Physical Workload and Musculoskeletal Symptoms in the Human-Horse Work Environment

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Abstract

Most work in horse stables is performed manually in much the same way as a century ago, with old-fashioned tools and equipment. It is one of the least mechanised sectors dealing with large animals, which often involves work in awkward postures and lifts of heavy loads. However, there is a lack of knowledge of the ergonomic risks in the human-horse work environment.

This thesis seeks to provide a deeper understanding of the human-horse work environment, work tasks, workload and frequency of musculoskeletal symptoms and to identify potential risk factors for the development of musculoskeletal symptoms.

Self-reporting methods (questionnaires, rating scales), observation methods (OWAS, REBA), descriptive task analysis (HTA, HA, GTS) and biomechanical analysis (JACK) were used to collect and analyse data. Riding instructors surveyed in the questionnaire study reported high levels of perceived musculoskeletal symptoms in at least one of nine anatomical areas during the past year and the past week. The most frequently reported problem areas were the shoulders, the lower back and the neck. Mucking out stables was considered to be the task involving the heaviest work. OWAS analysis showed that three work tasks contained a high proportion of unacceptably awkward work postures, namely mucking out, preparing bedding and sweeping. During mucking out and sweeping, the back was bent and twisted for most of the time.

There were many high-risk operations involved in mucking out boxes and disposing of bedding material. Emptying a wheel barrow on the muck heap included high-risk operations with awkward postures such as twisted, bent back arms over shoulder level and handling high loads. The analytical methods used clearly revealed where in the work tasks the ergonomic problems occurred. In almost all operations with a high risk level, a shafted tool or wheelbarrow was used. Analysis of the shaft length of two hand-held tools used for mucking out (manure fork, shavings fork) showed that the manure fork should have a longer shaft to reduce loading on the back. The results for the shavings fork were inconclusive, but indicated the importance of changes in work technique.

More in-depth knowledge of the musculoskeletal symptoms and work tasks performed in the human-horse work environment makes it easier to plan and implement measures to prevent musculoskeletal symptoms in this particular group of workers.

Keywords: Work tasks, ergonomics, work postures, long-shafted tools

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Contents

List of Publications

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

I Löfqvist, L., Pinzke, S., Stål, M. and Lundqvist, P. 2009. Riding instructors, their musculoskeletal health and working conditions. Journal of Agricultural Safety and Health 15(3):241-54.

II Löfqvist, L., and Pinzke, S. 2011. Working with horses: An OWAS work task analysis. Journal of Agricultural Safety and Health 17(1):3-14.

III Löfqvist, L., Osvalder, A-L., Bligård, L-O. and Pinzke, S. 2012. Ergonomic risk evaluation of body postures during daily cleaning tasks in horse stables. (Submitted)

IV Löfqvist, L., Babapour Chafi, M., Osvalder, A-L., Bligård, L-O. and Pinzke, S. 2012. Ergonomic evaluation of long-shafted tools used in horse stables: The effects of shaft length variation and work technique on working postures. (Submitted).

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The contribution of Lotta Löfqvist to the papers included in this thesis was as follows:

I Planned and carried out the investigation, processed the data and wrote the paper in collaboration with co-authors.

II Planned and carried out the investigation, processed the data and wrote the paper in collaboration with co-author.

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

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

Abbreviations

AFS 1998:1	Provisions of the Swedish National Board of Occupational Safety and Health on Ergonomics for the Prevention of Musculoskeletal Disorders.
CTD	Cumulative Trauma Disorder
GTS	Generic Task Specification
IEA	International Ergonomics Association (www.iea.cc)
HTA	Hierarchical task Analysis
HE	Heuristic Evaluation
MSD	Musculoskeletal disorders
NIOSH	The National Institute for Occupational Safety and Health, the United States' federal agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness. NIOSH is part of the Center for Disease Control and Prevention (CDC) within the U.S. Department of Health and Human Services.
OCD	Occupational cervicobrachial disease
OWAS	Ovako Working posture Analysing System
REBA	Rapid Entire Body Assessment
RSI	Repetitive strain injuries
WMSD	Work-related musculoskeletal disorders

Terms and definitions

Awkward work postures	Working with various parts of the body (*e.g.* limbs, joints, back) in a bent, extended or flexed position rather than in a straight and neutral position (Leijon *et al.*, 2005; Keyserling *et al.*, 1992).
Anthropometry	A science that studies the dimensions of the human body, especially the size and shape of the body and its parts (Pheasant & Haslegrave, 2006).
Box stall	An individual enclosure within a barn or stable in which an animal may move about freely without a restraining device.
Discomfort	Physical or mental distress and indication of a perceptual subjective phenomenon that is more diffuse than pain (Hagberg *et al.*, 1995).
Disease	Broadly refers to any condition that impairs normal function (Hagberg *et al.*, 1995).
Disorders	Descriptor for functional abnormality or disturbance of the musculoskeletal system (Hagberg *et al.*, 1995).
English stables	Loose boxes, *i.e.* stable design where the stable door opens directly to the outside instead of having a stable aisle. (The type of stable is characterized by fresh stable air among other things)(Ventorp & Michanek, 2003).
Ergonomics	Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimise human well-being and overall system performance (IEA, 2012).

Fatigue	Incapacity to continue strenuous physical or mental work at the same rate as previously (Hagberg *et al.*, 1995).
Hazard	A situation in the workplace that has the potential to harm the health and safety of people. A condition with the potential to cause injury, illness or death of personnel.
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).
Jack/Jill	Biomechanical manikins in the JACK® software.
Illness	A synonym of ill-health (Hagberg *et al.*, 1995).
Load	Physical stresses acting on the body or on anatomical structures within the body. These stresses include kinetic (motion), kinematic (force), oscillatory (vibration) and thermal (temperature) (National Research Council and the Institute of Medicine, 2001).
Loose housing	A group housing system where horses have free access to an unheated hall with bedding and a paddock (Ventorp & Michanek, 2003).
Manual handling	Transfer of loads, where employees exert muscle force to lift, deposit, push, pull, roll, carry, hold or support an object or a living being (Swedish Work Envionment Authority, 1998).
Manual work	Work performed by hand without machinery.
Pain	Unpleasant sensory and emotional experience associated with actual or potential tissue damage (Hagberg *et al.*, 1995).
Physical ergonomics	Concerned with human anatomical, anthropometric, physiological and biomechanical characteristics as they relate to physical activity. The relevant topics include working postures, materials handling, repetitive movements, work-related musculoskeletal disorders, workplace layout, safety and health (IEA, 2012).
Prevalence	The number of events, *e.g.* of a given disorder or condition, in a given population at a designated time (Last, 2001).
Riding school	A company that has lesson horses and offers riding lessons or riding to the public (Swedish Board of Agriculture, 2011).
Symptom	A phenomenon that arises from and accompanies a particular disease or disorder and serves as an indication of

	it (Hagberg *et al.*, 1995).
Torque	The tendency of a force to cause or change rotational motion of a body. Torque is calculated by multiplying force by distance, so the SI units of torque are Newton-metres (Nm), also known as moment.
Tie-stall	A stall just large enough to accommodate one animal, which is usually tied in by a neck chain (cattle), or a halter (horses).
Workload	See load
Work task	A specified amount of work, set of responsibilities or occupation assigned to an individual or a group.

1 Introduction

1.1 Horses in society

Horses have played a significant role in the history of mankind over time. Horses were historically used in farm work and as a means of transportation (Hausberger *et al.*, 2008). Today, the horse is no longer used for transportation or draught in most industrialised countries, but rather for riding, racing and limited farm/ranch work. In other countries, however, horses and donkeys are still an important source of draught power in agriculture and in transport (Endenburg, 1999).

The Food and Agriculture Organization has estimated that in 2010, there were almost 59 million horses in the world, with around 33.5 million in the Americas, 13.8 million in Asia, 6.3 million in Europe, 5.3 million in Africa and 400 000 in Oceania (FAOSTAT, 2012). There are an estimated 9.5 million horses in the United States alone.

The number of horses in Sweden decreased from around 700 000 in the early 1920s to around 70 000 in the 1970s, but during the past 30 years it has increased tremendously (Government Offices of Sweden, 2000). Today there are more than 360 000 horses, meaning that Sweden has one of the highest horses per capita densities in Europe. As the number of horses has increased, the number of cows in Sweden has declined. For the first time there are now more horses than cows (Swedish Board of Agriculture, 2012; Statistics Sweden, 2011). A similar increase in the number of horses has taken place in the rest of Europe, as well as in North America (Elgåker & Wilton, 2007).

The expansion of the equine sector means that today there are about 1 million Swedes (11%) who are regularly in contact with horses, about 500 000 of whom ride regularly in competitions, for exercise or recreation. Of these, 85% are female (Swedish Equestrian Federation, 2012). Among young people, equestrian sports come third after football and floor ball, and for young females they take second place (Swedish Sports Confederation, 2008). The range of people in contact with horses is broad and includes farriers, veterinarians, riding instructors, recreational riders, stable lads and grooms, jockeys, trainers, stable owners, breeders, inseminators and occupational riders such as ranchers, mounted police, *etc.* Furthermore, a number of people are occupied/engaged in operations that are connected with horses but have no direct physical contact with horses, for example at flat racing, jump and race tracks, or in feed production, insurance companies and manufacturing industries.

There are 77 800 business enterprises involving horses in Sweden and these provide full-time or part-time work for a total of 25 000 people (Swedish Board of Agriculture, 2011). Horses and horse establishments in Sweden are mainly situated around residential areas, *i.e.* about 75% of horses and 66% of equine establishments are in urban and periurban areas (Swedish Board of Agriculture, 2011). The majority (85%) of establishments house their horses in stalls with boxes, but approximately 25% have all or some of their horses in loose housing. Around two-thirds of those working with horses are women (Swedish Board of Agriculture, 2012). There are over 597 riding schools, almost 1000 riding clubs with 200 000 members and 75 trotting courts (Government Offices of Sweden, 2006).

The increasing horse sector is having a large impact on many levels of society, such as economic, social, sports and landscape planning (Elgåker, 2011; Flygare & Isacson, 2003). It is estimated that the annual turnover of the horse industry is around SEK 20 billion, of which SEK 10 billion can be attributed to gambling. Furthermore, it is estimated that an additional SEK 10-26 billion is generated in annual turnover as an indirect influence on the economy (Johansson *et al.*, 2004). Horses also play an important part in the development of a living countryside. Horses provide an additional income to farmers over and above conventional farming and encourage people to move to the countryside or to remain in rural areas (Flygare & Isacson, 2003).

The expansion of the horse sector also means that there are an increasing number of people now performing labour-intensive tasks in stables in connection with the care of horses, such as stable personnel, farmers, breeders and riding instructors (Hästnäringens Nationella Stiftelse (HNS), 2011). The past decade has seen major changes in agriculture, where mechanisation and automatisation with new machinery have replaced many manual work tasks. However, the horse industry has not undergone the same technological development as the rest of the agricultural sector

(Bengtsson, 2010; Wallertz & Bendroth, 2009). Horse farms are often small, outdated and not always appropriate to the activities conducted there, which can make them difficult to mechanise. There are technical solutions and housing systems that would facilitate mechanisation of work in these buildings (Wallertz & Bendroth, 2010; Wallertz & Bendroth, 2009). However, the tendency among horse owners to mechanise and automate is low, often due to factors such as economics and tradition. Instead, equipment and methods developed during the early 1900s are used (Wallertz & Bendroth, 2010; Bengtsson, 2010; Wallertz & Bendroth, 2009). This means that the majority of the hard physical work in most horse stables is still performed manually (Bengtsson, 2010). Therefore, there are several ergonomic issues in the human-horse work environment, especially the physical workload and its relation to musculoskeletal symptoms, that are important to investigate (Swedish University of Agricultural Sciences, 2011). Before these issues in the equine work environment can be discussed, a general brief description of terms in physical ergonomics relevant to this thesis is given below, with particular emphasis on workload, work postures and musculoskeletal disorders (MSD).

1.2 Physical ergonomics

Knowledge of ergonomics is important in order to prevent injuries and enhance health in the workplace (Swedish Work Envionment Authority, 1998). Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimise human well-being and overall system performance (IEA, 2012). Physical ergonomics is a domain within the discipline of ergonomics that is concerned with human anatomical, anthropometric, physiological and biomechanical characteristics as they relate to physical activity. The relevant topics in physical ergonomics include working postures, materials handling, repetitive movements, work-related musculoskeletal disorders, workplace layout, safety and health (IEA, 2012).

1.2.1 Physical workload

Physical load can be defined as physical stress acting on the body or on anatomical structures within the body, including motion, force, vibration and temperature. The level of load, repetition and duration are important to consider when estimating exposure to physical load (Li & Buckle, 1999; Bernard, 1997; Winkel & Mathiassen, 1994). Greater force exerted puts increasing demand on the body and creates greater muscle exertion, and therefore tasks that require forceful exertion put a greater load on tendons, muscles and joints (Bernard, 1997). If these structures are overloaded, acute injuries and more long-term chronic injuries can occur (Swedish Work Envionment Authority, 1998; Keyserling *et al.*, 1993).

1.2.2 Work postures

Posture is the position of the body while performing work activities. Working in awkward postures, such as a bent, extended or flexed position rather than a straight and neutral position, is associated with an increased risk of fatigue, pain or injury, especially if the posture is used repetitively or for prolonged periods (Keyserling *et al.*, 1992). Furthermore, constrained work postures of long duration are known physical risk factors associated with MSD (Leijon *et al.*, 2005; van der Windt *et al.*, 2000; Hoogendoorn *et al.*, 1999).

