working with healthy dairy cows have a better health than those working with less healthy dairy cows (Paper IV).

Structure of the Thesis

This thesis comprises several aspects of the work environment and health among Swedish livestock workers on large modern dairy and pig farms, such as factors related to the physical work environment (Papers I, II and IV), psychosocial work environment (Papers III and IV), animal health (Paper IV) and the possible impact of these on the livestock workers´ physical (Papers I, II, III and IV) and mental health (Papers III and IV), which is illustrated in Figure 9.

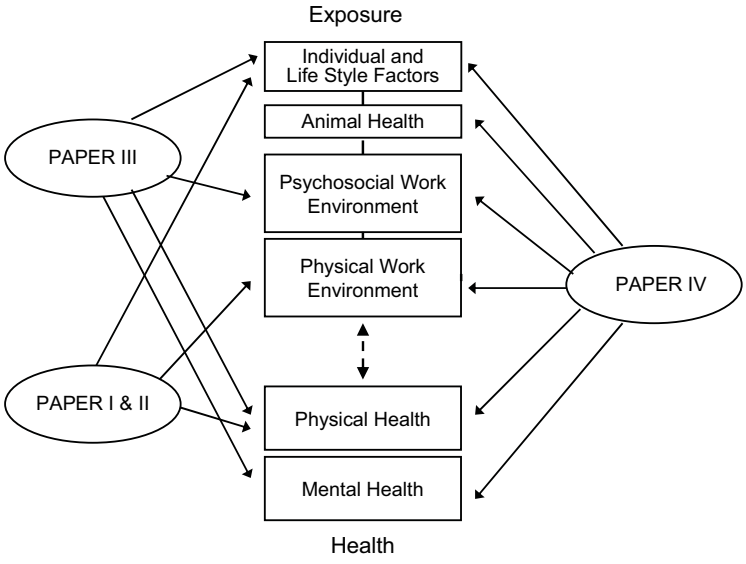

Figure 9. Work environment and health factors among Swedish livestock workers studied in this thesis.

Material and Methods

This thesis is based on four studies presented in Papers I-IV (Table 1). Different methods, mainly, questionnaires, but also a rating scale, data collection from an official database, a technical measurement, interviews and farm visits were used. The subjects in Papers I-IV comprised Swedish livestock workers and farmers on large modern dairy and pig farms. The details of the experimental procedures, data collections and analyses are described in Papers I-IV.

Table 1. *A brief description of the included papers in this thesis regarding the general areas, number of subjects, used measurements and main parameters studied.*

Paper	General area studied	Subjects	Measurements	Main parameters
Paper I	The prevalence of MSD Risk factors for MSD	42 dairy workers 37 pig workers	Questionnaires Rating scale Interviews Farm visits	MSD Physical factors
Paper II	Wrist positions and movements in rotary milking systems Comparisons between milking systems	13 dairy workers	Electro-goniometry Interviews Farm visits	Wrist positions & movements
Paper III	The psychosocial work environment Risk factors for MSD	37 dairy workers 30 pig workers	Questionnaires Interviews Farm visits	Psychosocial factors, incl. job satisfaction, general & mental health, vitality MSD
Paper IV	Associations between the health of the dairy cows and that of the dairy farm workers	82 dairy workers & farmers 6300 dairy cows	Questionnaires Official database Interviews	Physical, psychosocial factors, animal health Physical & mental health

Subjects

The overall demographic data of the subjects in Papers I-IV is presented in Table 2. In Paper IV dairy farmers, and family members occupied in the work, were also included in the study.

Table 2. *Overall demographic data of the subjects in Papers I-IV.*

	Paper I		Paper II	Paper III		Paper IV
	Livestock Workers					
	Dairy	Pig	Dairy	Dairy	Pig	Dairy
No. of subjects	42	37	13	37	30	82
Male/female	28/14	19/18	8/5	26/11	13/17	50/32
Age (year), mean	32	34	29	32	34	41*
BMI (kg/m^2), mean	25	24	24			
No of work hours per week, mean	39	36		38	38	40*
No of hours milking, mean	16					18*

* median

Subjects in Papers I and III

The Local Livestock Organisation provided us with names and addresses of representatives of large modern farms in Southern Sweden. Ten dairy and ten pig farms were randomly selected from this list. The subjects in Papers I and III comprised all workers from these farms (Table 2). The studies were conducted during the autumn of 2002. The response rate in Paper I was 100% for both dairy as well as pig farm workers. In Paper III the response rate amounted to 88% among the dairy and 81% among the pig farm workers.

The average herd sizes on the studied farms were approximately 300 dairy cows with offspring and 450 sows with piglets. The livestock workers carried out multiple tasks in the barns, performed almost the same work tasks and were mostly working in groups.

Two reference values were used for comparing the results in Paper III with other groups of workers a) Danish workers in 32 homogeneous jobs, comprising 1850 Danish females (49%) and males (51%), aged 20-59 years (Kristensen *et al.*, 2005; NRCWE, 2005), and b) Danish livestock workers (in dairy and pig production), comprising 146 Danish males (78%) and females (22%), aged 18-58 years (CASA, 2005).

Subjects in Paper II

The 13 dairy farm workers in Paper II worked on two similar newly built (2000) farms in Southern Sweden with rotary milking systems (carousels containing 24 cow places per carousel). The study was conducted during the spring of 2002.

All the workers were skilled milkers and were used to working in the rotary milking systems. They milked approximately 270 dairy cows per day on each farm, three times a day and each milking shift took about 2 hours and 40 minutes.

Subjects in Paper IV

The human subjects in Paper IV consisted of 47 dairy farmers, 29 farm workers, 3 employed farm managers and 3 family members from 62 dairy farms in four regions which represented the largest number of dairy cows in Sweden (Table 2). The study was conducted during late autumn 2004 and the response rate was 51%.

The animal subjects in Paper IV comprised approximately 6300 dairy cows mainly of Swedish Red or Holstein breed with a median milk yield of 24.7 kg energy-corrected milk per cow per day.

Questionnaires

Besides the specific structured questionnaires, presented in the following sections, all the studies (Papers I-IV) contained several questions about the livestock workers´ demographic data and some open-end questions.

The Standardized Nordic Questionnaire

The standardized Nordic Questionnaire (Kuorinka *et al.*, 1987) was used for analyses of perceived symptoms of MSD in nine different body parts, (neck, shoulders, elbows, hands/wrists, upper back, lower back, hips, knees and feet), 12 months and seven days prior to the study, and whether the problems had prevented the subjects from carrying out their daily work (Papers I, III and IV). The questionnaire had a binary 'yes' or 'no' scale. In Paper I, four clusters were constructed for symptoms in different body regions, *upper extremities*, *lower extremities*, *back* and *any body part*, which incorporated a combination of the nine different body parts described by Kuorinka (1987). In Paper III, two clusters were constructed for symptoms in the body regions, *upper extremities* and *back*.

Physical Work Factors

A modified questionnaire by Lundqvist (1988a) concerning physical work environmental factors was used in Papers I and IV for assessment of the subjects' apprehension of discomforting factors such as noise, vibrations, poor climate and illumination, heavy burdens, repetitive work, awkward working postures, dust, chemical solvents and noxious gases. The questionnaire had a binary 'yes' or 'no' scale.

Copenhagen Psychosocial Questionnaire

A Swedish translation of the short version of the Copenhagen Psychosocial Questionnaire, COPSOQ (Arvidsson *et al.*, 2005), developed by the National Institute of Occupational Health in Denmark (Kristensen *et al.*, 2005), was used for assessment of the perceived psychosocial work environment (Papers III and IV). Based on previous factor analysis, the questions had been weighed together to form eight dimensions evaluating: 1) *Work demands*, 2) *Work organization and job content*, 3) *Quality of leadership, feedback and social support at work, 4) Insecurity at work, 5) Job satisfaction, 6) General health, 7) Mental health and 8) Vitality* (Kristensen *et al.*, 2005). The questionnaire had an ordinal scale. The scores had equal weight to the items and equal intervals between response options. The eight dimensions were constructed as the sum of the scores of the response options for the items in the specific dimensions and presented as averages (average scores (AVS)) for the subjects. High values of AVS represented a high level of the concept being measured.

Borg's CR-10 Scale

Borg's CR-10 Scale (Borg, 1990), was used for analysis of the perceived physical exertion while performing different work tasks in the dairy and pig barns (Paper I). The subjects rated the physical exertion on a scale from 0 (none at all) to 10 (extremely strong). Besides rating the physical exertions, the subjects also had to state the time they spent on working with different work tasks (Paper I).

Electrogoniometry

A biaxial electrogoniometer, (XM65 and M110, Biometrics Ltd., Cwmfelinfach, Gwent, UK) was used for recording the flexion and deviation angles of both the right and the left wrist (Paper II). A 12-bit data logger with a sampling frequency of 20 Hz was used (Hansson *et al.*, 2003). After recording, the data were transferred to a personal computer and analyzed

(Hansson *et al.*, 1996). The reference position (0° of flexion and deviation) was defined as the wrist angles obtained when the subject was standing up with the arms and hands hanging relaxed alongside the body (Stål *et al.*, 1999). A wrist mobility test was also performed (Hansson *et al.*, 1996). The wrist positions during work were characterized, for both dorsal-palmar flexion and radial-ulnar deviation (Figure 10), by the median position (50th percentile of angular distribution) and the two extreme positions (10th and 90th percentiles).

