ABSTRACT

ROGERS, MEGHAN LYNN. Identifying and Evaluating Risk Factors for Musculoskeletal Disorders in Equine Veterinary Work. (Under the direction of Dr. David B. Kaber).

Equine veterinarians are exposed to tasks in their day-to-day work that often lead to injury. Beyond acute trauma, some of these injuries are in the form of work related musculoskeletal disorders (WMSDs). Previous studies have quantified this problem with reports of 100% injury prevalence rates over a 12-month period (Scuffham et al., 2010b). Studies have also surveyed veterinarians to assess what they believe are the leading factors in injuries. However, there is a need for research to identify veterinarian tasks that contribute to cumulative trauma injuries based on ergonomic analysis. This study provides an assessment of equine veterinary tasks to identify ergonomics-related risk factors and violations of established ergonomics criteria for worker protection. The risk assessment focused on the potential for distal upper extremity and low–back disorders. The study was expected to reveal those tasks contributing the most to the overall risk of veterinarian injury.

The study consisted of two phases. Phase 1 involved shadowing equine veterinarians at a university veterinary hospital. Ten equine veterinary tasks were observed and videos were analyzed to identify a subjective whole body risk for WMSDs. Results revealed lameness exams, rectal palpations, positioning and obstetric procedures had high risk scores. Phase 2 involved collecting quantitative hand forces and wrist postures and using the data to evaluate violations of validated ergonomic criteria. The Strain Index was used to assess whether observed wrist postures contributed to a high risk of developing distal upper extremity disorders. Results showed lameness exams, lifting, and performing ultrasound

procedures put equine veterinarians at high risk for these disorders. Analysis was conducted on average low-back compression forces for values exceeding the NIOSH spinal compressive force criterion for increased risk of injury. Results revealed none of the observed tasks to exceed the defined criterion. Finally, a measure of risk was calculated as the ratio of the product of task frequency by job demand divided by worker capacity. It was revealed that the six analyzed tasks contributed to worker risk from highest to lowest as follows: ultrasounds, restraint, lifting, palpations, lameness exams, and injections.

Based on the quantitative data analysis, the tasks of ultrasound, lameness exams, and lifting were considered to have the highest priority for ergonomic interventions. Recommendations were presented in the form of engineering controls, administrative controls, and personal protective equipment. Examples included raising horses to minimize flexion of the back and using a hoof jack to limit the need for prolonged awkward postures.

Identifying and Evaluating Risk Factors for Musculoskeletal Disorders in Equine Veterinary Work

by
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BIOGRAPHY

Meghan Lynn Rogers was born on March 9, 1984 in Savannah, GA. She grew up in both Savannah and Marietta, GA. In August 2007, she graduated with a B.S. in Mechanical Engineering from the Georgia Institute of Technology. After graduation she worked as a Human Factors Engineer at Gulfstream Aerospace Corp. in Savannah, GA. In 2009, she made the decision to further her education and enrolled in the masters program in the Edward P. Fitts Department of Industrial and Systems Engineering at N.C. State University. She was supported by the National Institute for Occupational Safety and Health (NIOSH) Occupational Safety & Health Graduate Education and Research Program Fellowship. She will graduate with a M.S.I.E in December 2011.

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LIST OF ABBREVIATIONS

WMSD: Work related musculoskeletal disorder

NIOSH: National Institute for Occupational Safety and Health

NCSU: North Carolina State University

PPE: Personal protective equipment

MSD: Musculoskeletal disorder

LAH: Large Animal Hospital

CVM: College of Veterinary Medicine

HTA: Hierarchical task analysis

FSRs: Force Sensing Resistors

3DSSPP: 3D Static Strength Predictor Program

ECNC: Ergonomic Center of North Carolina

RULA: Rapid Upper Limb Assessment

1 Introduction

Veterinarians' day-to-day work tasks put them at risk of various injuries and disease. Previous studies have assessed their susceptibility to particular injuries and the prevalence of injuries (Hafer et al., 1996; Jeyaretnam, Jones, & Phillips, 2000; Loomans et al., 2008; Boyle et al., 1997). These investigations have shown veterinarians are at risk for cuts, scratches, radiation exposure, disease, and a variety of other issues. In addition, veterinarians are also prone to work-related musculoskeletal disorders (WMSDs). Such disorders are often the result of awkward postures, high forces, and repetition of tasks (Hagberg et al., 1995).

Given the range of animal sizes that veterinarians care for, from household pets to horses and cattle, and the types of equipment required for animal care, it is important to understand the risks of WMSDs at particular levels of veterinarian practice. By gaining such an understanding of the extent and prevalence of WMSDs, appropriate interventions can be designed to prevent the occurrence or reduce the severity of injuries. Decreased injury rates and sick leave may represent significant benefits to animal hospitals and employers through reduced costs. A detailed review of types of disorders in veterinary operations, types of tasks and risk factors leading to injuries and incidence rates is presented below.