Posture is influenced by the task, the work situation, tool design and the anthropometric characteristics of the worker (Vieira & Kumar, 2004). If a high load is handled in an awkward posture, the body will incur damage faster than with a more favourable neutral posture (Kerst, 2003). There is no single posture that can be comfortably maintained for long periods of time. Any prolonged posture will lead to static loading of the muscles and joint tissue and cause discomfort. The natural behaviour of human beings is to change posture often, even during sleep (Magnusson & Pope, 1998).

1.2.3 Musculoskeletal disorders (MSD)

Musculoskeletal disorders represent a major problem in terms of human suffering, as well as economic losses for society; (European Agency for Safety and Health at Work., 2007; Woolf & Pfleger, 2003). They are one of the major sources of disability and lost work time (Buckle, 2005; Walker-Bone *et al.*, 2004; Norlund *et al.*, 2000; van der Beek & Frings-Dresen, 1998; Winkel & Westgaard, 1992). In the European Union, MSD are the most common work-related health problems, with 25% of European workers complaining of backache and 23% complaining of muscular pains (European Agency for Safety and Health at Work., 2007).

Musculoskeletal disorders is an umbrella term for disorders and diseases in the musculoskeletal system, which includes muscles, nerves, tendons, ligaments, joints, cartilage and spinal discs. Work-related musculoskeletal disorders (WMSD) include disorders and diseases of the musculoskeletal system that are believed to have a work-related causal component (Hagberg *et al.*, 1995). The term roughly corresponds to other concepts such as cumulative trauma disorder (CTD), repetitive strain injury (RSI) and occupational cervicobrachial disease (OCD). In this thesis, WMSD is used as an umbrella term for grouping together specific work-related musculoskeletal disorders. There are a couple of terms relevant to MSD; *disorder* is used as a descriptor for functional abnormality or disturbance of the musculoskeletal system, *disease* broadly refers to any condition that impairs normal function and *illness* is used as a synonym of ill-health. *Discomfort*, *fatigue* and *pain* are the most common symptoms associated with MSD. A *symptom* is a phenomenon that arises from, and accompanies, a particular disease or disorder and serves as an indication of it. *Discomfort* is defined as physical or mental distress and indicates a perceptual subjective phenomenon that is more diffuse than pain. *Fatigue* is a complex and diffuses term, defined as an incapacity to continue strenuous physical and mental work at the same rate as previously. Fatigue is also a normal, healthy condition when experienced after exertion or at the end of a day. *Pain* is defined as an unpleasant sensory and emotional experience associated with actual or potential tissue damage (Hagberg *et al.*, 1995).

MSD do not normally include injuries resulting from slips, trips, falls or similar acute injuries. Instead, these are considered to be cumulative trauma developed from repeated exposure to a stressor (Davis & Kotowski, 2007).

In this thesis, MSD is used as a descriptor for perceived symptoms, problems, aches, pains and discomfort in the musculoskeletal system.

Risk factors for MSD

In the literature, MSD are often described as multifactorial (David, 2005; van der Beek & Frings-Dresen, 1998; Bernard, 1997; Hagberg *et al.*, 1995; Armstrong *et al.*, 1993). Physical, psychosocial and individual factors contribute to the development of musculoskeletal disorders. There is strong evidence of an association between MSD and certain work-related physical factors, *e.g.* when there are high levels of exposure and especially in combination with exposure to more than one physical factor, for example repetitive lifting of heavy objects in extreme or awkward postures (Bernard, 1997; Nisell & Vingård, 1992). It is believed that manual material handling, frequent bending and twisting, heavy physical load, static work posture, repetitive movements, whole body vibration or lack of recovery can trigger or cause a pathological response that can manifest as MSD (Punnett & Wegman, 2004; National Research Council and the Institute of Medicine, 2001; van der Beek & Frings-Dresen, 1998; Bernard, 1997; Hagberg *et al.*, 1995; Bongers *et al.*, 1993). The level of load, duration and repetitiveness are therefore important factors to consider when estimating physical exposure and the risk of developing MSD (Bernard, 1997; Winkel & Mathiassen, 1994). Another important factor is lack of muscle recovery (Unge *et al.*, 2007; Sandsjö *et al.*, 2000).

Actual work postures and movements can cause specific disorders, such as carpal tunnel syndrome (repeated flexion of wrist) (Silverstein *et al.*, 1986), pronator syndrome (rapid pronation of the forearm) (Stål *et al.*, 2004), rotator cuff tendonitis (repeated shoulder movements, especially twisting and overhead throwing) (Järvholm *et al.*, 1988), tennis elbow (repeated twisting arm movements), and shoulder bursitis (repeated shoulder movements). These are all examples of work-related MSD in the upper extremities (Kroemer, 1989).

MSD in the agricultural sector

MSD are one of the most common non-fatal occupational injuries in agriculture and cause individual suffering and substantial economic losses (Fathallah, 2010; Kirkhorn *et al.*, 2010). MSD are common among dairy farmers, especially in the lower back, shoulders, hands/wrists and knees (Hartman *et al.*, 2006; Kolstrup *et al.*, 2006; Gomez *et al.*, 2003; Pinzke, 2003; Stål *et al.*, 2000; Stål *et al.*, 1999; Lower *et al.*, 1996; Hildebrandt, 1995). High frequencies of MSD have also been found among Swedish pig farmers, with a predominance in the shoulders and in the hands/wrists (European Agency for Safety and Health at Work., 2007; Kolstrup *et al.*, 2006; Stål & Englund, 2005) .

1.3 Human-horse work environment

The physical workload and its consequences in farm work with large animals have been investigated in a number of studies (Davis & Kotowski, 2007; Kolstrup *et al.*, 2006; Holmberg *et al.*, 2003; Pinzke *et al.*, 2001; Stål *et al.*, 1998). However, only a few studies have investigated the workload involved when performing manual tasks around horses like for example Adolfsson & Geng, (2008) and Swanberg (2012), but none of these has investigated the ergonomic situation in horse stables in detail.

The main factors that are relevant to the workload and ergonomic risks when working with horses are the horse itself, the human and aspects of the workplace, such as work tasks and tools.

1.3.1 The horse

Horses are large animals that weigh between 500-1000 kg. They are distinctly herd animals, with a strong herd instinct. This often controls their behaviour and it can for example disturb and frighten a horse to be separated from others, causing some behaviour that may appear irrational to humans. Horses are primarily 'flight' animals, *i.e.* their instinct is to flee when frightened. This reaction is typical of a prey animal, which reacts primarily by running as a defence strategy if cornered or trapped in a confined space (Grandin & Johnson, 2009; Christensen *et al.*, 2006; Myers, 2005). Stables with box stalls are the most common housing systems in Sweden (Swedish Board of Agriculture, 2012). Being housed in a box stall is somewhat against the horse's nature, since it prefers to be in the herd. Since flight is not possible in that situation, the horse's defence strategy may be to bite, kick, step or crush anyone who gets in the way (Grandin & Johnson, 2009; Myers, 2005). Understanding the horse and its instincts and keeping one step ahead is often necessary when dealing with horses. As a prey animal it reacts swiftly if the environment changes, *e.g.* if a sudden noise or other 'threat' arises (Thompson & von Hollen, 1996). A harmless object such as a plastic bag in an unfamiliar place can spook a horse (Grandin & Johnson, 2009).

There is often a strong connection or bond between horses and humans, and this interaction can cause a stressed keeper or rider to transfer the stress to the animal, which may increase the risk of injury (Keeling *et al.*, 2009; Visser *et al.*, 2008; Visser *et al.*, 2003; Goodwin, 1999). Because of this, it is important to be firm, calm and unstressed around horses, which is common knowledge for most people working with horses (Grandin & Johnson, 2009; Myers, 2005).

1.3.2 The human

As mentioned above, there are many different people who perform work tasks around horses. They are of different age, gender and ethnicity and they all have different physical abilities to perform the work. Not all of the people that work in horse stables are salaried personnel. Sometimes children help to do work tasks such as grooming horses, feeding and mucking out. At riding schools and suchlike, these tasks are performed as a part of learning how to take care of a horse (Alwall Svennefelt & Lundqvist, 2011). Thus, there are some children that are exposed to the same risks as adult employees (Alwall Svennefelt & Lundqvist, 2011). Therefore it is important to consider all people that perform work tasks in horse stables, regardless of age, sex or ethnicity, when looking at the risks in these workplaces. However, the majority of stable personnel in Sweden are women (Hästnäringens Nationella Stiftelse (HNS), 2011).

In workplace analysis and when planning workplaces, it is necessary to consider the work tasks, the tools and the users performing the task. Data on human dimensions (so-called anthropometric data) must be included so that the workplace is designed for human physical characteristics and dimensions. If not, those working in the workplace run an increased risk of injury. There are a number of factors that are affected by differences in body measurements, for example movement range area/clearance, range of reach, posture/working height and muscle strength (Pheasant & Haslegrave, 2006).

It is well known that there are large individual differences in body size and shape, but differences due to age, gender and ethnicity also influence body measurements (Pheasant & Haslegrave, 2006). There are distinct anthropometric differences between the sexes, with the average measurements for men exceeding those for women in all parameters except hip width (Pheasant & Haslegrave, 2006). There are also differences in terms of *e.g.* body composition and physiology. Women have relatively more fat than men and approximately 70-80% of the maximum oxygen uptake capacity of men (Åstrand, 1990; Astrand, 1960). Women have approximately 50-80% of the maximum muscle strength of men, with the greatest differences in the upper arm and shoulder muscles (Pheasant & Haslegrave, 2006; Janssen *et al.*, 2000; Kroemer & Grandjean, 1997; Miller *et al.*, 1993). Many factors influence muscle strength, with motivation and coordination of muscle groups being of great importance. The main reason for differences in muscle strength between men and women are that male muscles have a larger cross-sectional area than female muscles. Force is directly proportional to cross-sectional area (Pheasant & Haslegrave, 2006), at least in terms of strength measurements of shorter duration. One must also remember that there are large individual differences within the sexes (Pheasant & Haslegrave, 2006), so a large woman may have almost the same characteristics as a small man. Besides variation on an individual, sex and age level, there is also an ethnic variation (Pheasant & Haslegrave, 2006). Age differences are reflected in both size and physiology. The body size and measurements of a child are for obvious reasons less than those of an adult. However, even if a child is tall for its age and is almost the same height as an adult, there are differences in strength. Maximum strength is not reached until people are in their twenties. The muscular strength of boys and girls is similar during childhood and diverges at around the time of puberty. Muscle strength continues to increase in early adulthood, but declines in middle age and thereafter.

All variations in body composition and characteristics need to be taken into account when planning work tasks and workplaces.

1.3.3 The workplace

There are a number of different workplaces at which people work around horses, such as riding schools, trotting and gallop stables, race tracks, stud farms, veterinary surgeries and farms. This thesis focuses on the work environment in riding schools and the work tasks and staff involved in these. Riding schools in Sweden consist in general of stables/boxes for the horses, a barn or other kind of feed and bedding store, a riding arena, a paddock, meadows and a staff room/office. Of course this varies and there are large differences between riding schools. For example, some riding schools have no riding arena, so they perform their riding lessons outside in paddocks instead. The stables in Sweden most commonly consist of box and tie stalls (Swedish Board of Agriculture, 2012), with stalls on one side or on both sides of a stable aisle (Ventorp & Michanek, 2003). It is these types of stables that are studied in this thesis. Other forms of housing systems, such as English stables and loose housing (Ventorp & Michanek, 2003), are not included. Stable layout and the equipment in the stable have an impact on the workload and how the work tasks are performed. For example the distance to the muck heap, where the tools are stored and whether rugs are hung high up near the ceiling to dry can affect the amount of work performed above shoulder level and below knee level.

Work tasks

The work tasks performed in stables include mucking out, sweeping stable aisles, replacing bedding and feeding horses (Mellberg, 1998). Boxes and tie stalls are often mucked out using a pitchfork/manure fork, a shavings fork and a wheelbarrow. The used bedding material, droppings and urine are picked up with a fork and placed in a wheelbarrow. Mucking out with a shavings fork includes a work movement where the fork is shaken to separate the droppings from the shavings, while work with the manure fork involves more of a digging action. The manure is then transported to a manure heap, the wheelbarrow is emptied and the muck heap is levelled and shaped. Sweeping involves using a broom to sweep the stable aisles free of straw, while replacing bedding includes bringing fresh shavings or straw from the barn or loft and distributing the material with a shavings fork or pitchfork in the boxes and tie stalls. The horses are fed hay or silage, which is often weighed so the correct amount is given to each horse, using a big bag, wheelbarrow or basket. The horses are also given oats/horse nuts/minerals, which includes filling a cart, transporting the feed and distributing it in the crib using some kind of bucket or scoop (Mellberg, 1998). At riding schools, other work tasks performed by the personnel include grooming horses, putting on and taking off rugs, tacking up and letting horses out into grazing paddocks and bringing them back in. Riding and schooling horses may also be part of the working day.

The riding instructor is responsible for riding lessons and also the preparations beforehand. Riding lessons, with or without jumping exercises, may be given to children or adults. The preparations for riding lessons differ depending on the kind of riding lesson. Before an ordinary riding lesson, this can mean bringing the horse to the yard and helping pupils to brush it, put on the saddle and bridle and clean out the hooves. Before a jumping lesson, the preparations can include arranging a jumping arena and bringing out materials.