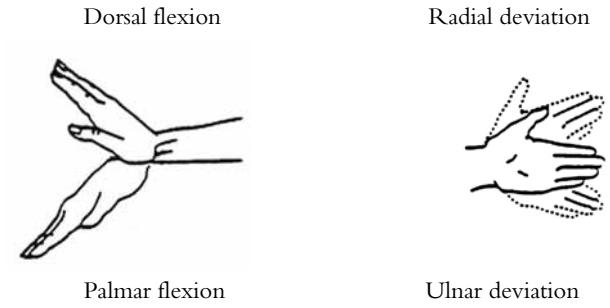

Figure 10. Illustration of dorsal/palmar flexion, and ulnar/radial deviation of the hands/wrists.

In order to describe the movements, the angular velocity was calculated, and the 50th and 90th percentiles of the velocity distribution as well as the mean velocity were used for characterization. Moreover, the mean power frequency (MPF) of the power spectra was calculated as a measure of repetitiveness. The fraction of time with a velocity below 1°/s for continuous periods of at least 0.5s was selected to characterize when the hand was still. Recordings, which were continuous, of each dairy farm worker were on average 30 minutes long.

The Swedish Milk and Disease-Recording Scheme

Data on dairy cows milk production and veterinary-reported cases of cow diseases were collected from the official Swedish milk and disease-recording schemes during the whole year 2004 (Paper IV) (Andersson, 1988; Emanuelson, 1988). Furthermore, information about cow housing and management was gained from the farmers through an additional questionnaire and a telephone interview during the summer 2004.

Calculated Indexes

The Physical Work Strain Index (PWS)

In order to gain a deeper understanding of how time related to different work tasks influenced the perceived physical exertion in dairy and pig farming, an index was constructed, named the Physical Work Strain index (PWS) (Paper I). The PWS was based on the CR-10 scale (Borg, 1990) and on the number of hours per week the participants spent on different work tasks. The indexes for the different work tasks were calculated according to the equation:

$$PWS_i = \frac{t_i \cdot p_i}{T}$$

where t and p are the number of work hours per week, and the physical exertion (CR-10 scale), respectively, for work task *i*, and T is the total number of work hours per week.

Physical (PHY) and Mental (PSY) Health Scores

Based on the standardized Nordic questionnaire (Kuorinka *et al.*, 1987), the questionnaire regarding the physical work factors (Lundqvist, 1988a) and the Copenhagen Psychosocial Questionnaire (Kristensen *et al.*, 2005), three continuous outcome health traits, ranging from 0 (best) to 1 (worst), were created for the dairy farm workers´ physical and mental health (Paper IV). The outcome traits represented the degree of physical (PHY) and psychosocial work-environment risks and symptoms (PSY), and a combination of PHY and PSY (TOT).

PHY was calculated as the mean of 18 dichotomous variables, representing the dairy farm workers´ apprehension of the occurrence of negative physical factors in his/her work, such as noise, vibrations, unsuitable climate, insufficient illumination, lifting heavy burdens, monotonous or repetitive work, awkward working postures, dust and noxious gases or chemical solvents, and of MSD in nine different body parts.

PSY was calculated similarly as the mean of 16 ordinal variables representing the dairy farm workers´ apprehension of their psychosocial work environment during the four weeks immediately prior to the study. Among these variables were: the need to work very fast, lack of influence over decisions, lack of influence over work load, lack of meaningfulness, lack of cooperation and teamwork among staff, lack of information, lack of participation in staff community, lack of help or support from superior, bad planning and poor handling of conflicts by superior, and symptoms of

irritation, fatigue, insomnia, headache, nervousness or abdominal pain. Finally, TOT was calculated as the mean of all 34 variables.

Animal Disease Incidence Rate (IR)

In Paper IV, the total animal disease incidence rate (IR) for dairy cows was calculated as the number of veterinary-reported clinical cases (only the first case for each cow counted) of assisted calving, endometritis, hoof lesion, mastitis, leg injury, puerperal metritis, retained placenta or teat lesion in the herd during 2004, divided by the mean number of dairy cows in the herd in the same year.

Statistical Analyses

The statistical methods have been described in detail in Papers I-IV. In Paper I, the Mann Whitney Test, Chi-Square analyses and Fisher's Exact Test were used for the statistical analysis of the results. In Paper II, the Wilcoxon matched-pairs signed-ranks test was used to analyze the differences between the right and left wrist. The Mann-Whitney test was used for comparisons between the rotary milking and the other milking systems.

In Paper III, Fisher's Exact Test, the independent- and the one-sample t-test were used for the statistical analysis of the results. The reliability of the Swedish translation of the COPSOQ questionnaire was tested as acceptable with Pearson's correlation and Cronbach's alpha (Cronbach, 1951) except for dimension 4. As a consequence, the results of this dimension were not taken into consideration.

The probability limits for evaluating statistical significance were $p \leq 0.05$, $p \leq 0.01$, $p \leq 0.001$ and a tendency was defined as $p \leq 0.1$.

In Paper I, physical and demographic risk factors for MSD, which had been identified by a univariate analysis ($p \leq 0.05$), and the four clusters for perceived MSD were treated in two stepwise multiple binary logistic regression models. In Paper III, psychosocial factors, demographic data and the two clusters for perceived MSD were treated in two stepwise multiple binary logistic regression models. The variables (Papers I and III) were introduced into the analysis as continuous or categorical variables (e.g. no/yes; male/female). In both Papers I and III, separate logistic regression models were created, one model for the dairy and one for the pig farm workers, respectively. The confidence interval (CI) for the Odds Ratio (OR) was determined at the 95% level.

In Paper IV, the outcome health traits were analyzed at the dairy farm worker level by linear mixed modelling. The models were defined by the equation:

$$Y_{ij} = \beta_0 + u_{0j} + \sum \beta_m X_{mij} + e_{ij}$$

where Y_{ij} is the health score of the dairy farm worker i in herd j, β_0 the intercept, u_{0j} a herd random-intercept effect, β_m regression coefficients expressing included fixed effects, X_{mij} covariates, and e_{ij} a random term at the dairy farm worker level. Least-squares means were also calculated for interactions to test differences between levels (total animal-disease incidence rate and gender). All the continuous variables were categorized; when biologically relevant categories were lacking, quartiles were used as cut-off points. Predictors justified by hypotheses representing the total animal-disease incidence rate in herd (< 0.38; 0.39–0.59; 0.60–0.98; > 0.98 per cow-year), dairy farm worker gender (*male*; *female*) and form of employment (*owner*; *employed worker*; *employed manager*; *family member*) were forced into all models (studied predictors), as well as dairy farm worker age (≤*34*; *35–40* year; *41–50* year; >*50* year).

Results

A summary of the results from Papers I-IV is presented in the following sections. The detailed results are presented in Papers I-IV.

Prevalence and Risk factors for MSD

Perceived MSD were frequently reported by the dairy and pig farm workers (86% and 78%, respectively), which is presented in Table 3. The most often reported MSD among both the dairy and pig farm workers were in the *upper extremities* (52% and 62%, respectively) and in the *back* (60% and 57%, respectively).

The female farm workers reported MSD more frequently in all the body parts, and especially the female dairy farm workers reported significantly more often MSD in the shoulders and in the wrists/hands than their male colleagues. Among the female pig farm workers MSD in the neck and elbows were reported significantly more often than by their male counterparts (Table 3).

Dust was the environmental work factor that was most frequently reported as being discomforting among the livestock workers, followed by ergonomic factors, such as awkward working postures, lifting heavy burdens and repetitive work, as well as the climatic conditions. The female dairy farm workers were those who reported the highest frequency of discomfort from these factors, as well as the feeling of being stressed by their work.

Almost all the livestock workers (98%) stated that they were very contented with their work tasks and colleagues.