1.1 Pilot Study

A pilot study was conducted to assess the risk factors for WMSDs in small animal veterinarians (Rogers, Gangakhedkar, & Kaber, 2011). During the spring of 2010, a small animal emergency clinic was designing a new veterinarian hospital in the Raleigh, NC area.

In order to enhance the overall design of the new facility, the owners requested North Carolina State University (NCSU) conduct an ergonomics study to identify risks factors associated with small animal veterinarian tasks and to provide recommendations of ergonomic interventions to implement in the new facility design.

The identification of risk factors followed a structured approach from initial problem-area identification, to task analysis, job screening for risk factors, and ergonomic data collection. The process began with extensive interaction with veterinarians, technicians, clinic staff and construction staff. After completing an analysis of veterinarian tasks that were considered problem areas by a subject matter expert (clinic manager), an ergonomics screening tool was used to determine which of these tasks posed a high-level of risk for developing WMSDs. The identified tasks were assigned subjective ratings by two ergonomists for three potential risk factors: extreme posture, high force, and repetitive motion. These ratings were used to determine total job priority level. The job priority levels were then used to categorize jobs into one of three ergonomic risk groups: high, moderate, and low. In addition, a survey was completed by the veterinarians and technicians that identified self-reported ergonomic disorder symptoms.

The data collected focused on tasks involving direct contact of technicians with small animal patients. The data and subsequent analyses revealed four tasks posing high risk for developing WMSDs. These tasks were: the transportation of animals, pre-surgery preparation, animal restraint techniques on the floor, and animal restraint techniques on a table. To validate the job risk ratings, the results of the screening tool were compared with the results of symptom surveys, using correlation analysis. In general, 26.7% of the variability in subjective symptom ratings by staff was accounted for by the ergonomics job risk ratings.

Based on the results of the job screening and ergonomic data collection, engineering, administrative and personal protective equipment (PPE) recommendations were formulated for the clinic towards mitigating ergonomic risk factors. Examples included using “slide-out” cages to minimize unsupported patient transport with substantial hand-to-body distance and using height adjustable tables to minimize leaning when restraining a patient.

1.2 Motivation for Study

While the pilot study on the small animal hospital provided insight into risk factors for these veterinarians, there remains a need to extend and apply similar analysis methodology to large animal veterinarian operations. Given the increased size and mass of patients in large animal hospitals and the consequent need for more extreme veterinarian postures and forces, it could reasonably be expected that the prevalence and severity of WMSDs among veterinarians would be greater than in small animal operations. However, very little quantitative data exists on WMSDs in large animal veterinarians. Because of the lack of existing literature on the subject, this thesis presents the results of a study that identifies and quantifies ergonomics related risk factors for WMSDs and identifies interventions for large animal veterinarians.

2 Literature Review

2.1 Musculoskeletal disorders in veterinary operations

2.1.1 Rates

Previous research has shown very high rates of WMSD prevalence among veterinarians. A survey of New Zealand veterinarians reported that over a 12 month period, there was a 96% prevalence rate of musculoskeletal disorders for all types of practices (e.g. small & large animal clinics). The same period showed 100% prevalence for equine and large animal veterinarians only (Scuffham et al., 2010b). Also, Poole et al. (1999) conducted an analysis of veterinarian lifting injuries in large animal practices by reviewing American veterinary worker's compensation claims between 1992 and 1994. The results can be seen in Table 2.1.

Table 2.1: Number of Large Animal Handling Injuries

Practice Type	Crush or Handling Injury (out of 305 responses)
Equine	17
Dairy	55
Cow and Calf	8
Mixed	38
Other	92
Total	**210**

These results show that 68.9% of large animal practitioners had an injury resulting from lifting as part of work tasks. Furthermore, Mee (2005) reported that 71% of bovine practitioners surveyed reported suffering from some type of cumulative trauma disorder (e.g., low back pain), and 53% of these disorders occurred in the shoulder.

2.1.2 Locations of Disorders

A few studies have identified specific body locations causing the workers pain. Table 2.2 shows the prevalence data per body part for a 12 month period and compares the results between two sources (Smith et al., 2009; Scuffham et al., 2010b).

Table 2.2: Musculoskeletal Disorder Prevalence Data per Body Part

Body Site	**Experienced MSD (12 month period)**	
	Queensland Veterinarians *Smith et al., 2009*	*New Zealand Veterinarians* *Scuffham et al., 2010b*
Neck	56.9%	58%
Shoulders	52.3%	59%
Upper Back	33.6%	30%
Arm	N/A	28%
Elbows	17.3%	29%
Hand/Wrists	31.9%	52%
Lower Back	62.6%	73%
Hips/Thighs	17.3%	24%
Knees	31.2%	38%
Ankles/Feet	23.4%	21%

These results show fairly similar prevalence rates for each body part between the two sources. The veterinarians in Queensland, Australia had a lower prevalence of wrist/hand and elbow injuries than the veterinarians in New Zealand. The most prevalent injury for both sets of veterinarians was low back disorders at 63% and 73% for Queensland and New Zealand respectively (Smith et al., 2009; Scuffham et al., 2010b).