The frequency with which different work tasks are performed differs from one riding school to the next. Certain work tasks are performed daily, such as feeding, sweeping, mucking out and replacing the bedding. Work tasks such as grooming horses, putting on and taking off rugs, tacking up and moving horses between paddock and stable are performed frequently. Other work tasks are carried out less frequently and some perhaps only once a year, for example thorough cleaning of stables is perhaps done once a year when the horses are out grazing during the summer. Bringing hay, silage and straw into the barn is perhaps also done only a couple of times during the year, but involves a high workload. Some work tasks are performed when needed, for example mending fences and equipment and painting. Cleaning the staff quarters, harrowing the riding arena and maintaining riding equipment such as saddles and bridles are included in the work of employees at a riding school.

In Sweden, the animal protection act (DFS, 2007:6) (Swedish Board of Agriculture., 2007) requires that horses should normally be given the opportunity to move freely in their natural gaits outdoors for some part of the day, so horses need to be moved to and from the paddock once a day. Some riding schools have a system whereby the horses run out to the paddock by themselves, while at others members of staff walk the horses individually to the paddock.

The work tasks include work at floor level and above shoulder level, repetitive work and lifting of heavy loads, but also work with less physical strain such as walking and working at waist level.

Tools

Hand-held tools with a long shaft are used in many of the chores in agriculture, work in stables, gardening and property maintenance. Scrapers, spades, shovels, brooms, rakes and forks are examples of hand tools often used. In horse stables common tools are shavings forks, manure forks, brooms, shovels and rakes. Furthermore wheelbarrows and different kinds of trolleys and wagons are generally used. Many of the tools look very much the same as they have done for the past century. Often the tools used in agriculture and gardening are designed for men but used by women (Yoder *et al.*, 2010), and this applies for the horse industry as well. There is more advanced technical equipment available on the market, such as sweepers, automatic forage dispensers and automatic manure handling systems (Wallertz & Bendroth, 2009; Michanek, 2008), but in many stables this is not available, often because of lack of money. Trotting and gallop stables often have a higher degree of mechanisation (Adolfsson & Geng, 2010; Wallertz & Bendroth, 2009).

1.4 Hazards when working around horses

A short description of the major physical hazards (injuries and MSD) involved in working with horses and the physical factors that contribute to these is given in this section.

Injuries

Working with large animals is a hazardous activity (Pinzke & Lundqvist, 2007; Johns *et al.*, 2004; Thelin *et al.*, 2004; Walker-Bone & Palmer, 2002). The risks of injuries in horse riding are also well-documented (Jagodzinski & DeMuri, 2005; Lim *et al.*, 2003; Exadaktylos *et al.*, 2002; Fleming *et al.*, 2001; Iba *et al.*, 2001; Sorli, 2000; Kriss & Kriss, 1997). Every year people die from horse-related injuries (Abu-Zidan & Rao, 2003; Griffen *et al.*, 2002). In Sweden, approximately 2-4 people die every year from a horse-related injury (IF insurance., 2006; Ingemarson *et al.*, 1989; Örnehult & Eriksson, 1989). A further 13 000 injuries every year requiring medical care in an emergency ward are related to riding or horsemanship in leisure time. Nine out of 10 of the injured are girls or women. In addition to leisure injuries, there are around 700 injuries annually in connection with work around horses (The Swedish Consumer Agency., 2006). The real figure of horse-related injuries is probably higher, as not all injuries are reported or recorded as horse-related. This has been seen in a study of injuries occurring in agriculture, where only 8% are reported and appear in the official statistics (Pinzke & Lundqvist, 2007). The most common types of injuries involving horses are falls from the horse, kicks and being trodden on by the horse (The Swedish Consumer Agency., 2006; Hendricks & Adekoya, 2001; Iba *et al.*, 2001). Work on the ground around horses results in a higher risk of kicks, while horseback riding result in a higher risk of falls (Johns *et al.*, 2004). The severity of the injuries ranges from minor, such as bruises and sprains, to more severe, such as trunk, head and spinal injuries (The Swedish Consumer Agency., 2006).

Physical factors

Previous studies of the work environment in horse stables reported that people working in such environments experience problems due to physical factors such as the climate and dust (Andersson, 2010; Andersson, 2009).

Work with horses is conducted all year around, which implies that the work is frequently done in cold conditions during wintertime in Sweden (Löfqvist *et al.*, 2009), which is also considered a risk factor for the development of MSD (Giedraitytė, 2005; Pienimaki, 2002; Hagberg *et al.*, 1995). Since blood circulation and nerve conduction speed are lower in cold tissues, the function of the locomotive organs is impaired, which reduces the capacity of an individual's physical performance, makes the movements slower and clumsier and the reactions slower and increases the risk of injury (Toomingas *et al.*, 2008). Often the hands and feet are more exposed to cold and this has an impact on hand grip (Toomingas *et al.*, 2008). There is also an increased risk of cold injury when working with bare hands/fingers in cold environments which is often required to perform manual precision tasks (Geng & Holmér, 2001). Stable work is sometimes also done in hot conditions, which in the worst cases can cause severe disorders such as heat stress (Toomingas *et al.*, 2008). Work in hot conditions increases the cardiovascular load on the individual, while long-term heat stress may impair mental and neuromuscular functions. This deterioration can lead to an increased risk of miscalculations and thereby an increased risk of accidents, while the capacity for gripping can also be influenced by sweaty hands. Furthermore, excessive sweating can cause an imbalance in body fluid levels (Toomingas *et al.*, 2008).

Stables and riding arenas are dusty environments, containing particles and substances that may be irritating to the skin, eyes and respiratory system

(Elfman *et al.*, 2009; Wheeler *et al.*, 2006). A study by Crichlow *et al.* (1980) showed that dust levels were highest when cleaning the stalls, which has also been seen in other studies (Curtis, 1996). Cleaning stalls is often the work task that occupies the most time (Bengtsson, 2010). Some studies in animal house environments have reported a correlation between high dust levels and musculoskeletal disorders, but these are mainly on pig farms (Von Essen & Romberger, 2003 ; Donham, 2000; Kirkhorn & Garry, 2000). A study by Kollar (2005) showed that riding instructors who worked mostly indoors in riding arenas had an increased risk of bronchitis. In connection with physical work, it is more likely for particles and substances to be drawn deeper into the lungs (Wheeler *et al.*, 2006). This could imply that the hard physical work in stables in combination with work in the indoor arena could increase the risk of lung problems.

Poor lighting can be a safety hazard, as it can increase the risk of people tripping over objects or slipping, for example on manure or ice. It also makes it more difficult to estimate the range of reach and to judge the position, shape or speed of an object, which can lead to accidents and injuries (Speed & Andersen, 2007).

Musculoskeletal problems

The work tasks performed in horse stables often involve lifting heavy loads, repetitive work and awkward work postures, factors known to increase the risk of musculoskeletal problems (see Section 1.2.3). However, only few studies of MSD among horse workers have been carried out to date. They conclude that shoulder, lower back and neck problems are common, *e.g.* among veterinary workers (Scuffham *et al.*, 2010; Smith *et al.*, 2009), riding instructors (Löfqvist *et al.*, 2009), farriers (Holler, 1984) and jockeys and trainers (Speed & Andersen, 2007).

1.5 Limitations

This thesis is based on comprehensive material from the whole of Sweden and more detailed material from field studies in southern Sweden. It concentrates on the work tasks and physical workload involved in work with horses. The psychosocial aspect was not studied. Furthermore, no studies were made in harness, flat or jump racing stables. The work tasks investigated in the riding schools were: riding lessons and selected work tasks in the stable. It was impossible to include all work tasks in this thesis, but a selection of the most common tasks performed by employees was studied.

2 Objectives and hypotheses

2.1 Overall objectives

The overall objectives were to obtain detailed information on the physical load in the human-horse work environment as a basis for preventing MSD, and to identify examples of ways to prevent MSD.

2.2 Specific objectives

Specific objectives were to:
• Gain a general understanding of the physical working conditions, physical workload and musculoskeletal health when working with horses in stables.
• Identify potential risk factors in the development of musculoskeletal symptoms.
• Identify work tasks that contain a high physical strain.
• Estimate the postural load in the work tasks performed in horse stables.
• Evaluate how variations in the shaft length of work tools used in horse stables affect the workload for the user.
• Investigate whether correction of predominant working techniques can decrease the physical workload.

2.3 Hypotheses

- There is a high frequency of perceived musculoskeletal symptoms among people that work with horses.
- The work tasks performed around horses in stables include high workload and awkward work postures.

- There is a correlation between strenuous work tasks and perceived musculoskeletal symptoms when working with horses in stables.
- Shaft length and the use of long-shafted, hand-held work tools affect the physical workload.

3 Structure of this thesis

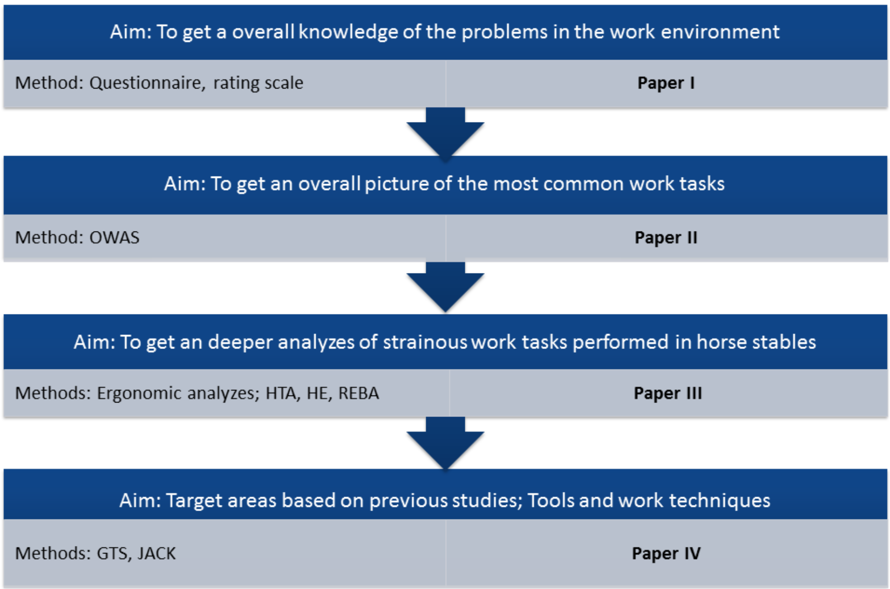

Figure 1. *Flow chart of the structure of the thesis, aims of the included papers and the methods used.*

Figure 1 is a flow chart of the papers included in the thesis; their aims and the methods used. Paper I provides an overview of the work environment around horses at riding schools in Sweden, the prevalence of MSD, physical workload and the work tasks performed by one type of profession working with horses. Since several of the work tasks performed in the stables were identified as work tasks with a high workload, Paper II examined which of the work tasks performed in stables involved the highest workload using a standardised observation method (OWAS) for posture analysis. Three work tasks, 'mucking out', 'sweeping' and 'replacing bedding', showed the highest workload among the work tasks performed daily. These work tasks were analysed further in Paper III using hierarchic task analysis (HE and REBA). Several operations in the work tasks showed an increased risk of ergonomic disorders. In Paper IV, the tools and working techniques used in "mucking out" were analysed further, with the focus on the shaft length of the tool and how that affected working technique and workload.


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4 Materials and Methods

4.1 Materials

Riding instructors, their musculoskeletal health and working conditions (Paper I)

The names and addresses of riding instructors for this study were collected in two ways; 1) by contacting all ridings schools in Sweden with an email address (456 out of 560 schools) and asking them for the their riding instructors names and addresses and 2) through the union Agrifack, which organises academics in the fields of agriculture, forestry, garden, environment and nutrition. In all, 186 riding schools responded giving 714 names of riding instructors and 84 names were provided by Agrifack. Questionnaires were sent out to these 798 riding instructors in Sweden, with questions about their working conditions and health. A total of 572 responses were received, giving a response rate of 72%. Of the respondents, 545 (527 females and 18 males) fulfilled the study criterion of being a riding instructor working at a riding school. Since female instructors constituted almost 97% of the respondents, the responses from the males were not used in the analysis. The female instructors were aged 14-72 years (median 34 years), their height was 152-185 cm (median 168 cm) and their weight was 47-100 kg (median 64 kg). The survey was conducted from spring to autumn 2006.

Working with horses: An OWAS work task analysis (Paper II)

Thirty-five riding schools within a radius of 70 kilometres from the town of Alnarp in southern Sweden were invited by mail to participate in the study; and five of these accepted the invitation. Twenty subjects (riding instructors and stable staffs) at the five riding schools participated in this study. Fifteen were women and five were men. All subjects were studied while they were working in the stables and while preparing and conducting riding lessons.

The following eight work tasks were analysed; 'mucking out', 'disposal of manure', 'sweeping' inside the box and stable aisle, 'replacement of bedding' material, 'feeding hay' to the horses, 'feeding' concentrate, 'preparing' and 'conducting riding lessons'.

'Mucking out' was done using a pitch fork, a shavings fork and a wheelbarrow. 'Disposing of manure' consisted of transporting the manure from the stable to the muck heap and preparing the muck heap. 'Sweeping' was done using a broom. 'Replacing bedding' included bringing the shavings or straw from the barn or loft into the stable and distributing the material with a pitchfork, hayfork or manure fork in the box or tie stall. 'Feeding hay' involved weighing a certain amount of hay and distributing it in the box, using a big bag, wheelbarrow or basket. 'Feeding concentrate' included preparing a cart for transportation of the feed and distributing it to the box or tie stall using some kind of bucket or scoop. 'Riding lesson' implied giving a riding lesson with or without jumping exercises for either children or adults. 'Preparing riding lessons' included the tasks the instructor had to carry out before a lesson and differed depending on the kind of riding lesson. Before an ordinary riding lesson, this could mean preparing the horse and helping the pupils to brush it, tacking up and cleaning out the hooves. Before a jumping lesson, preparations could include arranging a jumping arena and bringing out poles, cones, *etc.* The study was conducted from autumn 2007 to spring 2008.