Table 3. *Prevalence of* MSD *during the preceding 12 months in nine different body parts and four clustered body regions. The descriptive values [number (n), per cent (%) and significance] are listed according to branch and gender.*

	Dairy farm workers			**Pig farm workers**		
Body parts	Male & Female	Male	Female	Male & Female	Male	Female
	n = 42	n = 28	n = 14	n = 37	n = 19	n = 18
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Any body part *	*36 (86)*	*23 (82)*	*13 (93)*	*29 (78)*	*14 (74)*	*15 (83)*
Shoulders	20 (48)	10 (36)	10 (71)[a1]	16 (43)	6 (32)	10 (56)
Elbows	4 (10)	1 (4)	3 (21)	6 (16)	0 (0)	6 (33)[a2]
Wrists/hands	11 (26)	3 (11)	8 (57)[a2]	14 (38)	8 (42)[b1]	6 (33)
Upper extremities *	*22 (52)*	*11 (39)*	*11 (79)[a1]*	*23 (62)*	*10 (53)*	*13 (72)*
Neck	14 (33)	7 (25)	7 (50)	12 (32)	3 (16)	9 (50)[a1]
Upper back	11 (26)	5 (18)	6 (43)	8 (22)	3 (16)	5 (28)
Lower back	17 (41)	10 (36)	7 (50)	18 (49)	8 (42)	10 (56)
Back *	*25 (60)*	*15 (54)*	*10 (71)*	*21 (57)*	*9 (47)*	*12 (67)*
Hips	6 (14)	3 (11)	3 (21)	4 (11)	2 (11)	2 (11)
Knees	10 (24)	6 (21)	4 (29)	11 (30)	5 (26)	6 (33)
Feet	6 (14)	4 (14)	2 (14)	5 (14)	2 (11)	3 (17)
Lower extremities *	*16 (38)*	*11 (39)*	*5 (36)*	*14 (38)*	*6 (32)*	*8 (44)*

* Clustered body regions: Consisting of at least one of the following body parts:

Any body part	All nine different body parts
Upper extremities	Shoulders, elbows, wrists/hands
Back	Neck, upper back, lower back
Lower extremities	Hips, knees, feet

[a)] The studied groups of male respectively female dairy farm workers, and the studied groups of male respectively female pig farm workers.

[b)] The studied groups of male dairy farm workers and male pig farm workers.

[1)] Denotes significant level $p \leq 0.05$; [2)] denotes significant level $p \leq 0.01$.

The univariate analysis identified being a female (OR 5.7) or shorter than 176.5 cm (OR 8.0) or doing repetitive work (OR 4.8) as potential risk factors for MSD in the *upper extremities* among the dairy farm workers. Working in awkward working postures (OR 10.0), or being exposed to dust (OR 13.7) significantly increased the risk for MSD in the *upper extremities* among the pig farm workers. Poor illumination for the dairy farm workers (OR 3.0) and being exposed to dust for the pig farm workers (OR 8.4) were identified as potential risk factors in the development of MSD in the *lower extremities*. No significant risk factors were identified for MSD in the *back* among the livestock workers.

The logistic regression models identified body height (OR 6.5) and dust (OR 13.7) as potential risk factors for MSD in the *upper extremities* among the dairy and pig farm workers, respectively.

The dairy and the pig farm workers estimated the physical exertion according to the Borg's CR-10 scale (Borg, 1990) of all the work tasks at approximately the same level between *weak* and *moderate*, which is shown in Table 4.

Table 4. *Perceived physical exertion during different work tasks, number of work hours per week and Physical Work Strain index (*PWS*). Number (n), mean and standard deviation (*SD*).*

Work tasks for dairy farm workers	No. of workers	Physical exertion*	No. of hours per week	PWS**
	n	mean (SD)	mean (SD)	mean (SD)
Machine milking	26	3.46 (1.70)	15.33 (5.38)	1.46 (0.97)
Handling of feed	10	4.40 (2.17)	6.33 (4.33)	0.64 (0.47)
Manual raking of manure	24	3.16 (2.22)	3.80 (2.12)	0.38 (0.52)
Feeding (roughage & concentrate)	27	1.89 (1.40)	6.81 (4.52)	0.34 (0.31)
Strewing of litter (sawdust/straw)	24	2.88 (1.73)	4.18 (4.66)	0.28 (0.31)
Cleaning parlour & equipment	24	2.83 (2.16)	3.03 (1.46)	0.24 (0.23)
ALL WORK TASKS [1 a]	27	2.52 (1.29)	38.62 (10.03)	2.97 (1.45)
Work tasks for pig farm workers	No. of workers	Physical exertion*	No. of hours per week	PWS**
	n	mean (SD)	mean (SD)	mean (SD)
Manual raking of manure	28	2.62 (1.00)	10.64 (4.48)	0.86 (0.48)
Artificial insemination	18	2.97 (1.29)	5.75 (6.99)	0.45 (0.52)
Periodic cleaning	16	3.63 (1.36)	2.72 (1.68)	0.35 (0.29)
Daily inspection and treatment	26	2.25 (1.06)	4.61 (3.41)	0.30 (0.24)
Gelding of piglets	18	3.50 (1.20)	2.46 (1.62)	0.25 (0.18)
Strewing of litter (sawdust/straw)	30	1.52 (0.96)	4.89 (2.93)	0.21 (0.16)
ALL WORK TASKS [1 b]	30	2.41 (0.82)	33.83 (8.44)	2.34 (0.87)

* CR-10 scale of perceived physical exertion (Borg, 1990): 0=None at all; 0.5=Extremely weak; 1=Very weak; 2=Weak; 3=Moderate; 5=Strong; 7=Very strong; 10=Extremely strong.

** PWS (Physical Work Strain index) = Perceived physical exertion according to the CR-10 scale x Number of hours per week working with a specific task / Total number of working hours per week.

ALL WORK TASKS:

1) Were calculated on the basis of the individual means. Note that not necessarily all the participants had been performing every work task.

a) The work tasks on the dairy farms also included sweeping and cleaning in the barn, artificial insemination, daily inspection and office work. The results of these work tasks were included in ALL WORK TASKS, but not shown separately in Table 4.

b) The work tasks on the pig farms also included ear marking, weaning, relocation of pigs, weighing of pigs, feeding and office work. The results of these work tasks were included in ALL WORK TASKS, but not shown separately in Table 4.

Handling of feed and machine milking were estimated to be the most physically demanding work tasks by the dairy farm workers (4.40 and 3.46, respectively), which are shown in Table 4.

The pig farm workers estimated periodic cleaning of pig pens with a high pressure washer, and gelding of piglets to be the most physically demanding work tasks (3.63 and 3.50, respectively). Machine milking among the dairy farm workers (15 hours/week) and manual raking of manure (11 hours/week) were the most time-consuming works tasks.

When physical exertion was related to the actual time taken to perform the different work tasks, milking among the dairy farm workers and manual raking of manure among pig farm workers were ranked as the work tasks with the highest PWS values (1.46 and 0.86, respectively).

Wrist Positions and Movements in a Rotary Milking System

The hand positions among the dairy farm workers working in the rotary milking system were improved compared to the tethering and loose-housing parlour milking systems (Table 5). In the rotary milking system the right hand was held at 29° in a dorsi-flexed position for 10% of the recording time (10^{th} percentile) compared to 41° and 46° in the tethering and the loose-housing milking system, respectively (Stål et al., 1999). In the rotary milking system the right hand was held in a more palmar-flexed position (21°) compared with both the tethering and the loose-housing milking systems (14° and 10°, respectively).

In comparison with both the tethering and the loose-housing milking systems, considerable dynamic demands were found for both hands in the rotary milking system, for example the velocity and the repetitiveness were high, and there were scarcely any pauses.

The velocity in the rotary milking system was significantly higher for both hands in flexion (36°/s and 26°/s, respectively) compared to the tethering milking system (24°/s and 16°/s, respectively).

In flexion, the right and the left hands were held still for only 1.4% and 1.0%, respectively, of the total milking time in the rotary milking system. In the tethering and loose-housing milking systems, the corresponding values for the right and the left hands were 6.4% and 7.4%, and 4.9% and 5.6%, respectively.

In the rotary milking system both the right and left hands were exposed to a high degree of repetitive work in flexion and in deviation (Table 5). For both hands, the repetitiveness was higher in the rotary milking system compared to the tethering milking system in flexion and in deviation, and to the loose-housing milking system regarding the left hand in deviation.

Table 5. *Wrist positions, movements and repetitiveness for both right and left hands in flexion and deviation during milking in a rotary system. Mean values (m) and standard deviations (SD) are shown for 13 individuals. The corresponding data for tethering (n=11) and loose-housing parlour milking systems (n=11) are shown for comparison (Stål et al., 1999).*

	Flexion				Deviation			
	Right		Left[a]		Right		Left[a]	
	m	SD	m	SD	m	SD	m	SD
				Position[b]				
10th Percentile				Distribution, Percentile (º)				
Rotary	-29^{x,y,*}	9	-37*	9	-13	6	-15	6
Tethering	-41^{x,z,*}	8	-35*	8	-15	6	-22	9
Loose-housing	-46^{y,z,*}	10	-37*	7	-12*	7	-22*	6
90th Percentile				Distribution, Percentile (º)				
Rotary	21^{x,y}	12	16	8	14	7	11	11
Tethering	14^{x}	9	13	7	16	7	13	6
Loose-housing	10^{y}	12	12	8	17	8	12	6
				Velocity				
50th Percentile				Distribution, Percentile (º/s)				
Rotary	36^{x,*}	5	26^{x,*}	9	17	2	14	5
Tethering	24^{x,*}	8	16^{x,*}	3	15*	3	12*	2
Loose-housing	28*	8	20*	6	16	3	14	4
				Velocities below 1º/s (% time)				
Rotary	1.4^{x,y,*}	1.0	1.0^{x,y,*}	1.0	2.2^{x,y}	0.5	2.3^{x,y}	0.6
Tethering	6.4^{x}	4.4	7.4^{x}	2.8	9.4^{x}	5.6	8.7^{x}	2.4
Loose-housing	4.9^{y}	3.0	5.6^{y}	3.1	7.6^{y}	4.0	7.8^{y}	3.8
				Repetitiveness MPF (Hz)				
Rotary	0.57^{x}	0.11	0.46^{x}	0.12	0.50^{x}	0.08	0.53^{x,y}	0.11
Tethering	0.45^{x,z,*}	0.05	0.37^{x,*}	0.09	0.43^{x,*}	0.07	0.33^{x,z,*}	0.03
Loose-housing	0.50^{z,*}	0.08	0.42*	0.08	0.47*	0.00	0.39^{y,z,*}	0.05

a) Due to technical problems during recording n=12 in left dorsal/palmar flexion and n=10 in left ulnar/radial deviation.
b) Positive values denote flexion in the palmar direction and deviation in the ulnar direction.
x) Statistically significant difference between the rotary and tethering milking system.
y) Statistically significant difference between the rotary and loose-housing parlour milking systems.
z) Statistically significant difference between the loose-housing parlour and tethering system.
⋆) Statistically significant difference between the right and the left hand.