Other sources have mentioned discomfort in specific body parts but did not point to precise prevalence rates. Jeyaretnam & Jones (2000) conducted a study of worker's compensation claims for both small and large animal veterinarian practices. They found injuries occur most often to the back, spine and neck with some reports of carpal tunnel syndrome. As another example, Ailsby (1996) discussed a case where there was "slight wasting of the shoulder musculature in the deltoid and upper arm in the dominant right arm." After noticing these effects on a worker due to performing rectal palpations, he/she surveyed additional large animal veterinarians and many responded that painful arm, neck and shoulder problems were common.

2.1.3 Comparison to Similar Occupations

In addition to veterinarians, WMSDs are problematic for all health professionals, specifically, doctors, nurses, and dentists. Palliser et al. (2005) reported an annual WMSD prevalence rate for dentists of 53%, and Lipscomb et al. (2002) reported a 72% prevalence rate for nurses (as cited in Scuffham et al., 2010b). Compared to veterinarians who typically have an annual MSD prevalence rate of 70-100%, the rates for dentists and nurses are lower.

When focusing on injuries to specific body parts, studies have revealed that approximately 44% and 37-50% of doctors in China and Japan, respectively, reported low back pain (Smith et al., 2009). However, at 63 - 73%, veterinarians reported a higher prevalence of low back pain compared to doctors (Smith et al., 2009; Scuffham et al., 2010b). Hedge (2009) says that research has consistently shown that 40 – 60% of dentists reported chronic neck and low back pain in a variety of countries. A study by Leggat (2006) supports these results. He found that 58% and 53% of Queensland dentists have reported MSDs of the neck and shoulder, respectively (as cited in Smith et al., 2009). These neck and shoulder injuries rates are consistent with prevalence of injuries at similar locations in veterinarians. Lastly, Van Doorn (1995) found in a study of low-back disability claims among Dutch veterinarians and other health professionals that veterinarians had made more claims than doctors and that veterinarians were at greater risk of claiming low-back disability when compared with dentists (as cited in Smith et al., 2009).

2.2 Taxonomy of Work Tasks Leading to Injury

Veterinarians perform a number of tasks that could lead to musculoskeletal injury and contribute to the reported high prevalence rates. A few tasks, specific to large animal veterinarians, have been investigated in the past and have been shown to put significant strain on workers. Table 2.3 provides a matrix of tasks that have been previously identified as potentially causing WMSDs among veterinarians. Boxes marked with an “x” indicate the source identifying the task as being associated with MSDs. The numbers in parentheses represent the number of respondents who identified the task as most likely being a cause of musculoskeletal discomfort.

Table 2.3: Tasks Associated with WMSDs

<table>
<tr><th rowspan="2">Task</th><th colspan="4">Source</th></tr>
<tr><th>AVMA (2003)</th><th>Equine: (Scuffham, 2010b)</th><th>Large Animal: (Scuffham, 2010b)</th><th>Other Sources</th></tr>
<tr><td>Palpations</td><td>x</td><td>x (16)</td><td>x (71)</td><td>x (Ailsby, 1996) (Cattel, 2000)</td></tr>
<tr><td>Scanning/Ultrasound</td><td></td><td>x (5)</td><td>x (47)</td><td>x (Fourie and Hoffmann, 2004)</td></tr>
<tr><td>Obstetric Procedures</td><td></td><td>x (5)</td><td>x (35)</td><td>x (Loomans et al., 2008)</td></tr>
<tr><td>Large Animal Foot /Leg Work/Lameness Exams</td><td>x</td><td>x (18)</td><td>x (27)</td><td>x (Loomans et al., 2008)</td></tr>
<tr><td>Administration of Injections</td><td>x</td><td></td><td>x (18)</td><td></td></tr>
<tr><td>Restraint/ Animal Handling</td><td>x</td><td>x (22)</td><td>x (16)</td><td>x (Hafer et al., 1996)</td></tr>
<tr><td>Positioning</td><td></td><td>x (2)</td><td>x (6)</td><td></td></tr>
<tr><td>Patient Lifting</td><td>x</td><td rowspan="2">x (8)</td><td rowspan="2">x (5)</td><td></td></tr>
<tr><td>Carrying Equipment/Other Products</td><td>x</td><td></td></tr>
<tr><td>Surgery</td><td>x</td><td>x (8)</td><td>x (5)</td><td></td></tr>
<tr><td>Dental work/ Dentistry</td><td>x</td><td>x (4)</td><td></td><td>x (Loomans et al. 2008)</td></tr>
<tr><td>Floating teeth</td><td>x</td><td></td><td></td><td></td></tr>
<tr><td>Dystocias</td><td>x</td><td></td><td></td><td></td></tr>
<tr><td>Prolapse Repair</td><td>x</td><td></td><td></td><td></td></tr>
<tr><td>Venipuncture</td><td>x</td><td></td><td></td><td></td></tr>
<tr><td>Kennel and Stall Cleaning</td><td>x</td><td></td><td></td><td></td></tr>
<tr><td>Bleeding Swine</td><td>x</td><td></td><td></td><td></td></tr>
<tr><td>Surgeries Performed while Kneeling</td><td>x</td><td></td><td></td><td></td></tr>
<tr><td>Ear tagging</td><td>x</td><td></td><td></td><td></td></tr>
<tr><td>Grooming/Trimming</td><td>x</td><td></td><td></td><td></td></tr>
<tr><td>Dehorning/Velveting</td><td></td><td></td><td>x (14)</td><td></td></tr>
</table>