Ergonomic risk evaluation of body postures during daily cleaning tasks in horse stables (Paper III)

The same 15 stable workers studied in Paper II constituted the material to analyse the physical workload and work postures in three selected work tasks, 'mucking out', 'sweeping' and 'replacing bedding' as described in Paper II. However, 'mucking out' in Paper III also included 'disposing of manure'.

Ergonomic evaluation of long-shafted tools used in horse stables: The effects of shaft length variation and work technique on working postures (Paper IV)

In Paper IV a shavings fork and a manure fork were evaluated when used in the work task 'mucking out' as analysed in Paper III. However, the work task was delimited in Paper IV to the part of the work performed in the box or tie stall, *i.e.* transportation of the manure to the muck heap with a wheelbarrow was not included.

The analysis consisted of two parts. First, a Generic Task Specification (GTS) was used to describe the content and sequence of the work task in detail. Thereafter, load measurements and simulations of the work task were performed in the Jack human simulation system (JACK®) regarding the effects of varying tool shaft length and users' working technique on working postures and body loads.

One subject took part in the GTS analysis, a 22-year-old female (height 169 cm, weight 65 kg). The subject was an expert user, familiar with stable work and the long-shafted tools analysed. The results of the GTS analysis, *i.e.* a detailed division of the work task 'mucking out' into sub-tasks and photographs of both original and corrected work postures for the subject when working with both forks in every sub-task formed the basis for the load measurements in JACK®. Furthermore, CAD models of the manure fork and the shavings fork were created and imported to the JACK® software system. For the procedure with the use of JACK®, see Section 4.2.4.

In the JACK® system, three female user heights, 164, 169 and 174 cm, and five different shaft-lengths of the forks (Table 1) were simulated and tested regarding the effect on body loads for each sub-task in 'mucking out' (Table 5 in Section 4.2.4). The effect of work technique was also tested. Both the original and the corrected work technique were analysed for the original body height (169 cm). For the heights 164 and 174 cm, only the corrected work technique was tested.

For the load measurements with the use of JACK®, see Section 4.2.4.

Table 1. *Shaft length variation.*

Tool	**Variation (cm)**				
Shavings fork*	-10	-5	150	+5	+10
Manure fork**	-10	-5	125	+5	+10

* Weight 1 kg

** Weight 1.8 kg

4.2 Methods

Several different methods were used to describe the physical workload and the work tasks. These were: self-reporting methods (Paper I), observation methods (Papers II & III), descriptive work analysis (Papers III & IV) and biomechanical analysis (Paper IV).

4.2.1 Self-reporting methods

Questionnaire (Paper I)

The questionnaire sent out to riding instructors in Sweden consisted of four parts. The first part consisted of questions concerning individual background factors and environmental factors. The second part, the Standardised Nordic Questionnaire, was used to analyse the self-reported occurrence of musculoskeletal symptoms (ache, pain and discomfort) in nine body regions (neck, shoulder, elbow, wrist/hand, upper back, lower back, hip, knee and ankle/foot) over the past 12 months and the past seven days, and whether the symptoms had prevented the individuals from doing their daily work (Kuorinka *et al.*, 1987). Four clusters were constructed, incorporating symptoms in a combination of the nine different body regions ('in any body region', 'upper extremities', 'lower extremities' and 'the back'). Only data for the symptoms during the last 12 months and the past seven days are presented in Paper I. The third part included questions to determine what work tasks the riding instructor performed, how often and how much time they spent on each task.

Rating Scale (Paper I)

One part of the questionnaire contained questions where the riding instructor had to estimate the physical exertion of every task they performed, such as those described in Section 1.1, using the Borg CR-10 scale (Borg, 1990), and specify which body parts were exerted while carrying out each specific task. The ratings included the following grades;
0 = No exertion at all; 0.5 = Extremely weak; 1 = Very weak; 2 = Weak; 3 = Moderate; 5 = Strong; 7 = Very strong; 10 = Extremely strong.

Statistical Analyses (Paper I)

The SPSS program (ver. 14.0) for Windows was used for all statistical analyses in Paper I. Means and standard deviations were used to describe the background factors and the work tasks. The associations between occurrence of perceived musculoskeletal symptoms and different potential risk factors (background factors, work tasks, and environmental factors) were studied using logistic regression models and are presented as odds ratios (OR) with 95% confidence intervals (CI). The potential risk factors were introduced into the analysis as continuous variables or dichotomised as yes/no. The associations were first tested using a univariate analysis. The potential risk factors that were significantly ($p \leq 0.05$) associated with perceived musculoskeletal symptoms were then treated together in a stepwise multiple logistic regression model (backwards).

4.2.2 Observation methods

Ovako Working posture Analysis System (OWAS) (Paper II)

OWAS is a system for recording arm, back and leg positions in different work tasks and categorising the harmfulness of the tasks. Often video recordings are used for recording work postures. In that case the observer stops the film at predetermined intervals, for example in this study every 3 seconds, and makes a note of the posture in the work task being performed. The back, arm and leg positions are recorded and the weight of the load is accounted for. The method is used to show harmful work positions and work tasks and 84 different combinations are possible. Based on the different posture combinations, four different action categories (Table 2) can be used to classify the harmfulness of different work tasks (Engels *et al.*, 1994; Karhu *et al.*, 1977).

In Paper II, work task analysis was performed using OWAS. All 20 subjects included were video-recorded performing their work in the stable and preparing and conducting riding lessons.

Table 2. *Different action categories (AC1 to AC4), the harmfulness of the postures, and the action required (Karhu et al., 1977).*

Action Category	**Posture**	**Action**
AC1	Normal posture	No action required
AC2	The stress load of the posture is slightly harmful.	Action to change the posture should be taken in the near future.
AC3	The stress load of the posture is distinctly harmful.	Action to change the posture should be taken as soon as possible.
AC4	The stress load of the posture is extremely harmful.	Action to change the posture should be taken immediately.

Rapid Entire Body Assessment (REBA) (Paper III)

REBA is a survey method developed for use in ergonomic investigations of workplaces where work-related entire body disorders are reported (Hignett & McAtamney, 2000; McAtamney & Hignett, 1995). REBA is a screening tool that assesses biomechanical and postural loading on the whole body and is intended to be used as one tool of a broad ergonomic study. REBA is an observation method, where work positions and load usage are graded for different body parts. The estimation of the position of the different body categories results in calculation of a final number, the magnitude of which provides a guide to the priority for subsequent investigations, *i.e.* the number indicates to some extent how severe the ergonomic problem is (Table 3).

In Paper III, REBA was used to further analyse the potential ergonomic problems graded 3 and 4, *i.e.* high risk and very high risk in the Heuristic Evaluation (HE) (see Section 4.2.3), which contained body postures and body loads that could be harmful for the user in the long run. The REBA score was then compared with ergonomic grading to confirm the HE results.

Table 3. *REBA action levels according to Hignett & McAtamney (2000).*

Action level	**REBA score**	**Risk level**	**Action (including further assessment)**
0	1	Negligible	None necessary
1	2-3	Low	May be necessary
2	4-7	Medium	Necessary
3	8-10	High	Necessary soon
4	11-15	Very high	Necessary NOW

4.2.3 Descriptive task analysis

Hierarchic task analysis (HTA) (Paper III)

Hierarchic Task Analysis (Stanton, 2006; Kirwan & Ainsworth, 1992) involves analysing a work task by breaking it into sub-tasks. The sub-tasks are then further subdivided into sub-goals until a stop criterion is reached, often when the sub-goal consists of a single operation. Sub-goals on the lowest level are called operations. The degree of detail is determined on the basis of how the HTA results will be used. The results are often presented graphically in a hierarchical scheme (see Figures 6 and 7 in Results section).

In Paper III, the HTA method was used to analyse three selected work tasks, 'mucking out', 'replacing bedding' and 'sweeping', in a detailed and systematic way. Each work task was divided into a number of sub-tasks (Figure 6), which were sub-divided into operations on the level of physical actions, *e.g.* 'grasping the tool with both hands', 'walking', 'lifting up the tool' and 'lifting and balancing the tool' (Figure 7).

Heuristic Evaluation (HE) (Paper III)

Heuristic Evaluation is a systematic inspection method used in the field of ergonomics (Stanton *et al.*, 2005; Nielsen & Mack, 1994). The goal with the method is to find and rank the physical ergonomic problems (if any) found in a specific work task.

In Paper III the inspection was performed by an evaluator (one of the authors) on the video recordings and photographs of the 15 workers performing the three selected work tasks 'mucking out', 'sweeping', and 'replacing bedding' described in the Materials & Methods (see Section 4.1). The evaluator compared the work posture and load handled against ergonomic guidelines for physical work (Swedish Work Envionment Authority, 1998). In particular, asymmetric body loads and the position of the hands, wrists, neck, shoulders, back and legs were observed and compared with the neutral positions for these body parts. For evaluation of the ergonomic risk in the HTA operations, a five-step grading scale was used (Table 4). To illustrate the HE grading of the operations in the HTA, a colour coding was performed from low risk (green) to very high risk (red) (Table 4).

Table 4. *Ranking scale of ergonomic problems, risk and colour coding in the HTA diagrams (Bligård & Osvalder, 2006).*

Scale	Ergonomic problem	Ergonomic risk	Colour coding
0	Not an ergonomic problem	No risk	GREEN
1	Inconvenience problem; does not need to be fixed unless extra time is available.	Low risk	GREEN
2	Minor ergonomic problem; fixing should be given lower priority.	Medium risk	YELLOW
3	Major ergonomic problem; important to fix, high priority.	High risk	ORANGE
4	Very serious ergonomic problem; needs to be fixed immediately.	Very high risk	RED

Generic Task Specification (GTS) (Paper IV)

Generic Task Specification is a framework for describing task demands and mental/physical workloads. The method describes the body parts strained, the level of load on different body parts, the overall level of load, how repetitive the work is and how much skill the work requires (Bligård & Osvalder, 2012; Bligård & Osvalder).

In Paper IV a description of the task 'mucking out' was made in a laboratory setting to map out the work task and to get a framework for the physical task demands and body parts strained in the work task. The first step was to divide the work done with two forks (shavings and manure fork) into specific sub-tasks (Table 5). Every sub-task was analysed separately, with one original posture (the posture in which the subject automatically positioned herself) for each sub-task and with a corrected posture based on the observers' ergonomic knowledge. Photographs were taken of both original and corrected work postures in every sub-task. The analysis focused on the body parts strained, the level of load on these different body parts, the overall level of load, number of times the movements were carried out and the skill required. During the analysis, the test subject also gave her opinions about the discomfort and load she was experiencing in different body parts and the skill required. The results from the overall analysis were compiled in a matrix and then used in the JACK simulation programme (see Section 4.2.4).

4.2.4 Biomechanical method

The Jack human simulation system (JACK®) (Paper IV)

JACK® is a computer aided programme developed at the University of Pennsylvania in the United States which, by means of models of the human body (manikins), can perform ergonomic simulations. The programme provides the opportunity to change the physical dimensions (anthropometric measurements) on male (Jack) and female manikins (Jill) in order to test products and workplaces for people of all sizes (Sundin, 2004; Badler, 1993).

Table 5. *'Mucking out' a box or tie stall, divided into sub-tasks for each long-shafted tool through the GTS.*

Shavings fork	**Manure fork**
1. Grip shavings fork	1. Put down manure fork
2. Put down shavings fork	2. Dig with manure fork
3. Dig with shavings fork	3. Lift up manure fork
4. Lift up shavings fork	4. Walk with manure fork
5. Empty shavings fork	5. Empty manure fork

Within the JACK® programme, there are different modules for analysis, including a task analysis toolkit (TAT) for analysis of human performance capability. The TAT module includes several tools for quantifying specific task demands, such as Static Strength Prediction Program (SSPP) and Low Back Analysis (LBA). The SSPP tool evaluates the percentage of a worker population that has the strength to perform a task and the LBA tool evaluates the spinal forces acting on the lower back (Low Back Compression Force, LBCF) under an unlimited number of postures and loading conditions (Siemens Industry Software, 2012).

In this study the changes in workload due to variations in shaft length of a shavings fork and a manure fork were analysed with the JACK® programme. The five different lengths of both tools and the three body heights of a user described in the Material Section 4.1, were simulated and tested with the female manikin Jill positioned in different positions for each sub-task in ‘mucking out’ taken from the GTS analysis (Table 5). Furthermore, the changes in workload were investigated with one original and one corrected work technique. Figure 2 illustrates examples of the position of the manikin using a manure fork and a shavings fork, respectively.

The LBA tool in JACK® was used for calculating the forces acting on the lower back, which is expressed in Newtons (N), and the SSPP tool for analysing the torque in the shoulder and back, which is expressed in Newton metres (Nm). The SSPP tool calculated torque values for the shoulder movements; flexion/extension, abduction/adduction and rotation, and for the back movements; flexion/extension, lateral bending and rotation. However, only the torques for flexion/extension movements in shoulder and back was used in the analysis. In total, 150 simulations were performed.