Psychosocial Work Environment and Risk Factors for MSD

In general, the livestock workers assessed their psychosocial work environment as good. The livestock workers stated that they *rather seldom/sometimes* experienced high work demands, they were *sometimes/rather often* contented with the work organization and their job content, and they were *sometimes/rather often* contented with the quality of leadership, feedback and social support at work. Furthermore, the livestock workers were *pleased* with their work and considered their general health to be *good/very good*. They felt happy, committed to their work and experienced no stress (mental health), and felt vigorous and full of energy (vitality) *a large part of the time/most of the time*.

The psychosocial work environment was rated at the same level by the dairy and pig farm workers except for the quality of leadership, feedback and social support at work, which was significantly poorer on the dairy farms (AVS = 22.4) than on the pig farms (AVS = 26.4) (Table 6). There was a tendency that the female dairy farm workers were less contented with their work organization and job content compared with the male dairy farm workers. They also tended to report lower job satisfaction and vitality than their male counterparts (Table 6).

The livestock workers experienced lower work demands compared with the Danish workers and poorer vitality compared with the Danish livestock workers. Furthermore, the livestock workers reported poorer general and mental health both compared with the Danish workers and with the Danish livestock workers.

No significant risk factors related to the psychosocial work environment were identified for the frequently reported MSD in the *upper extremities* and the *back*.

Table 6. *The psychosocial work environment among livestock workers. The descriptive values, [average score (AVS)*, standard deviation (SD) and significance] are listed according to branch and gender.*

	Dairy farm workers			Pig farm workers		
Dimensions:**	Male & Female n = 37	Male n = 26	Female n = 11	Male & Female n = 30	Male n = 13	Female n = 17
	AVS * (SD)	AVS * (SD)	AVS * (SD)	AVS * (SD)	AVS * (SD)	AVS * (SD)
1) Work demands	9.3 (4.5)	8.7 (4.9)	10.6 (3.4)	8.2 (3.7)	8.0 (3.8)	8.4 (3.7)
2) Work organization and job content	26.0 (6.3)	27.2 (6.1)	23.2[b2] (6.2)	27.5 (7.4)	28.3 (7.3)	26.8 (7.6)
3) Quality of leadership, feedback and social support at work	22.4[a1] (6.5)	22.6[c2] (6.4)	22.0[d2] (7.2)	26.4 (6.4)	26.5 (7.4)	26.3 (5.8)
5) Job satisfaction	8.0 (2.2)	8.4 (2.1)	7.0[b2;d1] (2.0)	8.6 (1.6)	8.8 (1.9)	8.5 (1.4)
6) General health	2.7 (1.0)	2.7 (1.0)	2.5 (0.8)	2.3 (0.9)	2.5 (0.9)	2.2 (0.9)
7) Mental health	18.7 (3.6)	19.2 (3.5)	17.6 (3.7)	19.3 (4.0)	20.0 (3.2)	18.7 (4.5)
8) Vitality	12.2 (3.9)	13.0 (3.6)	10.5[b2] (4.4)	12.9 (3.4)	14.6 (2.8)	11.7[b1] (3.3)

* A high AVS score indicates a high level of the concept being measured.
** Dimension 4 was not included because of a low reliability of this dimension.
Denotes significant differences between:
[a)] The studied groups of dairy and pig farm workers (male and female taken together in each respective group).
[b)] The studied groups of male respectively female dairy farm workers, and the studied groups of male respectively female pig farm workers.
[c)] The studied groups of male dairy farm workers and male pig farm workers.
[d)] The studied groups of female dairy farm workers and female pig farm workers.
[1)] Denotes significant level $p \leq 0.05$; [2)] Denotes tendency level $p \leq 0.1$.

The Health Status of the Dairy Cows and the Dairy Farm Workers

The dairy farm workers frequently reported perceived discomfort from physical work environmental factors and from symptoms in the musculoskeletal system, reflecting their physical health (PHY). Particularly monotonous or repetitive work, unsuitable climate, lifting heavy burdens and dust were the work environmental factors most frequently reported as discomforting among the dairy farm workers (37%, 28%, 20% and 20%, respectively). The dairy farm workers reported MSD especially in the lower back, the shoulders, the neck and the wrists/hands (51%, 48%, 31% and 25%, respectively).

On the whole, the dairy farm workers seemed to be content with their psychosocial work environment and had very few mental health problems (PSY). However, 22% of the dairy farm workers reported that they *very often/rather often* had to work very fast and 12% reported that their superiors

were r*ather often/sometimes* bad at planning the daily work. The dairy farm workers working with healthy dairy herds (IR ≤ 0.38) had significantly poorer physical and mental health scores than those working with less healthy dairy herds (IR>0.98; PHY= -0.17 and PSY= -0.11, respectively), which is shown in Table 7.

Table 7. *Physical (PHY), mental health (PSY) and general health score (TOT) among dairy farm workers on 62 dairy farms [covariates, regression coefficients (β) and significance].*

Covariate	Level	PHY	PSY	TOT
		β	*β*	*β*
Herd incidence rate (IR) (per cow-year)	≤ 0.38	0[3)]	0	0[2)]
	0.39-0.59	-0.01	-0.05	-0.03
	0.60-0.98	0.11	-0.01	0.07
	> 0.98	-0.17[1)]	-0.11[2)]	-0.12[2)]
Gender	Male	0[2)]	0	0[1)]
	Female	0.23[2)]	-0.02	0.06
Employment form	Owner	0	0	0
	Worker	-0.07	0.06[1)]	0.06[1)]
	Employed manager	-0.17	0.09	0.02
	Family members	0.01	0.06	0.03
IR * Gender interaction	≤ 0.38 * female		0[1)]	0[1)]
	0.39-0.59 * female		-0.01	0.07
	0.60-0.98 * female		-0.09	-0.11
	> 0.98 * female		0.08	0.08

[1)] Denotes significant level p≤ 0.05
[2)] Denotes significant level p≤ 0.01
[3)] Denotes significant level p≤ 0.001.

The physical health score among the female dairy farm workers (PHY=0.23) was significantly poorer than that of their male counterparts. The dairy farm workers had a significantly poorer mental health score (PSY=0.06) than the dairy farm owners. There was no significant interaction of animal health with gender. However, the relationship of IR with PSY varied significantly according to the gender of the dairy farm workers (Table 7).

Discussion

Different aspects of methodology and the main results of the included papers I-IV will be discussed in the following sections.

Discussion of Methodology

This thesis is based on an interdisciplinary research approach within work science including physiology, psychology and sociology with focus on humans at work in relation to animals and technology. The strength of this thesis is that it takes on a holistic perspective of the work environment and health of livestock workers.

Study Design

The thesis is based on a group of livestock workers and their apprehension of their work environment and health. The designs in the included papers, except for Paper II, are cross-sectional studies with a retrospective aspect, which must be recognized when the results are interpreted. Cross-sectional studies can deal with large data sets but the determination of causality and aspect of time is uncertain when the studied exposure and outcome variables are registered at the same time (Checkoway *et al.*, 2004; Last, 2001; Altman, 1991). However, several of the implications found in this thesis are supported by previous research. In future studies it should be advisable to use follow-up studies, case-control studies or retrospective studies based on, for example interviews and medical records. Even clinical examinations and technical measurements regarding work environment exposure and health would be advantageous.

Confounding

In cross-sectional study designs confounding can be problematic. A confounding factor is a variable which is associated with the risk factor and independently influences the risk of the disease/symptom being studied (Checkoway *et al.*, 2004). Unlike studies performed in a laboratory setting, not all risk factors are controllable or known in cross-sectional studies (Altman, 1991).

Multiple logistic regression analyses are useful for the estimation of associations adjusted for several confounding factors simultaneously, when binary outcomes such as symptoms-not-symptoms are studied (Altman, 1991). In the included papers, known confounders such as age, gender, BMI, number of years working and number of animals tended were controlled for in the multiple logistic regression models. However, other possible confounders such as information about previous employments, type of employment, hobbies and domestic work were not collected and this could have biased the results (Checkoway *et al.*, 2004).