Furthermore, in a questionnaire surveying New Zealand veterinarians, large animal practitioners indicated rectal palpations, scanning/ultrasound, obstetric procedures, and lameness exams were the four tasks they considered most likely to result in MSDs (Scuffham, 2010a). Analysis also showed that as the frequency of performing dental procedures, foot trimming tasks, necropsies, obstetric procedures, rectal palpations, and surgical procedures (lasting less than 1 hour) increased, the severity of the MSD (pain, task performance problems, or absenteeism) increased significantly (Scuffham et al., 2010b).

2.2.1 Rectal Palpations

Rectal palpation is the process of extending the examining arm into the rectum of an animal (typically a cow or horse) in order to check the uterus in females for pregnancy. This task is often performed 250 times per week by a single practitioner with occasional seasonal peaks (Ailsby, 1996). This task involves an awkward posture and high repetition. Responses from a survey of bovine practitioners by Cattell (2000) showed rectal palpations were associated with WMSDs of the shoulder (53%), elbow (32%), wrist (24%), neck (23%), knee (18%) and hip (10%). Cattell (2000) also found the risk of developing a WMSD on the side of the body used for palpation to be significant.

2.2.2 Ultrasonographic Examinations

Ultrasounds are conducted externally to evaluate some lung and digestive system pathologies and soft tissue and tendon injuries. Internal ultrasounds are conducted for reproductive evaluations. According to an abstract by Fourie and Hoffman (2004), 75% of veterinarian sonologists surveyed reported WMSDs. Discomfort typically occurred in the neck, back, shoulder, wrist, and hand of the scanning arm. Awkward postures during scanning and poor scanning techniques were identified by sonologists as the main contributing factors.

2.2.3 Obstetrical Work

Obstetrical work can involve rectal palpations, ultrasonography, vaginal exams, foaling, and dystocias. Survey results presented by Loomans et al. (2008) revealed that Dutch equine veterinarians deemed obstetrical work to be both strenuous and demanding for the entire body. More specifically, they cited the back, shoulders, and arms to be particularly susceptible to injury.

2.2.4 Treatment of the Distal Limbs of Animal Patients

A variety of large animal veterinarian tasks can involve the distal limbs of the animals including hoof testing, hoof trimming, nerve blocks, lameness exams, etc. (Loomans et al., 2008). Equine veterinarians often perform lameness exams on horses that can involve holding up the horse’s leg for 30-90 seconds. The horse is not always receptive to this examination and will try to move their legs, thus adding additional stress to the examiner. A survey of Dutch equine veterinarians revealed that these tasks are often considered strenuous and demanding. The postures the veterinarians are required to maintain during these tasks are considered to be the source of discomfort (Loomans et al., 2008). Furthermore, Boyle et al. (1997) found an association between foot trimming of cattle and injury, while Scuffham and others (2010b) demonstrated that foot trimming was associated with musculoskeletal discomfort.

2.2.5 Lifting and Animal Handling

Heavy lifting is a common task involved in veterinarian work. In fact, almost all ergonomics research in this area addresses the issue of lifting animals as a contributing factor in developing MSDs. In addition, large and heavy equipment and materials may also need to be carried or transported (A. Allen, DVM, personal communication, November 29, 2009).

Research has shown a positive correlation between the weight of the animal being lifted and the risk for musculoskeletal disorders. After gathering feedback from Minnesota veterinarians, Gabel and Gerberich (2002) found a higher risk of injury when lifting between 41 and 75 pounds as compared to lifting less than 40 lbs. The risk rate was found to almost double when lifting above 100 pounds. Also, veterinarians who chose not to use hydraulic lifts experienced an increased rate of injury risk 1.3 times that for veterinarians who used the lifts (Gabel & Gerberich, 2002). Furthermore, a survey administered by Hafer et al. (1996) revealed 31% of swine veterinarians experienced back pain due to manual handling or movement of pigs. The back pain was considered mild for 45.4%, moderate for 37.8%, and severe for 16.8% of the respondents.