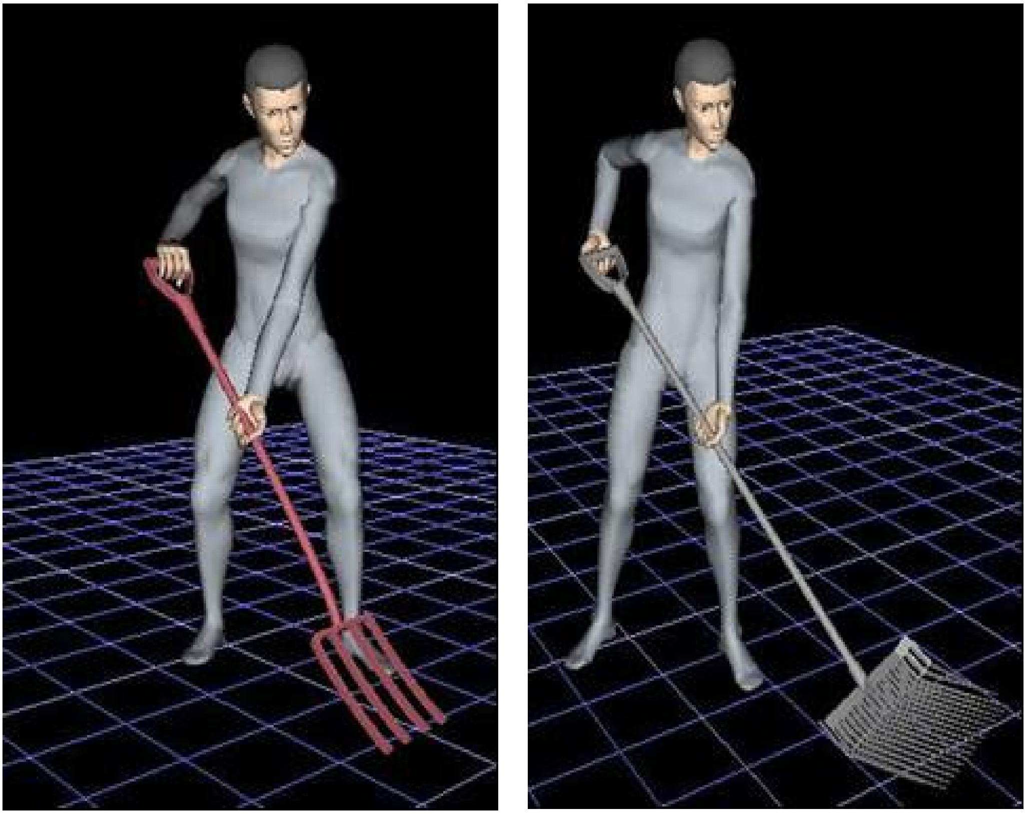

Figure 2. *The manikin using a manure fork at the left and a shavings fork at the right*.

5 Results

5.1 Riding instructors, their musculoskeletal health and working conditions (Paper I)

5.1.1 Perceived symptoms of pain, ache and discomfort

In all, 474 (90.6%) of the 527 instructors surveyed had experienced symptoms during the previous 12 months in at least one of nine body regions asked about using the Standardised Nordic Questionnaire (Table 6). Perceived symptoms of pain, ache and discomfort during the previous 12 months were most frequently reported to be in the shoulders (60.8%), lower back (56.4%) and neck (52.2%). The instructors reported musculoskeletal symptoms from the clustered body regions ‘the back’ (76.3%), ‘the upper extremities’ (69.4%) and ‘the lower extremities’ (53.2%). During the previous seven days, 55.2% had experienced symptoms in at least one of the nine body areas, most frequently in the shoulders (27.5%), lower back (26.3%) and neck (25.3%) (Table 6).

5.1.2 Physical exertion and exerted body regions during work tasks

The following three work tasks were considered to have the greatest workload, between moderate and strong according to the Borg CR-10 scale: ‘mucking out’ (4.1), ‘removal of manure’ (3.9), and ‘handling straw, shavings and hay’ (3.6). During most work tasks, the lower back or the shoulders were the two body regions considered to be placed under the greatest strain. In percentage terms, ‘the back’, including the neck, upper and lower back, was the most physically strained clustered body region during ‘riding lessons’, whether with (64.6%) or without jumping exercises (52.5%). ‘The upper extremities’, including the shoulder, elbow and wrist/hand, suffered the greatest strain during ‘sweeping’ (58.6%), ‘mucking out' (54.7%) and 'grooming' (52.5%). 'The lower extremities' *i.e.* the hip, knee and ankle/foot, were under the greatest strain during 'riding lessons' without jumping exercises (23.2%) and 'correcting and training horses' (18.8%).

Table 6. *Prevalence of pain, ache and discomfort during the previous 12 months and the previous seven days as reported by riding instructors (N=527, missing=4).*

	12 months		**7 days**	
Body region	**N**	**(%)**	**N**	**(%)**
Neck	273	52.2	131	25.3
Shoulder	318	60.8	142	27.5
Elbow	83	15.9	42	8.1
Wrist/hand	151	28.9	51	9.9
Upper back	202	38.6	92	17.9
Lower back	295	56.4	134	26.3
Hip	167	31.9	68	13.3
Knee	145	27.7	55	10.7
Ankle/foot	96	18.4	42	8.1
Clustered body regions				
'In any body region' [a]	474	90.6	291	55.2
'The upper extremities' [b]	363	69.4	172	33.5
'The lower extremities' [c]	278	53.2	133	26.3
'The back' [d]	399	76.3	212	41.7

[a] 'In any body region' consists of at least one of the following body regions: Neck, shoulder, elbow, wrist/hand, upper back, lower back, hip, knee and ankle/foot

[b] 'The upper extremities' consists of at least one of the following body regions: Shoulder, elbow and wrist/hand

[c] 'The lower extremities' consists of at least one of the following body regions: Hip, knee and ankle/foot

[d] 'The back' consists of at least one of the following body regions: Neck, upper back and lower back

The work tasks that significantly were related to perceived musculoskeletal symptoms during the previous 12 months in the univariate logistic analysis are presented in Table 7. The instructors who had the task of removing manure had a more than doubled risk of sustaining musculoskeletal symptoms in 'the upper extremities', OR= 2.12 (CI 1.10-4.09) especially in the shoulder, OR= 2.51 (CI 1.33-4.76) (Table 7).

In general, there was an increased risk of developing musculoskeletal symptoms in 'the upper extremities' in connection with several of the work tasks (Table 7). Furthermore, the risk of developing musculoskeletal symptoms in the hand increased in connection with the work of sweeping, OR= 1.17 (CI 1.02-1.32), and handling horse blankets, OR= 1.16 (CI 1.03-1.31). The risk of developing musculoskeletal symptoms in the neck increased significantly with the time the instructors spent saddling and putting the bridle on the horse, OR= 1.12 (CI 1.01-1.25). There was no significant relation between musculoskeletal symptoms and the work tasks of paperwork or riding lessons. The multivariate analysis showed no significant relations between work tasks and musculoskeletal symptoms.

Table 7. *Work tasks related to affected body regions presented as Odds Ratios (OR) with 95 % Confidence Intervals (CI).*

Work tasks	**Body region affected**	**OR**	**95 % CI**
Feeding	Hand	1.09 **	1.02-1.16
	Shoulder	1.09 *	1.01-1.18
	Elbow	1.09 *	1.02-1.17
	Neck	1.09 *	1.02-1.17
	'The upper extremities'	1.09 *	1.01-1.19
Mucking out	Hand	1.07 ***	1.04-1.11
	Shoulder	1.04 *	1.00-1.08
	Elbow	1.04 *	1.01-1.08
	'The upper extremities'	1.06 *	1.01-1.11
Removal/handling manure (except mucking out)	Shoulder	2.51 **	1.33-4.76
	'The upper extremities'	2.12 *	1.10-4.09
Handling straw, shavings and hay	Hand	1.16 ***	1.07-1.26
	Shoulder	1.13 **	1.03-1.24
	Elbow	1.12 **	1.04-1.22
	Foot	1.09 *	1.01-1.18
	'The upper extremities'	1.16 **	1.04-1.29
Sweeping	Hand	1.17 *	1.02-1.32
Handling horse-blankets and leg protectors	Hand	1.16 *	1.03-1.31
Putting on the saddle and bridle	Neck	1.12*	1.01-1.25

Significant levels: * = $p \leq 0.05$, ** = $p \leq 0.01$, *** = $p \leq 0.001$

5.1.3 Injuries and environmental factors

During the winter, 89.8% of the Swedish riding instructors surveyed worked in cold conditions at some time during the week, with around 72% working in an unheated indoor arena. More than half (55.9%) the instructors considered working in a cold environment to be a problem, giving rise to lower back pain, cold feet, numb fingers or infections, and 14.5% reported having sustained an injury during the previous year. The severity of these injuries ranged from concussion and fractures to 'less severe' injuries such as sprained ankles. In general, the respondents considered their health and their work environment to be good (79.8% and 84.7%, respectively). Almost all (96.6%) enjoyed their work. More than half (53.4%) of the instructors exercised or did sports at least two hours a week (riding excluded).

The instructors who, during the year prior to the questionnaire, sustained an injury had in the univariate logistic analysis a 9-fold significantly increased risk of having musculoskeletal symptoms in any part of the body, OR= 8.85 (CI 1.20-65.15). Those who had problems with working under cold conditions had an increased risk of having symptoms in 'the back', 'the upper extremities' and problems 'in any body region', OR= 2.75 (CI 1.78-4.25), 1.94 (CI 1.31-2.88) and 2.19 (CI 1.16-4.14), respectively. The risk of having musculoskeletal symptoms especially in the lower back, and in the hand decreased with physical exercise at least two hours a week, OR= 0.68 (CI 0.48-0.96) and OR= 0.56 (CI 0.38-0.82), respectively. The multivariate analysis showed no significant relationships between individual and environmental factors and musculoskeletal symptoms.

5.2 Working with horses: An OWAS work task analysis (Paper II)

Three work tasks involved almost 50% of work positions in the three categories (AC 2, 3 and 4) within which action is needed according to the OWAS system. These work tasks were 'mucking out' (50%), 'replacing bedding' (48%) and 'sweeping' (48%). 'Feeding hay' had 40% of work positions in these categories (Figure 3).

The back was bent and twisted 30% of the time during 'mucking out' and 28% of the time during 'sweeping' (Figure 4). During 'mucking out', 'replacing bedding' and 'sweeping', over 60% of the time was spent in a work position where the back was bent, twisted or both bent and twisted (Figure 4).

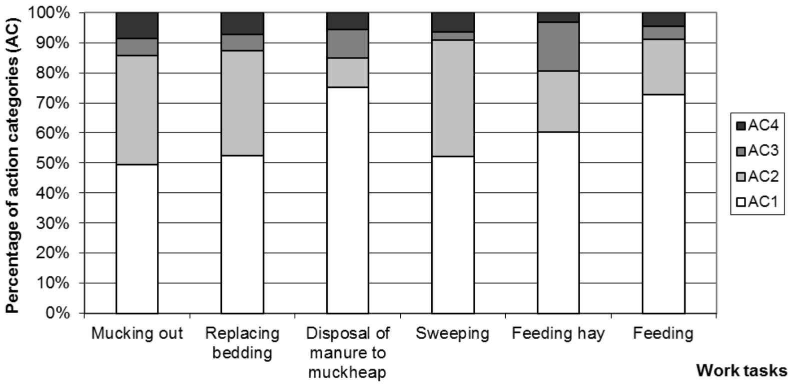

Figure 3. *Work tasks performed in the stable (n=15), with the harmfulness of these tasks categorised into action categories (AC) 1-4.*

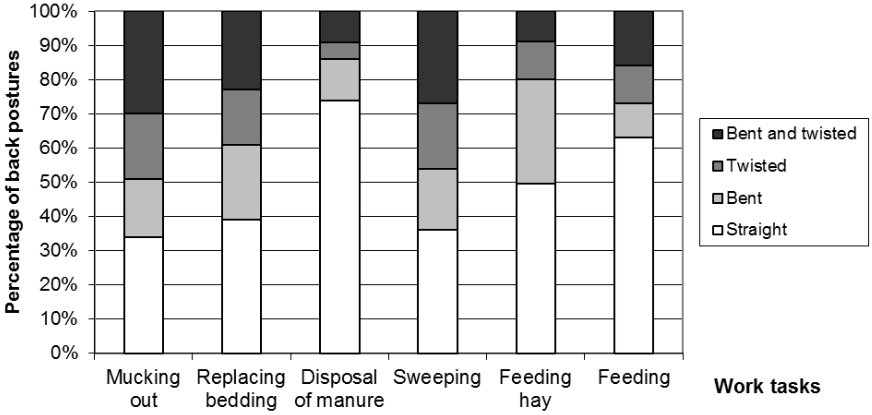

Figure 4. *Percentage of time spent in different work postures of the back when performing the work tasks in the stable (n=15).*

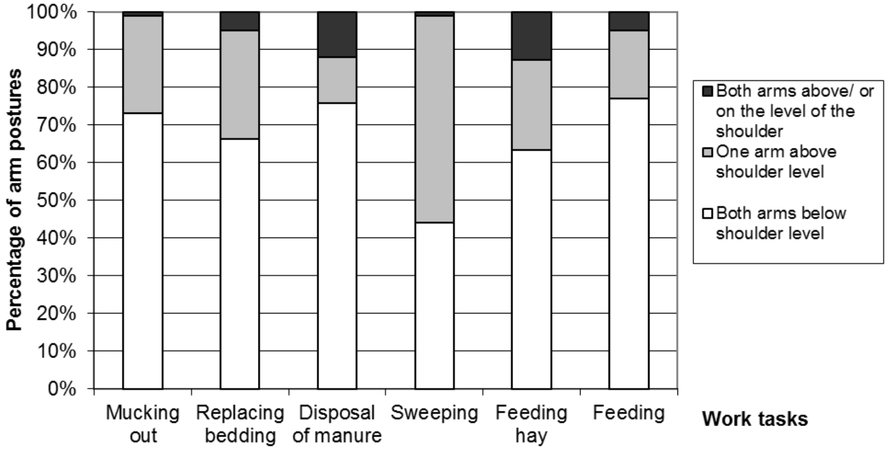

Figure 5. *Percentage of time spent in different work postures of the arms when performing the work tasks in the stable (n=15).*

For more than 10% of the time, the subjects had both their arms above shoulder level during the two work tasks ‘disposal of manure’ and ‘feeding hay’. During ‘sweeping’, one arm was above shoulder level for more than 50% of the time (Figure 5).