In cross-sectional studies, there is a risk of a healthy worker effect (Li & Sung, 2004; Last, 2001). This implies that those who, for example experience severe ache, pain and discomfort in the musculoskeletal symptom are more liable to change work tasks, occupation or receive sick pension, while healthy workers stay in the work place. A healthy worker effect might have led to an underestimation of the concept being measured among the different groups of livestock workers and between the males and females.

Sample Size

The size of the study groups in this thesis is a limitation. Because the studies were based on a small selection of Swedish livestock workers it is possible to draw only broad conclusions. Nevertheless, several of the results found in the papers have been confirmed in earlier studies conducted with a considerably larger number of participants. Furthermore, the high response rates in Papers I and III, the farm visits and interviews with farmers and workers have strengthened the results and conclusions in this thesis. A problem in assembling a large sample size of livestock workers is the lack of reliable official registers. Today, the only possible way to reach this target group is through contact with the farmers. Nevertheless, in future studies it would be preferable to use larger samples.

Methods

The ambition was to use previously validated instruments when possible. The instruments in the included papers have been tested for reliability and validity, and discussed in Kuorinka *et al* (1987) regarding MSD (the Nordic Standardized questionnaire), in Kristensen *et al* (2005) regarding the psychosocial work environment (the Copenhagen Psychosocial Questionnaire, COPSOQ), in Borg (1990) regarding the physical exertion (Borg´s CR-10 Scale), in Hansson *et al* (1996) regarding electrogoniometer measurements and computer analysis, and in Andersson (1988) and Emanuelsson (1988) regarding dairy cows milk production and veterinary-reported cases of cow diseases.

The main reason for using the previously validated questionnaires was to be able to make comparisons between different studies. Questionnaires, often used in cross-sectional study designs, are an effective technique to collect a large amount of information at relatively low cost and fairly quickly. However, the use of structured questionnaires with predefined questions may inhibit the extent, the variation and the quality of the answers (Wilson & Corlett, 1995). In further studies, it would be preferred to use open-end questionnaires, interviews or diaries among a representative number of livestock workers. This would increase the possibilities of additional interpretations and improve the comprehension of the work environment, private life situation, health, and the human-animal associations.

The perceived symptoms of MSD, the psychosocial work environment and the exposure variables were measured by self-reporting and self-administrated questionnaires and the results in this thesis may be influenced by reporting bias, with an over- or underestimation as a consequence (Papers I, III and IV). This thesis focused on the individual's own apprehension of his/her work environment and health, and this subjective apprehension must be considered if a correct picture of how the work influences his/her health is to be obtained (Rubenowitz, 1984).

Bias

Another issue to be raised concerning research methods is that people do not always respond in a veridical manner. Respondents might not understand the questions or know the answers and therefore guess rather than provide a *truthful* judgment. Since respondents sometimes have a tendency to respond in a slightly more favourable way, social desirability, can also bias the results (Arvidsson, 2006).

Selection bias, meaning that some of the subjects being invited to take part in the study declined participation, may be a problem as well (Last, 2001). However, all livestock workers took part in Paper I and 81% to 88% of the workers participated in Paper III. In Paper IV, the response rate was lower and this might have biased the results.

Recall bias is another important aspect to consider in studies based on collected retrospective data. Having symptoms, which a respondent believes might be related to a variety of exposures in the work environment, renders the individual more prone to remember such exposures (Last, 2001; Coggan *et al.*, 1993). One way to avoid recall bias could be to ask questions relating to other symptoms or diseases, or to use interviews instead of self-administered questionnaires to obtain more consistent information about exposure and health.

The gender distribution among the Danish livestock workers (22% females) was different from that of the studied dairy and pig farm workers (42% females). This might have affected the results in Paper III and a possible consequence could be an overestimation of the differences between the dairy and pig farm workers and Danish livestock workers.

In the measurements of the hand and wrist positions with the electrogoniometer, bias caused by cross-talk may occur. This can be the case when pronounced flexion/extension and/or deviation appear in combination with a simultaneous supination/pronation of the forearm. However, only a fraction of the forearm rotation was transferred to the goniometer when the hand and wrist positions were measured (Paper II) and therefore the bias was not considered to invalidate the results (Hansson *et al.*, 1996).

Human Health

In Paper IV, the ambition was to describe the dairy farm workers´ health as a state of physical, mental and social well-being according to the World Health Organisation (WHO, 2005; WHO, 1946). Questions of a validated origin were used to exemplify the health of the dairy farm workers (Kristensen *et al.*, 2005; Lundqvist, 1988a; Kuorinka *et al.*, 1987). The questions included some of several important physical aspects, such as MSD, discomfort from the farm work environment related to the physical health, and psychosocial aspects, such as well-known risk factors and symptoms concerning mental health and vitality.

These aspects were a somewhat narrow definition of human health and it would be preferred to enlarge the number of variables describing human health in order to get a more profound characterization of the health

concept. Furthermore, in order to obtain an improved measure of the concept it would also be valuable to complement the participants' perceived health with clinical health examinations and information about their life style.

Animal Health

In Paper IV, animal health was operationalized by the herd incidence rate of veterinary-treated cases of eight common clinical diagnosis groups. Although this is likely to reflect the overall animal health status in dairy herds, it does not include some disease conditions which may also relate to animal well-being, animal behaviour and dairy farm workers´ health.

Not all animal diseases are reported to the official animal disease recording scheme and especially hoof lesions in Sweden are to a great extent treated by non-veterinarians (Hultgren et al., 2004). These lesions are often protracted and painful, causing lameness (Manske et al., 2002; Murray et al., 1996), reduced milk production, poor reproductive performance and culling, and as a consequence extra labour for the workers (Rajala-Schultz & Gröhn, 1999; Enting *et al.*, 1997; Sprecher *et al.*, 1997).

Discussion of Results

In the following sections the results of the included papers I-IV in this thesis will be discussed.

Prevalence and Risk Factors for MSD among Dairy Farm Workers

The development of technical improvements on large modern dairy farms during the last decades ought to imply that farm workers are exposed to lower levels of physical work load, and as a consequence, an expected decrease in the prevalence of MSD. However, in Paper I, the studied dairy farm workers still reported high frequencies of MSD, despite their relatively young age and few years of occupational exposure. No decrease in the overall prevalence was observed compared to previous studies conducted among Swedish dairy farmers with a higher average age and mainly working in old-fashioned tethering systems with less technical equipment (Pinzke, 2003; Gustafsson *et al.*, 1994). Specifically, an increase in MSD was observed in the upper extremities especially among the females and a decrease in the lower extremities.

One possible explanation for the findings might be the changed milking systems, which have implied an alteration of the working postures. In old-fashioned dairy barns where the cows were kept in tethering systems,

milking was performed in postures that involved bending and twisting. In these systems MSD were observed both in the lower back, knees, and in the upper extremities as well (Gustafsson *et al.*, 1994; Neméth *et al.*, 1990; Lundqvist, 1988b). Several studies have found that the work load and MSD among workers in loose-housing systems, where milking is performed in an upright standing position, are located to the upper extremities (Hartman *et al.*, 2006; Pinzke, 2003; Stål *et al.*, 1996). This indicates that with changed milking systems and working postures, MSD among the workers have shifted from the *lower extremities* to the *upper extremities*.

Another contributing explanation for why a high prevalence of MSD was found could be that work on large modern farms involves more specialized and monotonous daily work tasks compared to working on farms with a smaller number of dairy cows (Pinzke *et al.*, 2001; Stål *et al.*, 2000; Stål *et al.*, 1996). In addition, the workers might also increase their work tempo in order to keep up with, for example, the capacity of the milking system or an increased amount of work (Jakobsson, 2000). Although the prevalence of MSD still seemed to be as high as before, the severity and degree may well have decreased because of the modern milking systems.

Short stature was found to be a possible risk factor for MSD in the *upper extremities*. Ergonomic solutions, such as flexible floors have been introduced in many modern milking systems to adjust the work to the body height of the individual. This means that the work can be performed in a suitable upright working position. However, short persons might still have difficulties to reach for the cow's udder, so there is a risk that they will be working in physically demanding postures with, for example, their arms in extended positions. These positions have been identified as risk factors for the development of MSD in the *upper extremities* (Stål *et al.*, 2000; Arborelius *et al.*, 1986).

Several studies have shown that besides extreme work postures, repetitive and monotonous work in dairy farming constitutes risks for MSD in the hands/wrists (Pinzke *et al.*, 2001; Stål *et al.*, 1999). In Paper II, the hand and wrist positions during milking in the rotary system were improved which means that the wrist positions were less extreme compared to tethering and loose-housing parlour milking. However, the velocity and repetitiveness were increased and there was almost no time to rest the hands/wrists. The high level of repetitiveness was comparable with results from studies of occupations such as the fish processing industry (Ohlsson, 1994) and poultry processing (Juul-Kristensen *et al.*, 2001).