2.2.6 Injections

Administration of injections is an extremely common task undertaken by large animal practitioners (Loomans et al., 2008). Due to the high frequency, this task often leads to WMSDs. Results from a survey of members of the American Association of Swine Practitioners revealed 51% of respondents reported pain from repetitive motions associated with performing frequent injections. Complaints were identified as sore wrists, elbows, and blistered fingers from using a pistol-grip syringe (Hafer, 1996).

2.2.7 Dental Work

Finally, veterinarian dentistry can require sustained awkward postures as well as lifting and use of hand tools (DeForge, 2002). In equine dentistry, the horse is heavily sedated during the procedure. The veterinarian must hold up the animal's head and then bend his/her body in order to gain a proper view of the teeth. Drills and other equipment used during dental procedures are also often heavy (A. Allen, DVM, personal communication, November 29, 2009). Equine practitioners in the Netherlands reported dental work to be very demanding for the arms, shoulders, back and neck. In some cases they were able to alleviate some of the discomfort by using mechanical equipment, extra personnel to support the animal, and division of work among colleagues.

2.3 Effect of Musculoskeletal Disorders on Veterinarian Operations

2.3.1 Work Disruption

Over a 12 month period, New Zealand equine veterinarians had a 75% prevalence rate of MSDs that affected their work. Furthermore, 22% of equine veterinarians experienced a disorder at a level of severity that caused them to be absent from work (Scuffham et al., 2010b). More specifically, of the Queensland veterinarians that reported shoulder related disorders, 42% had experienced work disruption due to their injuries, as well as 39% of those with neck injuries, and 34% with upper-back MSDs (Smith et al., 2009).

2.3.2 Worker's Compensation

Along with lost time on the job, veterinary practices suffer from expensive worker's compensation claims when the practicing veterinarians develop a musculoskeletal disorder.

Although they only accounted for 5% of the overall compensation claims, back injuries caused by animal handling totaled 12% of the cost of worker's compensation losses for insured veterinarians according to the American Animal Hospital Association. According to occupational disease data in Germany, 7% of veterinarian claims in that country were due to lower back issues (Smith et al., 2009).

Aghazadeh and Nimbarte (2004) gathered data regarding worker's compensation claims in large animal veterinary practices for the year 1995 from the American Veterinary Medicine Association. It was reported that injuries resulting from lifting animals accounted for 6.25% of all claims. Aghazadeh and Nimbarte (2004) also supplied data regarding the total incurred cost of these claims. For equine veterinarians, lifting accounted for 6% of the total cost (4.5% for lifting animals and 1.57% for lifting other) of worker's compensation claims. This number increased for large animal veterinarians with 15.32% of all claims (14.03% for lifting animals and 1.29% for lifting others) being associated with injury due to lifting. When all these claims are taken into account, in 1995 lifting injuries cost the American Veterinary Medicine Association $1,332,065 (Aghazadeh & Nimbarte, 2004).

2.4 Research Needs

Despite the passion veterinarians have to help animals, their day-to-day work subjects them to severe injury rates, some as high as 100%. The reported prevalence rates for injury to veterinarians are as high as, or higher than, other healthcare providers such as doctors, nurses, and dentists. Although previous literature has quantified the extent of the problem of WMSDs in large animal veterinary operations, there is a lack of research focused on the causes of WMSDs. Previous studies have primarily relied on passive surveillance techniques such as surveys for indentifying risk factors. There is a need to use active surveillance methods to quantify work postures and forces in veterinarian tasks and to identify the underlying risk factors causing the high prevalence of injuries reported in the literature. Specifically, the tasks of lameness exams, lifting, surgery, rectal palpations, injections, positioning, restraint, obstetric procedures, ultrasounds, and dentistry have been identified by two or more sources as potentially being hazardous to veterinarians. These tasks may be the most critical and should be subjected to further ergonomic analysis. Furthermore, particular attention should be paid to veterinarian body areas, such as the upper extremities (neck, shoulder, and hand/wrist) and lower back, which all have WMSD prevalence rates greater than 50%.

2.5 Objective

The overall goal of the present research was to identify potential underlying causes of WMSDs in large animal operations, to quantify the extent of veterinarian exposure, and recommend control measures. The steps as part of the study include the following: 1) task analysis of typical veterinary tasks for treating large animals; 2) identification of risk factors of MSDs in typical veterinary tasks using both qualitative and quantitative methods; 3) identification of ergonomics principle violations in current veterinary tasks; and 4) recommendations of ergonomic interventions to improve veterinary task safety.

3 Methods

This research was conducted across two phases: a risk identification phase and a deep dive ergonomics analysis phase. The outcomes of Phase 1 were used to influence the direction of Phase 2. The overall flow of the study and the outputs are shown in Figure 3.1 and described in detail below.