Standing straight or walking were the most common work postures of the legs for each of the work tasks. The legs were in these two positions almost 80% of the time for all work tasks combined.

5.3 Ergonomic risk evaluation of body postures during daily work tasks in horse stables (Paper III)

The three work tasks evaluated, ‘mucking out’, ‘sweeping’ and ‘replacing bedding’, were broken down into 12 sub-tasks, as shown in the HTA in Figure 6. These were further divided into 193 operations (83, 13 and 97 operations, in the three work tasks respectively). Most operations (103 out of 193) showed no ergonomic or inconvenience problems and thereby no or low risk. These operations were coded green in the HTA. Of the remaining operations, 36 showed minor ergonomic problems (coded yellow), 49 major ergonomic problems (coded orange) and 5 operations involved very serious ergonomic problems (coded red). The work tasks evaluated as not having an ergonomic problem were tasks that involved ‘walking’ with no load and ‘grasping’ or ‘lifting’ objects with low load. These work operations were performed in favourable working positions, such as upright posture with straight legs, standing or walking on even surfaces. ‘Walking’ and ‘grasping’ a tool were the most common operations.

The operations coded orange were found to have REBA scores of 7-11 and the red operations REBA scores of 10-12, indicating high or very high risks of musculoskeletal injury and action needing to be taken soon or immediately (Table 3).

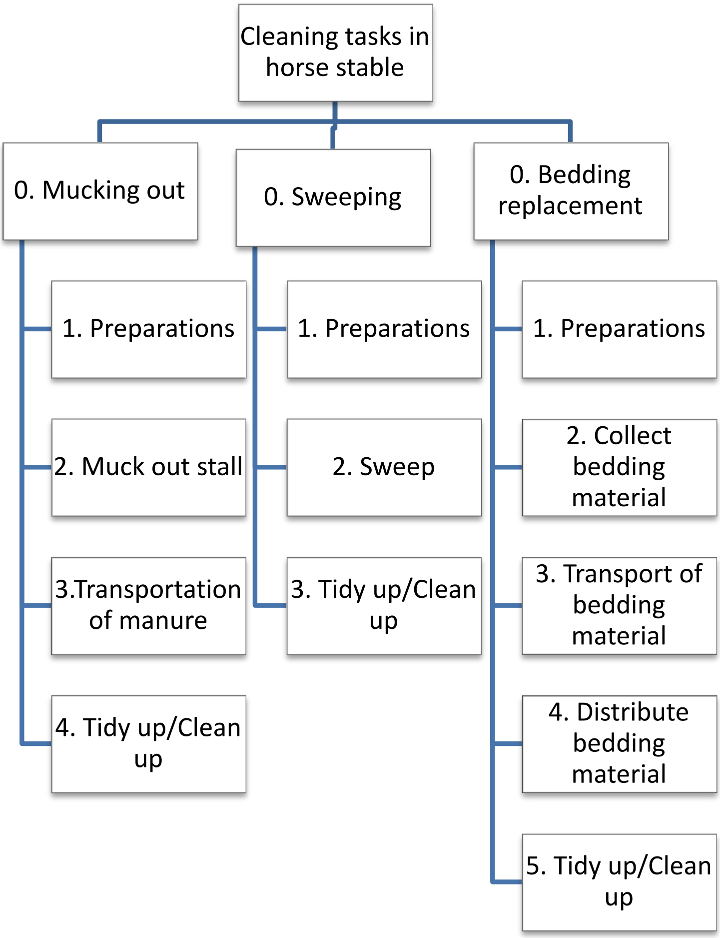

Figure 6. Overall HTA of the cleaning tasks in a stable.

5.3.1 Mucking out

'Mucking out' was divided into four sub-tasks: 'preparation', 'mucking out stall', 'transport and disposal of manure' and 'tidying/clearing up' (Figure 6). 'Transport and disposal of manure' and 'mucking out stall' were the two sub-tasks that involved ergonomic risks.

In the sub-task 'transport and disposal of manure', five operations were colour-coded red and had REBA scores ranging between 10 and 12. 'Transporting manure to the muck heap' and 'emptying the wheelbarrow' were the operations evaluated as having the highest risks in the sub-task (Figure 7).

The other high risk sub-task, 'mucking out stall', had 22 orange-coded operations, with REBA values ranging from 7-11. The use of a fork and loading manure into the wheelbarrow comprised entirely orange operations (high risk). The user's working posture in these operations involved bent and twisted back, wrists in extreme flexion and arms above shoulder level. One of the highest risk levels was found in the operation when the wheelbarrow was lifted up on the manure heap and pushed forward to empty it. In doing so, the arms were above shoulder level, the wrists in extreme flexed position, the back bent and twisted and a high load of approximately 75-100 kg was being pushed forward. The operations with no or low risk (green) during 'mucking out' were *e.g.* 'walking' and 'fetching tools'.

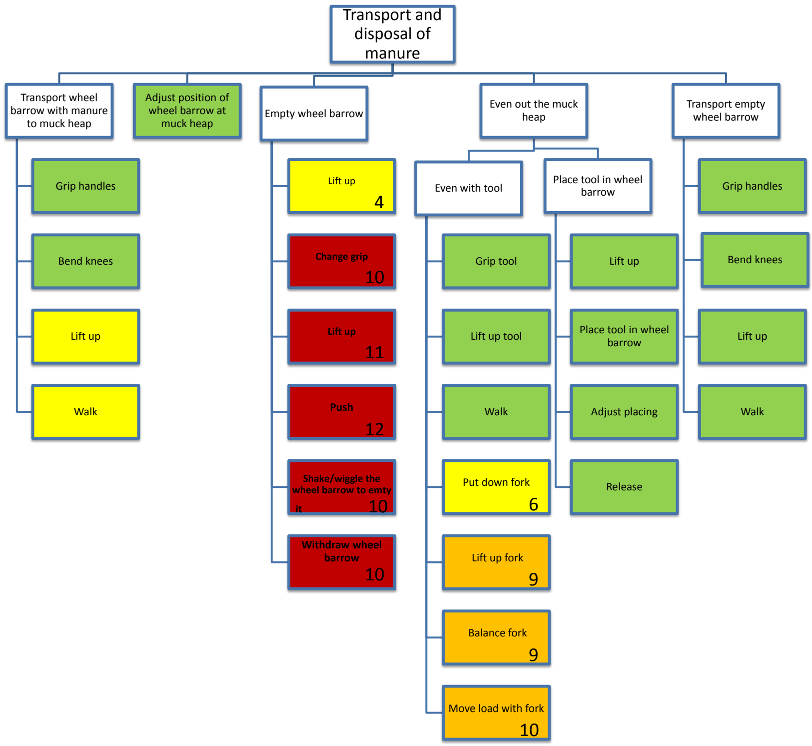

Figure 7. *Hierarchic Task Analysis (HTA) diagram showing the sub-task 'transport and disposal of manure', one of four sub-tasks in 'mucking out'. The operations are colour-coded on the level: Green=no/low risk, yellow=medium risk, orange=high risk, red=very high risk. The figures in boxes (operations) represent REBA scores where: 1= negligible risk level, 2-3= low risk level, 4-7= medium risk level, 8-10= high risk level and 11-15= very high risk of ergonomic injuries.*

5.3.2 Sweeping

'Sweeping' was divided into the three sub-tasks 'preparation', 'sweeping' and 'tidying up' (Figure 6). Only the sub-task 'sweeping' itself contained operations with high risk levels, with REBA values ranging between 7 and 9. However, these operations were repeated continuously for almost the whole work task.

5.3.3 Bedding replacement

'Replacing bedding' was divided into five sub-tasks (Figure 6) and included 97 operations. The three sub-tasks 'distributing bedding material', 'collecting bedding material' and 'transporting bedding material' contained 19 high risk operations (orange), with REBA scores between 7 and 10 (high risk). The highest risk was associated with 'shaking the bedding material', an operation performed with a high frequency and often with the arms elevated and positioned far from the body and with the tool at a 90-degree angle to the body. 'Putting down a bale of shavings' also had a high REBA score (10). This operation includes a work posture with a bent and twisted back and the bale is ungainly to grasp, which makes it difficult to handle and puts strain on the wrists and lower arms. However, 78 of the 97 operations (80%) in 'replacing bedding' had a low ergonomic risk (green).

5.4 Ergonomic evaluation of long-shafted tools used in horse stables: The effects of shaft length variation and work technique on working postures (Paper IV)

The force values acting on the lower back (LBCF) and torque values in the shoulder and back of female users of different heights performing different sub-tasks in 'mucking out' and using shavings forks of different lengths, with one original and one corrected work technique, are shown in Table 8. The corresponding values when using manure forks of different lengths are shown in Table 9.

5.4.1 Shavings fork

The highest compression forces and torques acting on the lower back when using the shavings fork were found in sub-task 'digging with the shavings fork' (sub-task 3) in general, irrespective of body height, shaft length and work technique. Changes in shaft length had no clear effect on the load on the lower back, irrespective of body height, sub-task and work technique.

The load on the shoulders was almost the same irrespective of body height, shaft length and work technique. A corrected work technique compared with the original considerably reduced the load on the back in all sub-tasks except for ‘emptying shavings fork’ (sub-task 5), where the correction had limited effect. For example, with an unchanged shaft length, it was possible to reduce the LBCF by 38-65% in the various sub-tasks (Table 8).

5.4.2 Manure fork

The highest compression forces and torques acting on the lower back when using the manure fork were found in sub-task ‘digging with the manure fork’ (sub-task 2), irrespective of body height, shaft length and work technique. In general, adding 10 cm to the handle of the current manure fork gave the greatest reduction on the loading of the back, especially on the compression forces, irrespective of body height, sub-task and work technique. The loads on the shoulders remained similar irrespective of body height, shaft length and work technique. A corrected work technique compared with the original marginally reduced the LBCF (Table 9).

Table 8. *Shavings fork. Variations in shaft length (+10, +5, 0, -5, -10 cm from original value of 150 cm) and body height (164, 169, 174 cm) in five different sub-tasks. Corrected work technique for all body heights and uncorrected work technique for 169 cm body height (169u). Ls=torque on left shoulder joint (Nm), Rs=torque on right shoulder joint (Nm), B=torque on lower back (Nm), CF=compression force on lower back (N). Sub-task 1=Grip shavings fork, 2=Put down shavings fork, 3=Dig with shavings fork, 4=Lift up shavings fork, 5=Empty shavings fork.*

	+10 cm				+5 cm				150 cm				-5 cm				-10 cm			
	Ls	**Rs**	**B**	**CF**	**Ls**	**Rs**	**B**	**CF**	**Ls**	**Rs**	**B**	**CF**	**Ls**	**Rs**	**B**	**CF**	**Ls**	**Rs**	**B**	**CF**
Sub-task 1																				
164	36	40	185	1023	47	33	184	762	47	42	181	632	48	43	161	499	47	45	169	618
169	47	40	162	683	47	41	169	627	47	42	164	618	46	30	180	629	47	45	167	606
169u	46	27	178	1179	46	30	179	1170	45	27	189	1358	46	30	180	1118	46	34	180	1014
174	47	40	163	702	47	33	184	762	47	42	164	751	47	43	174	683	47	46	169	650
Sub-task 2																				
164	48	42	172	686	48	42	172	647	48	42	172	629	48	42	172	856	48	42	172	856
169	48	42	173	725	48	43	176	756	47	44	178	763	47	45	194	798	47	38	203	994
169u	45	30	180	1329	45	30	189	1450	45	30	189	1493	46	35	190	1319	45	36	195	1398
174	48	42	172	686	48	43	172	691	47	44	178	733	47	45	178	802	47	45	194	905
Sub-task 3																				
164	48	39	149	548	48	40	164	615	48	30	183	960	48	42	169	639	48	43	178	704
169	47	31	172	889	47	32	183	989	47	33	184	889	47	44	176	846	47	45	176	850
169u	45	33	208	1492	44	33	216	1537	45	37	215	1442	44	34	214	1590	46	38	222	1480
174	48	31	164	728	48	33	170	781	48	32	200	1041	47	35	181	863	47	35	186	862
Sub-task 4																				
164	47	44	155	518	47	44	155	523	47	44	155	523	47	44	155	536	47	45	155	550
169	47	44	155	519	47	45	155	524	47	44	155	531	47	45	155	543	47	46	155	559
169u	47	33	172	1349	47	33	174	1361	47	32	180	1531	46	34	180	1178	46	33	174	1181
174	47	44	155	530	47	44	155	536	47	45	155	539	47	45	155	553	47	46	155	559
Sub-task 5																				
164	42	40	145	634	42	40	145	650	42	40	145	657	42	43	145	690	42	44	145	717
169	43	40	145	653	43	40	145	657	43	41	145	671	43	44	145	718	43	44	145	740
169u	43	40	146	629	45	41	146	593	45	40	146	820	43	41	146	573	43	45	146	673
174	43	41	145	679	43	42	145	690	43	42	145	710	43	44	145	742	43	45	145	767