The milking procedure in the rotary system is performed continuously with the cows entering the rotating platform which moves without

stopping. The milking process is mostly limited to three works tasks: cleaning the udder, premilking and attaching the teat cups involving high velocities and extreme wrist positions (Pinzke *et al.*, 2001). In the traditional tethering and parlour milking systems the workers are not only tied to these tasks, but also perform other tasks such as grouping of cows. Thus, working in rotary systems implies very little time for pauses, and insufficient recovery time which may contribute to the development of hand/wrist injuries.

Prevalence and Risk Factors for MSD among Pig Farm Workers

Overall, the male and female pig farm workers reported a high prevalence of MSD, especially in the *upper extremities* and in the lower back (Paper I); this has also been found in other studies (Stål & Englund, 2005; Nyström, 1997; Hildebrandt, 1995). In general, the female pig farm workers reported a higher prevalence of MSD than their male colleagues, which has been confirmed in the study by Stål & Englund (2005).

Very few studies have been found dealing with MSD among pig farm workers, especially on farms with small herds. Therefore, it is not possible to compare large modern pig farms with small and less technically well-equipped ones. However, it should be assumed that the technical development on large modern pig farms during the last decades, such as automated feeding and removal of manure in culverts, has resulted in a reduction of the physical work load and improved health. This development has also made it possible to handle a large number of livestock and operate intensive large-scale pig production. Despite the technical development, the expansion of herd sizes may imply that the pig farm workers spend more time working inside the barns performing the same work tasks. This means that the duration of exposure to physical work loads and air pollutants may have increased compared to working with fewer numbers of livestock (Stål & Englund, 2005; Frank *et al.*, 2004; Christensen *et al.*, 1992).

Although technical improvements, there are still several physically demanding work tasks in the large pig barns. These tasks include heavy lifting of pigs, awkward working postures when catching and lifting piglets and manual raking of manure in the pig pens. Furthermore, gelding, vaccination and handling of piglets, and cleaning of pig pens with a high pressure washer imply repetitive and monotonous work (Stål & Englund, 2005; Nyström, 1997; Christensen *et al.*, 1992). All these manual work tasks involve working postures, positions and movements that have been identified as possible risk factors for MSD in the upper extremities and in the back (Hartman *et al.*, 2000; Stål *et al.*, 2000; Stål *et al.*, 1999; Nyström, 1997; Christensen *et al.*, 1992; Lundqvist, 1988b).

When we visited the farms we noted large amounts of dust on the fittings and on the walking areas, although the farms had automatic feeding equipment and some were using wet feeding. Only some of the workers were using protective masks. About half of the pig farm workers reported that they were troubled by dust, which also appeared to be a predictor of MSD especially in the *upper extremities*. It is well known that workers on pig farms who are exposed to organic dust may develop an acute flu-like condition, Organic Dust Toxic Syndrome (ODTS), resulting in several symptoms including muscle pain and fatigue (Von Essen & Romberger, 2003; Donham, 2000; Kirkhorn & Garry, 2000; Donham *et al.*, 1990). However, there might also be other effects such as coughs, sneezes, phlegm and scratchy throat (Donham & Thelin, 2006; Christensen *et al.*, 1992). An assumption may be that the effects of an irritation in the pulmonary system could be increased muscle tension and pain in the shoulders and upper back. Additionally, inhalation of dust particles might reduce respiratory capacity, oxygen uptake rate and oxygenation of the muscles, which also may lead to muscle fatigue and pain.

Physically Work Strain Index (PWS)

In Paper I, the livestock workers were asked to estimate the most physically demanding work tasks in the livestock barns. However, it is not just the level of physical exertion that determines the physical exposure, the duration and repetitiveness of the performed work tasks are also important (Pinzke, 1999a; Winkel & Mathiassen, 1994). When the physical exertion was related to the actual time taken to perform the different work tasks, an index illustrating a combined measure of the physical exposure was designed, the Physical Work Strain Index (PWS).

The purpose of this index was to highlight work tasks that, although they were not perceived as very physically demanding, might constitute an increased risk for developing MSD if the tasks were performed over a longer time. Although not rated as the most physically demanding, machine milking in the dairy barns and removal of manure with a hand rake in the pig pens were reported to be the most time-consuming work tasks, and as a consequence were ranked with the highest PWS values.

PWS values, as calculated in Paper I, can also be used as a measure to compare physical exertion between different branches. However, at present, there are no such corresponding values available. Besides ranking the physical strain from the PWS values, further studies are needed to establish and validate the meaning of the level and the importance of the PWS value

itself. Furthermore, studies are needed to investigate whether or not the PWS values can be used for prediction of MSD.

The high prevalence and risk factors for MSD found in this thesis indicates that appropriate measures need to be taken in order to reduce the physical strain in the livestock barns, especially regarding machine milking and manual raking of manure. This is of particular importance with the growing livestock herds and the presumed prolonged time spent on these work tasks for the individual farm worker. Further development, evaluation and introduction of a support arm for the milking cluster and development of an automatic washing teat cup in dairy farming, should be given priority (Stål *et al.*, 2003). In pig farming, improvements such as the development of a device for catching and lifting piglets to avoid bending and twisting the back, a portable carriage with an adjustable chair to use when gelding and vaccinating the piglets would be beneficial.

However, not all the physically demanding work tasks can be minimized with technical solutions. In general, it is advisable to reduce the time for exposure to the heavy work loads and to make changes in the organization of the work on these large modern farms. It is also important to develop instruction programmes for correct working postures and techniques in order to avoid MSD.

Furthermore, it would also be beneficial to teach why, how and when to use different protective equipment for example wrist protection, protection shoes, respiratory protection mask, and gloves when milking or handling medication and chemical solvents.

The farmers also need to learn how to organize the work in the barns to avoid health problems among their workers. The development of better working routines, such as alternating work tasks, maximum time spent on working with the same task and resting time in between tasks would be beneficial. Warming up before working, physical relaxation and stretching during and after carrying out lengthy, monotonous and physically demanding work tasks might also be important measures to introduce at the work places.

Female Livestock Workers and MSD

The results in Paper I revealed that more female than male livestock workers reported symptoms of MSD. Previous studies have shown that both female industrial and farm workers doing repetitive work and lifting heavy burdens report more problems in the musculoskeletal system especially in the upper extremities than their male colleagues (Howard *et al.*, 2005; de Zwart *et al.*, 2000; Nordander *et al.*, 1999; Stål *et al.*, 1996; Gustafsson, 1990). In some

studies, this has been explained to be mainly a result of segregation in job titles and work tasks between males and females. (Nordander *et al.*, 1999; Fransson-Hall *et al.*, 1995; Messing *et al.*, 1994). However, the livestock workers in this thesis were performing almost the same work tasks and worked or milked almost the same number of hours per week. One possible explanation for why female livestock workers reported higher frequencies of MSD than the males might be that the agricultural equipment and machines are often designed to match the physical requirements and capacities of men (Stål *et al.*, 1999).

Women's work capacity is lower on average than men's regarding, for example, muscular strength and aerobic capacity (Ahonen *et al.*, 1990; Åstrand, 1960). Heavy workloads for females engaged in certain types of agricultural work are often disproportionate to their physical capacity, which was something we observed on our visits to the farms. Moreover, there might also be factors not related to work involved in the prevalence of MSD such as domestic work, biological and cultural differences, for example that it is more acceptable among females than males to admit ache and pain (Treaster & Burr, 2004).

In Sweden about 33% of dairy and 50% of pig farm workers are females and their proportion is increasing (Statistics Sweden, 2005). Consequently, it is important to take the female anthropometrical measures and physical capacity into consideration when designing and developing technical equipment and machines in order to prevent and reduce the prevalence of MSD.

Psychosocial Work Factors and MSD

No risk factors associated with the psychosocial work environment were found for MSD among the livestock workers, although they reported high frequencies of MSD (Paper III). A possible explanation might be that the sample size was too small to find associations. Moreover, using the short version of COPSOQ might not be adequate to measure all the dimensions of the psychosocial work environment, and instead the long version of COPSOQ should have been applied.

In Paper I the female dairy farm workers felt stressed more often by their work compared to their male dairy colleagues, and compared to the female and male pig farm workers. Studies have shown that stress might be associated with MSD (Larsman, 2006; Torp, 2001). An increase in stress level may increase muscle tone which, in the long run, may lead to increased symptoms or development of MSD. On the other hand, it might also be that having constant ache and pain in the musculoskeletal system may lead to

poor mental health and develop into psychosomatic problems (Bongers *et al.*, 1993). However, in this study no significant associations between MSD and mental health were found (Paper III).

Psychosocial Work Environment among Livestock Workers

The dairy and pig farm workers assessed their psychosocial work environment as good, and in general they were contented with their work as livestock workers (Paper III).