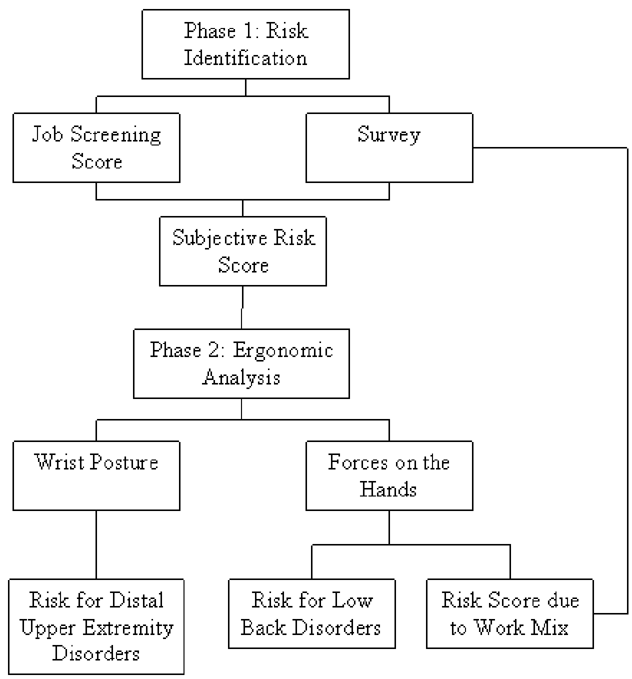


Figure 3.1: Flow Diagram of Study

3.1 Phase 1: Risk Identification

The first portion of this study involved work shadowing and use of verbal protocols in order to analyze veterinary task procedures. Two researchers shadowed veterinarians during their daily work activities and used video-tape to record typical equine veterinarian tasks. Shadowing visits were completed on seven non-consecutive days for a total of 26.5 hours of observation on 18 different tasks. The observed participants were not instructed to perform specific tasks or to manipulate their work in any way. All participating veterinarians signed an informed consent form indicating they were aware they would be filmed. Shadowing was discontinued once each task of concern was observed and recorded at least twice. Verbal protocols were hand recorded during the observations or analyzed from the videos by two researchers. Results were used to gain insight into the procedures being observed and to guide the formulation of the hierarchical task analyses.

3.1.1 Facilities

All observations, except those made on dental work, were completed at the Large Animal Hospital (LAH) of North Carolina State University's (NCSU) College of Veterinary Medicine (CVM). The CVM at NCSU is ranked 3rd among the nation's colleges of veterinary medicine and is recognized for strength in patient care (U.S. News & World Report, 2011) The CVM is a referral hospital that treats over 20,000 total patients annually. Some of the tasks done at the hospital are not typically performed in private practices. Private practitioners are often limited to tasks that can be performed at a farm, such as vaccinating horses, floating teeth, lameness exams, radiography, reproductive work, and minor surgery. These tasks are also performed at the CVM, along with extensive surgical procedures, in a highly equipped and controlled environment (Figure 3.2).

Figure 3.2: Surgery Room Set-up at CVM

The equine services offered at the LAH include ophthamology, theriogenology (reproductive medicine), radiology, soft tissue surgery, orthopedic surgery, advanced medicine, and intensive care. Due to the limited number of dental procedures performed at the CVM, the observations of dental work were made on rounds with a local private practice equine veterinarian. All procedures were performed at barns within the Raleigh, NC area.

3.1.2 Participants

Participants for the observational portion of the study included NCSU LAH staff members as well as one private practitioner. For the observational analysis, the participants were distributed across the equine services including: soft tissue surgery, orthopedic surgery, medicine, and theriogenology. Participants were all knowledgeable in performing large animal veterinarian procedures but their experience ranged from students to interns to residents to faculty.

3.2 Tasks

Ten tasks were observed in this study including: ultrasounds, dentistry, lameness exams, lifting, obstetric procedures, positioning, rectal palpations, restraint, and surgery (see examples in Table 3.1). These tasks were chosen based on previous literature that identified them as being likely to cause WMSDs. Each of these tasks was observed under normal operating conditions at least twice during the observational portion of the study The total number of observations for each task were as follows: palpations, 3; ultrasounds, 4; lameness exams, 5; injections, 4; restraint, 2; positioning, 3; obstetric procedures, 3; lifting, 3; surgery, 3; and dentistry, 2. These observations served as a basis for reducing the set of tasks to those meriting further quantitative analysis.