Table 9. *Manure fork. Variations in shaft length (+10, +5, 0, -5, -10 cm from original value of 125 cm) and body height (164, 169, 174 cm) in five different sub-tasks. Corrected work technique for all body heights and uncorrected work technique for 169 cm body height (169u). Ls=torque on left shoulder joint (Nm), Rs=torque on right shoulder joint (Nm), B=torque on low-back (Nm), CF=compression force on lower back (N). Sub-task 1=Put down manure fork, 2=Dig with manure fork, 3=Lift up manure fork, 4=Walk with manure fork, 5=Empty manure fork.*

	+10 cm				+5 cm				125 cm				-5 cm				-10 cm			
	Ls	**Rs**	**B**	**CF**	**Ls**	**Rs**	**B**	**CF**	**Ls**	**Rs**	**B**	**CF**	**Ls**	**Rs**	**B**	**CF**	**Ls**	**Rs**	**B**	**CF**
Sub-task 1																				
164	47	32	205	844	46	35	211	1004	46	36	211	999	46	37	211	1035	46	40	211	1040
169	47	33	205	844	46	36	211	1019	46	37	211	1015	46	38	211	1058	46	40	218	1122
169u	46	33	205	1073	46	35	205	1071	46	36	205	1088	45	38	205	1113	45	39	205	1139
174	47	43	211	859	46	36	211	1064	46	37	211	1053	46	38	211	1086	46	40	224	1235
Sub-task 2																				
164	45	34	239	1283	45	35	235	1270	44	35	244	1352	44	36	244	1390	45	37	242	1366
169	45	34	239	1338	45	34	238	1354	45	37	244	1392	44	36	249	1465	45	37	244	1423
169u	46	35	234	1360	45	37	234	1410	45	38	234	1441	45	40	234	1464	45	41	234	1478
174	45	35	241	1396	45	34	241	1440	45	36	244	1450	45	38	244	1460	45	38	244	1469
Sub-task 3																				
164	46	33	180	818	46	34	180	830	46	34	180	838	46	44	180	868	46	45	180	911
169	46	34	191	932	46	35	191	942	46	35	191	1023	46	35	191	1001	46	36	187	1046
169u	47	35	191	968	47	36	191	988	47	36	191	1005	47	37	191	1033	47	37	191	1065
174	47	34	187	945	47	35	187	957	47	35	187	978	47	36	187	1007	47	37	187	1044
Sub-task 4																				
164	45	44	160	686	45	44	160	708	46	46	160	734	45	45	160	763	45	46	160	787
169	46	44	160	698	46	45	160	721	46	45	160	731	45	45	160	765	46	47	160	791
169u	47	45	160	743	47	45	160	752	47	45	160	772	47	47	160	799	47	47	160	826
174	47	46	160	696	37	46	160	693	37	47	160	704	39	48	160	742	39	49	160	789
Sub-task 5																				
164	44	40	158	557	45	41	158	591	45	42	158	605	45	43	158	659	45	45	158	683
169	45	40	157	583	45	41	157	605	45	42	157	622	45	44	157	673	45	45	157	734
169u	45	40	159	584	45	41	159	616	45	42	159	629	45	43	159	681	45	45	159	719
174	45	41	161	588	45	42	161	619	45	43	161	638	45	44	161	699	45	45	161	723

6 Discussion

The overall objectives were to obtain detailed information on the physical load in the human-horse work environment as a basis for preventing MSD, and to identify examples of ways to prevent MSD.

6.1 Musculoskeletal symptoms

More than 90% of the riding instructors surveyed in the study had suffered pain, aches and discomfort in at least one anatomical area during the 12 months prior to answering the questionnaire, above all in the shoulders, lower back and neck. In addition, more than 55% had experienced similar symptoms in the previous week. The shoulder prevalence is in line with what seen in other female workers in agriculture, *e.g.* dairy farmers (Stål *et al.*, 1996) and pig farmers (Stål & Englund, 2005). However, the shoulder prevalence in riding instructors can be considered as alarmingly high since their median age (33 years) is lower than farmers (44 years and 36 years respectively). The frequency of reported lower back and shoulder symptoms was also correspondingly high in both men and women when compared to other professions including dentists (Akesson *et al.*, 1999), physiotherapists (Cromie *et al.*, 2000), construction workers (Holmström, 1992), and nursing personnel (Lagerstrom *et al.*, 1995). The high degree of self-reported neck symptoms among the riding instructors was, almost the same as shown in studies of air traffic controllers (Arvidsson *et al.*, 2006), which was more expected due to their static computer work with the neck in an almost constantly flexed position. The analyses reported in this thesis showed that the risks of musculoskeletal symptoms, especially in the upper extremities, were related to several of the instructors' work tasks. However, it is unlikely that the high prevalence of neck symptoms is wholly explained by the studied work tasks or by environmental factors. Another plausible explanation for the neck symptoms is the riding itself; something that was not studied in this thesis. The riding instructors had, on average, about 25 years of riding experience, and their necks had therefore suffered many jerks and repetitive head movements. Another explanation for the neck symptoms may be past injuries. When a rider falls from a horse, the head and spine often sustain injuries (Bixby-Hammett, 2006; Silver, 2002; Kriss & Kriss, 1997).

The level of perceived hand and wrist symptoms was not as high as could be expected, which is slightly surprising since when talking to riders they often mentioned hand and wrist injuries/problems. One reason could be that their shoulder and back problems overshadow any hand symptoms.

Of course it is always difficult to know what is work-related or not, and shoulder, neck and back problems are also widely reported in the general population (Swedish Work Environment Authority 2010; Gummesson *et al.*, 2006). It must be kept in mind that more than one-third of the instructors surveyed here had other jobs in addition to being a riding instructor, which could of course have influenced their musculoskeletal symptoms. For example, they held occupations in healthcare, farming, teaching, as farriers and in the industrial sector, occupations known to incorporate a high workload and contain risks of MSD.

6.2 Work tasks, work postures and workload

In Papers II and III, 'mucking out', 'sweeping' and 'replacing bedding' were shown to contain strenuous work, with a risk of musculoskeletal injuries. These work tasks involved a high number of awkward postures for the back, more than half the time in a flexed or twisted posture. The position of the spine is of great importance when load is applied and it affects the tolerance significantly. A study by Gunning *et al.* (2001) showed that when flexed, the spine may be as much as 40% weaker than during an upright posture. In some parts of 'mucking out', such as emptying the wheelbarrow, high loads are handled in awkward postures. Emptying the wheelbarrow requires a wheelbarrow to be pushed and tilted forward to empty out the manure, during which the back is often flexed and twisted, with the load far from the body (a long lever) and with a large torque that creates a high strain on the back muscles and the discs (Pope *et al.*, 2002). That task involves postures that are well known to be a risk factor for MSD (Bernard, 1997; Hagberg *et al.*, 1995). In addition, there is a high strain on the shoulders, since the arms are often held far over shoulder level when tilting/tipping the wheelbarrow. In Paper II, ‘mucking out’ had the greatest workload of the work tasks investigated, and this corresponds with the results from the study of riding instructors in Paper I.

‘Replacing bedding’ included work postures with the back bent and twisted, arms elevated over shoulder level, neck in a non-neutral position and wrists in an extreme flexed position. In this task the bale was ungainly to grasp, which made it hard to handle and put a strain on the wrists.

Work with the arms over shoulder level is also considered to pose a risk of musculoskeletal problems in the shoulder, since the anatomical structures in the shoulder are compressed when the arm is elevated over shoulder level, creating less blood flow and less oxygenation to the tissues, which can lead to ischemia and tissue damage. This can lead for example to the rotator cuff tendons being compressed and injured between the humeral head and the coracoacromial arch (Svendsen, 2004). The loose construction of the glenohumeral joint makes the range of motion optimal, but this is at the expense of stability (Omoumi *et al.*, 2011). In particular, ‘sweeping’ involves a lot of work with the arms elevated, as seen in Paper II.

6.3 Tools

Biomechanical analysis showed that using a longer shaft of manure fork than the conventional length gave lower strain on the back in terms of both compression force and torque for all three body heights investigated, since the back could be held more upright. This has also been seen in studies of other tools such as shovels (Hansson & Öberg, 1996). However, this effect was not seen in analyses of the shavings fork, perhaps since this tool is already long enough to allow work in an upright position. An altered work technique, by working with the arms closer to the body and more flexed knees, had a greater impact on the back load than the length of the tool shaft. Besides changes in tool design, it is also important to consider work technique in preventing MSD (Kjellberg, 2003; Kjellberg *et al.*, 2000; Sogaard *et al.*, 1996; Kilbom, 1994; Kilbom & Persson, 1987).

In Paper IV, correction of the back posture lowered the loading on the back, but gave a slightly higher loading on the shoulders. This was also seen in studies by Huang & Paquet (2002) and McGorry *et al.* (2003), which showed that a tool with an angled shaft contributed to a less bent back when shovelling snow, but the upper extremities were exposed to more load.

Length of tool shaft is one of the parameters that users consider to be the most important (Bligård & Osvalder, 2012). That is one of the reasons why in this study the length of the tool shaft was investigated. Other studies have looked at changes in shaft angle, blade angle and separate handles and have also concluded that increases in shaft length decrease the forces on the spine (Kotowski *et al.*, 2009; Yanagi *et al.*, 2006; McGorry *et al.*, 2003; Huang & Paquet, 2002; Hansson & Öberg, 1996; Öberg, 1993; Degani *et al.*, 1993; Freivalds, 1986). However, modified tools can meet with resistance from users (Kotowski *et al.*, 2009). Therefore, the user perspective must be allowed to play an important role in the design of tools and guidelines, since it is difficult to change people's perspectives and habits (Kotowski *et al.*, 2009).

6.4 Methodological considerations

How good are people's memories? When analysing results from questionnaires, it is important to remember that the recollection of musculoskeletal symptoms during the past 12 months can be both over- and under-estimated. A number of studies have found that there can be problems with people's accuracy in recollecting previous pain, with both under- and over-estimations reported (de Wit *et al.*, 1999; Carey *et al.*, 1995; Jamison *et al.*, 1989; Linton & Melin, 1982). However, some studies also report reasonable accuracy by subjects in recalling pain (Bolton, 1999; Salovey *et al.*, 1993). It is more likely for a person's recollection of the past week to be more accurate than that of the past year. However, a general picture of musculoskeletal symptoms can be obtained by questionnaires and such studies are a common and easy way to collect a large amount of data.

The questionnaires discussed in this thesis were sent out to riding schools that had e-mail addresses, which is of course a form of selection. Was there a difference between riding schools with or without e-mail addresses? One assumption could be that the riding schools without e-mail addresses are less 'modern', but it is uncertain whether this would affect the work environment. Having access to a computer and e-mail has perhaps no influence on the work environment of the riding school. However, no check was made on this. No complete list of riding schools in Sweden exists, so a register had to be made. This was very time-consuming but was still the fastest way to reach as many riding schools as possible.

Paper II was an observation study based on video-recordings. The video-recordings should be considered a snapshot in time of the most common work tasks; certain work tasks were perhaps not carried out on the day of the recordings. Moreover, a number of work tasks were not recorded because they were seldom done, although some of them could involve a heavy workload, for example bringing hay and bedding materials into the barn. Thus, observation studies are based on what is happening in that moment, and there is also a risk that people perform their work tasks in a different way when they are being watched. However, observation studies are a good way to get knowledge about work tasks and how they are performed (Li & Buckle, 1999).

OWAS is a rather general method, but it can give a good overview of different work tasks and indicate where the greatest workload is and which work tasks should be focused on when initiating preventive measures. According to Takala *et al.* (2010), OWAS has good intra- and inter-observer repeatability, but there are some limitations to the method. For example, it does not separate right and left upper extremities, and assessments of neck and elbows/wrists are missing. Furthermore, it is time-consuming and does not consider repetition or duration of the sequential postures (Takala *et al.*, 2010).

In Paper II, five riding schools accepted the invitation that was sent out. Of course it would have been better to have had a larger sample size, but the matter of processing the data would have imposed limitations in that case. The riding schools were all situated in the south of Sweden, and it would have been better to have had a selection of riding schools from other parts of Sweden to get a better overall picture. However, in Paper I, no significant differences in work environment, work tasks and MSD were observed between different parts of Sweden. Nevertheless, wintertime in the north of Sweden is colder and has much more snow than southern Sweden, which could have an impact on the work environment.

Paper III was a theoretical study, based on ergonomic knowledge and data collected in Paper I and II regarding the work tasks and workplace. Through the methods used (HTA, HE, REBA), it proved possible to identify where in the work task the main problems were and grade the ergonomic risk. However, one must consider that it was a subjective approach and the evaluator made all the decisions based on ergonomics, photos, videos and workplace knowledge. This may have introduced bias into the results. However, triangulation of methods was one way to validate the findings (Kruuse, 1998).