Earlier studies have demonstrated that farmers have high work demands, but at the same time, also have more control over their work situation (Holmberg *et al.*, 2004; Thelin, 1998; Gustafsson & Lundqvist, 1993; Lundqvist, 1988a). In this study, we did not find that the livestock workers had high work demands nor did they have a high degree of control over their work situation. A plausible explanation is that workers have quite a different work situation than farmers, when it comes to work demands, their possibility to control the amount of work assigned to them and even regarding external factors such as the financial situation and comprehensive strategic decision making that takes place on the farms (Wallis, 2006; Hildebrandt, 1995; Walker *et al.*, 1986).

Possible explanations for why the livestock workers were contented with their psychosocial work environment might be found in their personal comments. Several livestock workers stated that the reasons why they enjoyed working on a livestock farm was because it meant flexible work hours, work that was more physically active than white-collar jobs, they were able to work with the animals and the latest technique and something new and unexpected always happened which made the work exciting. To work independently, having good work colleagues and a certain degree of responsibility were also important factors which the livestock workers stated made the job worthwhile. However, a few of the livestock workers considered job turnover and wanted to work on smaller farms instead of large, because it was less hectic and monotonous; they felt that they would have more responsibility, influence over their work situation and more varying tasks working on farms with smaller herds. Another explanation might also be that the livestock workers had little experience from work outside agriculture and thus a narrower frame of reference.

Livestock workers on farms with large numbers of livestock do not have to work alone unlike many farmers on smaller farms. They have working colleagues and often work in groups, which is considered to be a positive and beneficial development (Hartman *et al.*, 1999; Gustafsson & Lundqvist, 1993). Being employed on a large farm probably also implies that it is easier

to work regular hours, have periods of consecutive vacation days, job rotation, and as a consequence, the possibility to gain new knowledge (Stup *et al.*, 2006; Hadley *et al.*, 2002; Hartman *et al.*, 1999).

Studies have shown that large livestock farms had better resources than smaller farms regarding better pay. It was also easier for these farms to recruit and maintain qualified workers when they had the latest technical resources and a good work environment (Hadley *et al.*, 2002; Bewley *et al.*, 2001). However, little is known concerning the reasons and motivation for why livestock workers have chosen this occupation and why they stay or leave; and future studies of these issues are needed.

Even though the psychosocial work environment was assessed as good among the livestock workers, the results indicated that the quality of leadership, feedback and social support at work was slightly poorer at the dairy farms than at the pig farms (Paper III). It was not possible to identify the exact reasons for this difference because of the limited information gained from the questionnaires.

The dairy farm workers reported that they did not *very often* receive adequate help, support and feedback from their superiors and the superiors were *not often very good* at planning the daily work. A possible explanation might be found in the transformation of livestock farming from smaller labour intensive family businesses to larger technology-oriented business enterprises, which requires an increasing amount of decision making, leadership and strategic management skills. Many farmers are not so familiar with labour management and to become an employer is probably a large and difficult step (Stup *et al.*, 2006; Törnquist & Hakelius, 2006; Hadley *et al.*, 2002; Bewley *et al.*, 2001).

Today, there are few educational programmes for farmers and employed managers regarding leadership and labour management. Discussion groups, courses and similar activities to create a platform for acquiring new knowledge and exchange of experiences concerning leadership could be important tools for improving the psychosocial work environment in livestock farming in general.

Livestock Workers Mental Health

The livestock workers assessed their general and mental health, and vitality as good, though slightly poorer compared to Danish workers (for example teachers, office workers and construction workers) and Danish livestock workers (Paper III). The reason for these differences was not clear, but the private life situation in combination with the job, might have contributed to the findings. The most frequently reported responses regarding mental

health and vitality were related to being nervous and downhearted, not having a lot of energy, and feeling exhausted and tired; this was found especially among the females.

Work stressors combined with stressors outside the job may increase the overall burden on workers, especially if there are conflicts between family and work goals (Karasek & Theorell, 1990). Studies have shown that farmers´ wives who are responsible for domestic work, child care, have a full-time job away from home and sometimes work on the farm as well, have a *third shift*; they often become stressed and fatigued because of these multiple tasks (Bushy, 1998; Gallagher & Delworth, 1993; Walker & Walker, 1987; Walker *et al.*, 1986). Some female livestock workers stated that at times it was complicated to work early mornings, late evenings and sometimes weekends when they had a family and young children in need of day care, or small farms at home to take care of. Possible solutions to ease the daily work intensity for these workers could be even more flexible working hours. However, further research is needed in order to explain the complexity and possible associations between the private life situation, the work situation and mental health among the livestock workers.

Health Benefits of Animal Health on Livestock Workers Health

It has been suggested that people who feel close to nature (Ulrich, 1993) or companion animals have less risk of contracting diseases than people without such sentiments (Beck & Katcher, 1996). In Paper IV possible associations between animal and human health were investigated. The results indicated that dairy farm workers working with healthy dairy herds had poorer physical health than those working with herds with comparatively high disease incidence rates. There was also a similar tendency with respect to the mental health status. The associations we found between the health of the dairy cows and the health of those looking after them were not as we expected.

Most farm animals are production resources, but farmers have for a long time treated and viewed them with affection as companions (Fraser & Broom, 1997). Humans working closely with farm animals might develop relationships similar to those found between humans and their companion animals (Bokkers, 2006; Hemsworth & Coleman, 1998).

Our unexpected findings might be explained by the fact that it requires a lot of hard physical work, devotion and diligence to keep a dairy herd in good health. Lactating dairy cows are frequently handled and well-cared for, and a dairy farm worker may interact with the whole herd twice daily at milking. Effective cleaning routines in the dairy barn, especially the milking

parlour and cubicles, are necessary in order to maintain good animal health, milk quality and animal welfare (Barkema *et al.*, 1999). Grouping of cows, separate milking and culling of cows as a consequence of for example subclinical mastitis might involve extra labour for the dairy farm workers (Rajala-Schultz & Gröhn, 1999; Enting *et al.*, 1997; Sprecher *et al.*, 1997). The manual raking of manure from large numbers of cubicles and the clearing of feed bunks or mangers once or twice daily may also be physically demanding.

A study conducted by Barkema *et al* (1999) concluded that farmers who worked careful and accurate regarding teat cleaning routines, paid more attention to individual cows, and implemented measures to prevent mastitis, more often had a better milk quality than farmers with a management style characterized as quick and dirty. Additionally, several studies have demonstrated the magnitude of good stockmanship and a good human-animal relationship for farm animals' health, welfare and performance (Coleman *et al.*, 2000; Lensink *et al.*, 2000; Hemsworth & Barnett, 1987; Seabrook, 1984; Seabrook, 1972).

In Sweden, a study have found that livestock workers get their greatest pleasure from the actual milking job as well as from their work to promote the welfare of the animals (Pinzke, 2003). Not much is known why these workers have chosen to work with animals or with a specific type of animal and a forthcoming research project will focus on what motivates and attracts young people to work with livestock.

General Consideration

In Sweden, it is difficult to recruit qualified people to work on livestock farms (Öresund, 2007; Andersson, 2006; Björkqvist, 2003) and several Swedish farmers see the value of improving the work environment (Troedson, 2008; Lundqvist, 1996). However, we know that working in livestock barns is physically demanding and might jeopardize the workers´ health. Additionally, we know that many workers are contented with their psychosocial work environment and enjoy working with livestock. Consequently, it is important to continue to integrate the needs of the workers and the animals in the design of the livestock barns and in developing and choosing a technique that best serves the demands of the human and the animal. Further *Engineering* (technical aid) as well as *Enforcement* and *Education* are needed in order to make these work places and work situations for livestock workers more attractive, safe and healthy.

Conclusions

The general aim of this thesis was to investigate the work environment and health among Swedish livestock workers on large modern dairy and pig farms and to identify possible effects of the work environment on their health. An overall view of the aims, hypotheses and outcome is presented in Table 8. The main conclusions of this thesis are:

- The livestock workers reported high prevalence of MSD, mainly located to the *upper extremities* and the *back*.

- The prevalence of MSD had decreased in the *lower extremities* among the dairy farm workers compared to previous studies conducted among farmers on smallar farms with traditional milking systems. However, the prevalence had increased in the *upper extremities* especially among the females.

- MSD among livestock workers appeared to be associated with the physical work factors. In dairy farming, MSD was found to be associated with repetitive work and the body height of the workers. Organic dust and awkward working postures were potential risk factors for MSD in pig farming.

- Machine milking among dairy farm workers and manual raking of manure among the pig farm workers were the most time-consuming work tasks and the tasks with the highest rated physical work strain (PWS).

- The dynamic demands on the hands/wrists (high values of velocity and repetitiveness) among dairy farm workers had increased in the rotary milking system compared to milking in the tethering or the loose-housing parlour systems. Moreover, there was almost no time to rest the hands and wrists during milking.

- The livestock workers assessed their psychosocial work environment as good and they were contented with their work. In addition, they assessed their mental health as good.

- The quality of leadership, feedback and social support at work was experienced as poorer by the workers on the dairy farms compared to the workers on the pig farms.

- No psychosocial work factors were identified as possible risks in the development of MSD among the livestock workers.