Table 3.1: Examples of Observed Procedures

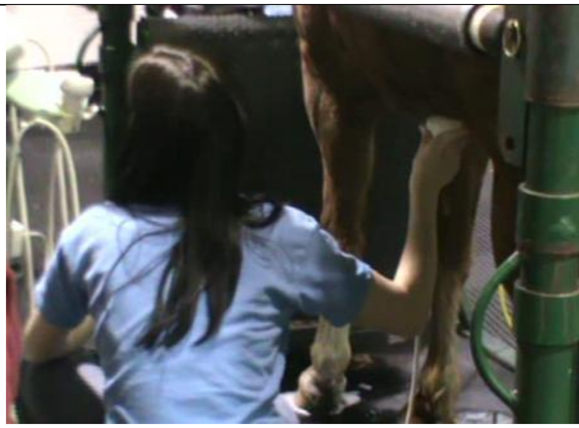
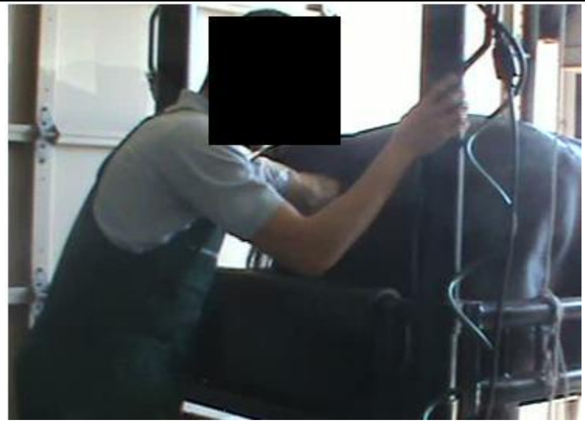
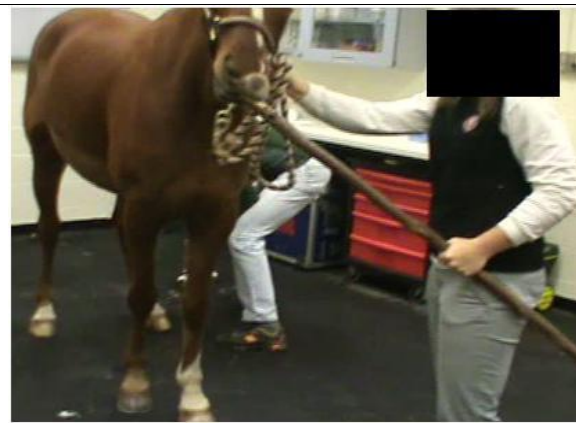
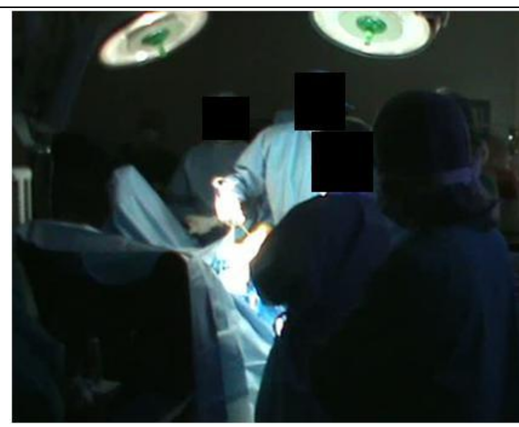
	
Example of Ultrasound Procedure	Example of Obstetric Procedure
	
Example of Dentistry Procedure	Example of Patient Positioning Procedure

Table 3.1 Continued

	
Example of Injection Procedure	Example of Rectal Palpation
	
Example of Lameness Exam Procedure	Example of Patient Restraint Procedure
	
Example of Equipment Lifting Procedure	Example of Surgical Procedure

3.2.1 Hierarchical Task Analysis

A hierarchical task analysis (HTA) was conducted for all of the observed tasks using the videotapes made by the researchers. The HTA approach to a task analysis identifies the overall objectives of a system and the operation(s) and suboperations that are needed to meet the objective. Suboperations are linked through plans to identify the flow of the task (Salvendy, 1987). The results of the analysis are represented in a hierarchical diagram and can be used as a basis for identifying areas of risk factor exposure or areas in need of ergonomic improvement. The results were verified by an equine veterinarian subject matter expert.

Tasks were broken down into subtasks and required operations by two researchers based on videotape review and verbal protocols provided by participants. Analysts jointly viewed videos of tasks and prepared HTA diagrams. The subtasks were used to identify time windows for the wrist posture and force data collection. Task location maps were also created to show the environment in which the tasks were performed and identify points where necessary equipment is used. Subsequently, the number of times a veterinarian worked in a certain location during the task was recorded and this information was included in the maps. A final version of the location maps indicated the order of subtasks by marking required transitions between points with an arrow. The arrows were labeled according to the step in which transitions took place. Multiple arrows between locations identify the number of times a veterinarian transitioned between those locations. The HTAs and location maps for each task are included in Appendix A.

3.3 Survey

The equine practitioners at NC State's CVM were asked to complete a survey that combined Mats Hagberg's (1995) discomfort survey with questions about their typical work mix. Respondents had an average age of 40 years (S.D. 14 yrs) and had spent an average of 3.8 years (S.D. 3.6 yrs) at this particular job. A copy of the survey is attached in Appendix B. The discomfort survey asked participants to identify any discomfort they experienced in their work by indicating the anatomical area of discomfort from a chart of the front and back of the body. If they did experience discomfort, respondents were asked to provide ratings in terms of pain, stiffness, ache, numbness/tingling, burning, etc. Participants were also asked to identify any musculoskeletal disorders they suffer from or had suffered in the past. A description of the disorder and its symptoms were identified on the survey based on descriptions from Karwowski and Salvendy (1998).