Although using the JACK® software was found to be useful and beneficial for analysing biomechanical loads, the method had several limitations. Different phases of the modelling, simulation (manipulation and positioning) and analysis phases are time-consuming (Sundin, 2004; Dukic *et al.*, 2002; Chaffin, 2001). It should be noted that the task was not animated. This means that the physical load was estimated in static moments of a work task, with dynamic work divided into static moments. This in turn means that the estimations do not give a complete measure of the biomechanical load. However, as the focus in Paper IV was to study varying tool lengths in comparison with different user heights, by using the JACK® method it was possible to investigate different variations in both height of the manikins and shaft length of the tools. It should be noted that JACK® is based on calculations of the human body and offers a limited flexibility in comparison with reality, so *e.g.* it was found to be difficult to adjust the position of the elbow and arms. Good ergonomic practice advocates working with the arms as close to the body as possible and using the torso or legs as support to reduce the load and tension in the upper extremities (Swedish Work Envionment Authority, 1998). However, it was not possible to incorporate this to the full extent in the simulations. Therefore, some of the 'good working techniques' could perhaps have better impacts if practised in reality.

Only the torque values for movement direction flexion/extension in the shoulder and back were analysed due to limitation of resources and time, *i.e.* the values of abduction/adduction and rotation of the shoulder and lateral bending and rotation of the back were not treated. To get a more complete picture of the biomechanical load all three directions need to be analysed (Hansson & Öberg, 1996). Furthermore, the SSPP tool only calculates the static torques on the different body joints and assumes that the effects of acceleration and momentum are negligible (University of Michigan Center for Ergonomics., 2011). This is another limitation for a complete measurement of the load. However, since the analysis was a comparison between different lengths of tools, only measuring in one direction and only the static forces could be considered sufficient. The comparison between lengths was the main goal, not analysis of the total load in the task.

In this thesis, time was not taken into account. Some comprehension of this issue was obtained through self-estimations in the questionnaire study, where the respondents estimated how much time they spent on every work task they performed. There can be difficulties in estimating how much time every work task requires, with both under- and over-estimations. The fact that time was not included in the analysis means that the full picture of the workload cannot be complete. Future studies could include full-day trials with other methods that better reflect the time aspect, such as EMG, goniometry or inclinometry.

6.5 Preventive measures

There are several different approaches that people working with horses can adopt to prevent musculoskeletal symptom. These include:

- Mechanisation/automatisation of strenuous work tasks
- Workplace design
- Variation in work tasks
- Individual factors

Mucking out is the work task which contains the highest workload, so mechanisation of this task should be considered. There is machinery available on the market that can perform this task and while it is expensive, having people on sick leave is also expensive for a business. Unfortunately, many smaller horse businesses do not have the financial resources to invest in large mechanised systems for disposal of manure. However, an inventory has shown that money can be saved by investing in automatisation such as rail-mounted carts or scrapers in culverts under the stable floor (Bengtsson, 2010; Wallertz & Bendroth, 2009). Furthermore, machinery such as feed dispensers, sweepers and electric wheelbarrows could also lower the workload.

Other ways to reduce workload that are perhaps not so costly could be to use better designed tools. Some of the ergonomic issues could perhaps be minimised by changing the building and equipment so they fit the humans instead of the other way around. If the work environment (buildings and equipment) encouraged and facilitated a good work technique, this would perhaps encourage stable personnel to perform different work tasks with a 'good' work technique. This conclusion was also reached by Kirkhorn *et al.* (2010), who concluded that the most effective intervention is perhaps to design out the hazards by physically modifying methods, materials, tools and machinery. As examples of this, those authors mention: modified wheelbarrows with adjustable handles, added push-bar and three wheels, modified handle attachment and lever arm for beef calf weighing station. Other examples could be to move equipment from floor and ceiling level, scrapers in culverts and automatic straw transporters.

Another way to reduce the workload could be to alternate between different work tasks. For example, shifting between mucking out and feeding horses may be a way to use different parts of the body by providing variability and reducing unvaried exertion. Variability in work tasks is important, since repetitive work has been found to be a source of musculoskeletal problems (Hagberg *et al.*, 1995). One of the riding schools studied here alternated between different work tasks and made one box or tie stall ready at a time. First they did the mucking out, then the sweeping, and lastly prepared the bedding. In this way, the physical workload was more varied, and different muscle groups were exerted for a shorter time, which ought to lower the risk.

Paper I showed that physical exercise seemed to have a positive impact on musculoskeletal symptoms in general among the riding instructors. Many of the respondents were physically active, but it appears that other types of exercise besides riding were important. This was also shown by Meyers (2006) in a study of the effects of equitation training among college females, which found that this type of training needed to be supplemented with aerobic and load-bearing exercise. The human body is made for physical activity, but to remain strong and enduring, variation is essential. Miranda *et al.* (2001) stressed that it was not only important to detect the general physical activity but also to specify the different modes of exercise. In the questionnaire study the respondents were asked if they did any exercise for more than 2 hours a week besides riding and they could leave an open comment about the kind of exercise, but the type of alternative exercise was not specifically analysed. This is of course a shortcoming, making it difficult to draw conclusions.

6.6 Reflections

Horses have a large impact on many people's lives. Many people spend a great amount of their time in horse stables, riding and taking care of horses. It is for many a way of living, a lifestyle. The horse has first priority and the human second, which is in a way the source of the problems that exist in the work environment for those working with horses on a professional basis. In many other sectors that deal with large animals, there has been widespread mechanisation and automatisation of heavy and strenuous work tasks in recent years, but not so in the horse industry. Here, a lot of works are still done by hand.

It is not only people that work professionally with horses that are exposed to injury and ergonomic problems in the working environment, since there is a large group that 'works' with horses on a leisure basis. They perform almost the same work tasks as paid workers, but are not workers in the proper sense. Different types of injuries that happen in leisure time can have a large impact on these people's ordinary work. For example, if a person is injured or strained during their spare time it will affect their work time. If the work situation is improved (due to a decrease in workload, tool improvement) for all those working professionally with horses, this should also have a large impact on the people that spend time with horses on a leisure basis.

The traditional European and North American method is to keep horses in tie or box stalls in a stable. Naturally, there are highly mechanised stables that use modern tools, but in many others the work is done in a traditional way and resembles the work recorded in this study. Based on the results of this study, believe that it is possible to generalise about this traditional way of horse handling.

The focus of this thesis was on the 'physical work environment', but the psychosocial part of the work also has a large impact on how people cope with difficulties and physical strain (Nisell & Vingård, 1992). A Swedish doctoral thesis by Forsberg (2007) showed that girls who spent a lot of time with horses learned important skills besides taking care of the horse. It is necessary to be firm when handling large powerful animals such as horses, which develops the girl's self-image of courage, action and determination and results in the development of qualities that make a good leader. Other studies have shown a darker side of horse businesses, with sexual harassment and overuse of the labour of young girls (Andersson, 2009). Furthermore, a study performed by one of the unions in Sweden showed that there was a lack of interest in dealing with the work environment (Andersson, 2010).

Many of the riding instructors in Paper I regarded their work as both physically and psychologically demanding. Even so, almost all of the participating instructors commented that they enjoyed their work, and many of them loved doing it and saw it as a great advantage to be able to work with their main interest: "Inspiring and educational to work with children and adolescents" and "It is positive to be outdoors; it's dynamic and feels like a natural environment." These were common opinions put forward in the questionnaires. Even if some of the instructors experienced the work as hard and fraught with a number of disadvantages, they still enjoyed it: "It is hard work and low pay but very nice." This makes it even more important to reduce some of the physical workload when working with horses, so that people can stay in the business doing what they love and not have to retire ahead of time due to physical problems.


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7 Conclusions

The main findings were that:

There is a high frequency of perceived musculoskeletal symptoms among people that work with horses.

• More than 90% of the riding instructors surveyed had suffered pains, aches and discomfort in at least one anatomical area during the 12 months prior to answering the questionnaire, above all in the shoulder, lower back and neck. More than 55% had experienced similar symptoms in the previous week (Paper I).

The work tasks performed around horses in stables include high workload and awkward work postures.

• 'Mucking out', 'sweeping' and 'replacing bedding' were the tasks that contained the highest workload, with a high risk of musculoskeletal injuries. Of these, 'mucking out' was the task that the riding instructors considered to be the most strenuous. All three work tasks involved over 60% work postures with the back bent, twisted, or both bent and twisted. In 'mucking out', the most strenuous sub-task was 'emptying the wheelbarrow' on the muck heap, which included awkward work postures and handling high loads (Papers I, II, III).

There is a correlation between strenuous work tasks and perceived musculoskeletal symptoms when working with horses in stables.

• There was a correlation between the three strenuous work tasks 'mucking out', 'sweeping' and 'replacing bedding' and perceived musculoskeletal symptoms in the upper extremities (Paper I).

Tool shaft length and the use of long shafted hand-held work tools affect the physical workload.

• A longer shaft length of a manure fork compared with the existing length significantly reduced the loading on the back. However, a corrected work technique compared with the original reduced the loading on the back only marginally. Changes in shaft length of a shavings fork showed no clear effect on the loading of the back but a corrected work technique compared with the original considerably reduced back loads (Paper IV).

8 Future

There was no strong correlation between neck symptoms and any of the work tasks. Are the reported neck symptoms perhaps more related to riding and riding injuries? Could there perhaps be a kind of whiplash injury if the horse suddenly stops and the rider's head is projected forward? It would be interesting to investigate the source of the high prevalence of neck symptoms in future studies.

Further studies concerning the development of tools and equipment that can improve work with horses need to be performed. Such research should closely involve users in the development and adaptation of tools.

Another important issue to consider is the improvement of work technique to lower the risks of injury. Is it possible to teach an old dog new tricks? The answer must be yes, as otherwise we would not try to implement ergonomic thinking in the work environment. However, to achieve a high impact on interventions and preventive measures, it is perhaps the really young that should be the target group. Therefore, work techniques and ergonomics ought to be included in education programmes for horse workers. Is it too late to teach ergonomics at the higher levels of equestrian education? Should the focus be to teach children starting to ride how to work in an ergonomic way?

Many previous studies have found that physical activity is a way to reduce the risk of injury, but what kind of physical activity does this already physically active group need? Further studies are needed to increase our knowledge about exercise and to specify the alternative modes of exercise needed for people that work with horses.

Some riding schools have worked hard to reduce the workload by mechanisation and alterations in workplace design, for example moving items from the floor and ceiling to waist height and mechanisation with broom machines, automatisation of manure removal, automatic feed units, *etc.* It would be interesting to make comparative studies of the time requirements and workloads, for example with EMG, on workers in this kind of riding school and those in a more traditional school. It would also be interesting to investigate conditions before and after a large work environment change, to determine what kind of impact this results in regarding workload.

9 Sammanfattning på svenska

Arbetet med hästar utförs oftast för hand och på ungefär samma sätt som för hundra år sedan, många gånger med gammalmodiga redskap och utrustning. Hästbranschen är en av de minst mekaniserade sektorerna som arbetar med stora djur. Arbetet innefattar tunga lyft och besvärliga arbetsställningar vilket är välkända riskfaktorer för belastningsbesvär i rörelseorganen (MSD). Det föreligger dock en brist på kunskap om de ergonomiska förhållandena i arbetsmiljön kring häst. Den här avhandlingen syftar till att ge en djupare förståelse för arbetsmiljön, arbetsuppgifterna, den fysiska arbetsbelastning och frekvens av belastningsbesvär i samband med arbetet kring häst, samt att identifiera potentiella riskfaktorer för MSD.
Följande metoder har använts för att samla in och analysera data; självrapporterande metoder (frågeformulär, skattningsskalor), observationsmetoder (OWAS, REBA), arbetsanalyser (HTA, HA, GTS) och biomekanisk analys (JACK). De medverkande i studierna var ridinstruktörer och stallpersonal på ridskolor.

De ridinstruktörer som medverkade i enkätstudien rapporterade höga frekvenser av MSD i minst en av nio kroppsregioner både under det gångna året och den senaste veckan. Besvären var främst lokaliserade till axlarna, nedre delen av ryggen och nacken. Mockningen ansågs vara en arbetsuppgift som innebar det mest ansträngande arbetet.

Analysen med OWAS-metoden visade att följande tre arbetsuppgifter innehöll höga andelar av besvärliga arbetsställningar; mockning, strö och sopning av stall. Under mockning och sopning, hölls ryggen i en böjd och vriden arbetsställning en stor del av tiden.

I den fördjupade analysen av dessa tre arbetsuppgifter framkom en ökad risk för belastningsbesvär i flera delmoment av själva mockningen inne i boxen eller spiltan samt vid utspridning av strömaterial. Ett annat arbetsmoment med hög risk var tömning av skottkärran på gödselstacken som både innebar oergonomisk arbetsställning för ryggen och hantering av tung last. Genom att använda flera olika analysmetoder blev det tydligt var, och i vilka moment i arbetsuppgifterna, som de största problemen fanns. I nästan alla arbetsmoment som hade en förhöjd risknivå användes ett skaftredskap eller skottkärra.

Resultatet från den biomekaniska analysen visade att en gödselgrep bör ha ett längre skaft än det befintliga för att minska belastningen på ländryggen. Motsvarande effekt kunde inte ses vid en förändring av skaftlängden på en spångrep men där i stället en förändring av befintlig arbetsteknik till en mer ergonomiskt korrekt sådan gav en lägre ländryggsbelastning

Denna avhandling har inneburit en fördjupning i vissa av de arbetsuppgifter som dagligen utförs i häststallar. Kritiska arbetsmoment och vissa förbättringsmöjligheter har kunnat identifieras. Förhoppningsvis kan denna fördjupade kunskap om den fysiska arbetsbelastningen och om de arbetsuppgifter som utförs i den här arbetsmiljön, underlätta planering och genomförandet av åtgärder som kan förebygga belastningsbesvär för de som arbetar med hästar.

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