- There was an inverse relationship between the health of the dairy cows and dairy farm workers, i.e. good dairy herd health was associated with comparatively poorer physical and mental health among dairy farm workers.

Table 8. The aims, hypotheses and outcome for the thesis and included papers I-IV.

	Aims	Hypotheses	Outcome
Thesis	Investigate the work environment and health among Swedish livestock workers on large modern dairy and pig farms and to identify possible effects of the work environment on their health	The structural and technical development in Swedish livestock farming has contributed to a reduced work load, resulting in a positive effect on the livestock workers´ health	Ambiguous
Paper I	Investigate the prevalence of MSD	The prevalence of MSD has decreased among livestock workers	No
	Identify physical work environmental risk factors for MSD	Risk factors for MSD are associated with the physical work environment	Yes
Paper II	Quantify the wrist positions and movements among dairy farm workers in a rotary milking system and compare the results with tethering and loose-housing milking systems	Working in a rotary milking system is less physically demanding for the hands and wrists among dairy farm workers compared to tethering and loose housing milking systems	No
Paper III	Investigate the psychosocial work environment and mental health	Livestock workers assess their psychosocial work environment and mental health as good	Yes
	Identify risk factors associated with the psychosocial work environment for MSD	Risk factors for MSD are associated with the psychosocial work environment	No
Paper IV	Investigate possible associations between the health of the dairy cows and that of the dairy farm workers	Dairy farm workers working with healthy dairy cows have better health than those working with less healthy dairy cows	No

Desirable Improvements

This thesis has contributed to reveal that further measures need to be taken in order to improve the work environment and health among workers in Swedish livestock farming. These improvements could involve:

- Further development and introduction of the support arm for the milking cluster and development of an automatic washing teat cup in order to reduce the work load during milking on dairy farms.

- Development of work load reducing devices for catching and lifting piglets and a carriage with an individually adjustable chair and work table, boxes for tools and a device for holding the piglets for example during gelding and vaccination.

- Evaluation studies of new technology in livestock farming should include both human and animal health and welfare. Enacting of enforcements, which require evaluation of the effect of new equipment and machines on human health and welfare before design, development and marketing of these new technologies.

- Adaptation of the female anthropometrical measures and physical capacity when new technical equipment and machines are designed and developed in order to reduce the work load.

- Reduction of the exposure time to the heavy work loads through changes in the organization of work, for example better working routines, alternating work tasks, and maximum time spent on working with the same work task, and resting time between physically demanding work tasks.

- Educational programmes for livestock workers about correct work techniques and work postures, and the importance of all-round physical exercise in order to avoid acute and long-term bodily disorders.

- Educational programmes for farmers and managers regarding work organization, leadership and labour management. Additionally, discussion groups, courses and similar activities to create a platform for acquiring new knowledge and the exchange of experience concerning leadership management could be important tools for improving the psychosocial work environment.

- Information and educational programmes about why, how and when to use protective equipment.

- Implementation of these educational programmes on the farms and as compulsory courses for students, workers and farmers attending livestock and agricultural schools.

Future Research

This thesis has generated supplemental and new research issues of interest and further studies are needed regarding:

- Case-control and follow-up studies on both large and small modern livestock farms in order to get a more profound understanding of the effects of structural and technical development on livestock workers´ health.

- Intervention studies in a laboratory and on commercial farms in order to evaluate the impact of technical devices such as the support arm and a possible automatic washing teat cup.

- Studies to quantify and compare the work load and postures in different milking systems, for example, parallel and herringbone systems.

- Studies in order to establish and validate the meaning of the level, the importance of the calculated PWS value and whether or not the PWS value can be used for prediction of MSD.

- A comprehensive study to get a profound understanding of the complexity and associations regarding the psychosocial work environment, mental health and private life situation, as well as from a gender perspective.

- Qualitative studies in order to obtain deeper understanding of the difference regarding dairy and pig farm workers´ apprehension of the quality of leadership, feedback and social support.

- Studies with a larger number of variables describing both human and animal health in order to get a more profound characterization of the health concepts.

- Studies of how attitudes towards caretaking of farm animals affect livestock workers´ health and performance.

- Studies of livestock workers´ motivation for choosing and remaining within livestock farming in order to get a better basis for how to attract the young generation to the occupation.

Svensk Sammanfattning

Svensk husdjursproduktion har under de senaste årtionden genomgått en betydande strukturell och teknisk utveckling. Gårdar med mjölk- eller grisproduktion har blivit allt färre i antal, men större med hänsyn till besättningsstorlek. Idag, finns det ungefär 8000 mjölkgårdar och 2400 grisgårdar med en genomsnittlig besättningsstorlek på 51 mjölkkor respektive 116 suggor. Samtidigt med den strukturella utvecklingen så har det introducerats mer teknik i stallarna. Lösdriftsstallar med mjölkning i grop eller i karusell har blivit vanligare på gårdar med många mjölkkor. I grisstallarna har avancerad teknik och mer automatik i utfodrings-, utgödslings- och ventilationssystemen introducerats.

Den strukturella och tekniska utvecklingen har sannolikt påverkat arbetsmiljön och hälsan bland de sysselsatta inom svensk husdjursproduktion i flera avseenden. Syftet med denna avhandling var att undersöka den fysiska och psykosociala arbetsmiljön bland anställda djurskötare på stora moderna gårdar med mjölk- och grisproduktion. Dessutom var syftet att undersöka om arbetsmiljön hade påverkat djurskötarnas fysiska och mentala hälsa. Studierna genomfördes främst med frågeformulär, men även med intervjuer och gårdsbesök, samt genom mätning av handledsvinklar vid mjölkning.

Resultaten visade att djurskötarna på både mjölk- och grisgårdarna rapporterade höga frekvenser av belastningsbesvär (MSD) i rörelseorganen. Besvären var främst lokaliserade till de *övre extremiteterna* och *ryggen* och detta speciellt bland de kvinnliga djurskötarna. Repetitivt arbete och kroppslängd var de faktorer som identifierades som potentiella risker för MSD i de *övre extremiteterna* bland djurskötare i mjölkproduktionen. Bland djurskötarna på grisgårdarna var damm och besvärliga arbetsställningar möjliga riskfaktorer för MSD i de *övre extremiteterna*.

Arbetsuppgifter såsom maskinmjölkning på mjölkgårdarna och manuell skrapning av gödsel i grisboxar på grisgårdarna, var de mest tidskrävande

arbetsuppgifterna bland djurskötarna. Det var också de uppgifter som hade högst värde (PWS) med hänsyn till upplevd fysisk ansträngning satt i relation till den faktiska arbetstiden som djurskötarna använde för dessa arbetsuppgifter.

Mjölkning av kor i karusellsystem innebär att mjölkaren, i motsats till mjölkning i grop, står kvar på samma plats medan korna kontinuerligt kommer in i karusellen och blir mjölkade. Arbetsuppgifterna i karusellen är reducerade till att enbart omfatta avtorkning av juver, förmjölkning och påsättning av mjölkningsorgan. Resultaten av mätningarna visade att mjölkningsarbete i karusellsystem var fysisk krävande för händer och handleder med hög hastighet och repetivitet. Dessutom fanns det nästan ingen tid för vila av händerna under mjölkningspassen. Dessa faktorer har i tidigare studier visats vara riskfaktorer för utveckling av symptom och skador i händer och handleder.

Djurskötarna på gårdarna med mjölk- och grisproduktion värderade sin psykosociala arbetsmiljö och mentala hälsa som god och de var nöjda med sitt arbete som djurskötare. Dock värderade djurskötarna på mjölkgårdarna att ledarskap, feedback och socialt stöd var något sämre i jämförelse med hur djurskötarna på grisgårdarna värderade dessa psykosociala faktorer. Det var dock inte möjligt att i denna studie fastställa orsaken till skillnaden i värderingarna.

Vi undersökte också om det fanns samband mellan MSD i de *övre extremiteterna* och de psykosociala arbetsmiljöfaktorerna. Resultaten indikerade att det sannolikt var fysiska arbetsmiljöfaktorer i stället för psykosociala som kunde vara möjliga orsaker till den höga prevalensen av MSD bland djurskötarna.

Möjliga samband mellan djurens och djurskötarnas hälsa undersöktes i en av studierna. Resultaten visade, något oväntat, att djurskötare som arbetade med mjölkkor med bra hälsostatus, hade sämre fysisk och mental hälsa än de som arbetade med mjölkkor med sämre hälsostatus. Anledningen till detta kan vara att för att upprätthålla en god djurhälsa, så krävs det mycket arbete, noggrannhet och omsorg om djuren i det dagliga arbetet, både med hänsyn till hög hygien i stallet som helhet och med hänsyn till noggranna avtorkningsrutiner vid mjölkningen.

Sammanfattningsvis, kan det konstateras att djurskötarna på de studerade gårdarna med mjölk- och grisproduktion hade hög prevalens av MSD i olika kroppsdelar, men de var nöjda med sin psykosociala arbetsmiljö och med sitt arbete som djurskötare. Prevalensen av MSD var snarare associerad till den fysiska än den psykosociala arbetsmiljön.

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