To further understand the frequency with which tasks were performed as part of veterinarian activities, the participants were asked to supply information about occurrence of these tasks during the work year, as well as the work day, for each task type. The nature of the facility in which the experiment was conducted is such that the veterinarians do not perform a standardized and consistent set of tasks every day. Veterinarian workload fluctuates according to the needs of the patients referred to the CVM. Therefore, in order to better understand the performance frequency of the tasks being analyzed, equine veterinarians were surveyed regarding the amount of time they spend on the 10 target tasks in days, weeks, months or years. The lowest common denominator between the responses was in years; therefore, the results were analyzed according to number of times the tasks were performed per year. To further quantify the amount of time spent on these tasks, the veterinarians were also asked to supply information regarding the time spent per day performing the tasks, based on the assumption of an 8 hour work day (Loomans et al., 2008; Moore and Garg, 1995; U.S. Department of Labor, 2004).

3.4 Phase 2: Ergonomic Analysis

The second phase of the study involved a quantitative ergonomic analysis of those veterinarian work tasks identified as high risk, based on Phase 1, including direct measurement of veterinarian posture positions and contact forces during performance. The tasks and body parts analyzed were also informed by the results of Phase 1.

Data collection was performed at the Teaching Animal Unit of the NCSU CVM and involved one of the teaching unit horses. Before beginning the experiment, participants were briefed on the tasks to be performed and the equipment. They were then asked to read and sign an informed consent form. Next, participants were outfitted with electro-goniometers on their right (dominant) wrist and four force sensing resistors (FSR) located at the palm (see Figure 3.3). More detail on these devices and their use is provided in Section 3.4.2. Participants were asked to perform the six high-risk tasks (Section 4.2.2) twice, with the exception of the injection task (due to the nature of the task and the safety of the animal). Video recordings were also made for data verification and further postural analysis.

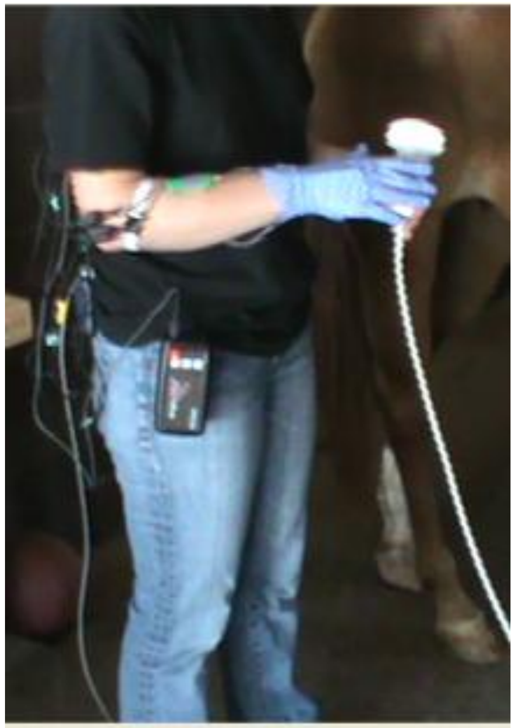


Figure 3.3: Equipment Setup for Phase 2

3.4.1 Participants

The sample size for the quantitative analysis was limited to two veterinarian participants (1 female and 1 male), based on the availability of the staff at the CVM. One was a graduate from NCSU's CVM with 1 year of experience and the other was an equine surgery resident with 3 years of experience. The female participant was 29 years old, 65 inches in height and weighed 140 lbs. The male was 28 years old, 73.5 inches in height and weighed 200 lbs.

3.4.2 Equipment

The equipment used in Phase 2 included an electro-goniometer mounted on the participant's wrist, four FSR sensors mounted on the participant's hand and a video camera.

The XM180 twin axis electro-goniometer from Biometrics, Ltd. was used to measure flexion-extension and radial-ulnar deviation of the wrist (see Figure 3.4 for an image of the device). The XM180 had a measuring range of 150° and recorded postural angles with an accuracy of ±2°. The goniometer was mounted in a manner consistent with the equipment user manual (see Figure 3.4). The participant's arm was extended and pronated and the distal endblock was placed on the center of the back of the hand. With the wrist fully flexed, the other endblock was attached to the forearm (see Figure 3.5). For the task of rectal palpations, the electro-goniometer was shielded by wrapping an ace bandage around the participant's arm and then a full arm plastic glove was worn over the bandage. This ensured the edges of the goniometer did not harm the animal. The XM180 was connected to a FlexComp Infiniti eight channel analog to digital encoder unit. Data were sampled at 2048 Hz and then exported at a rate of 256 Hz for analysis using BioGraph Infiniti Software version 5.0.

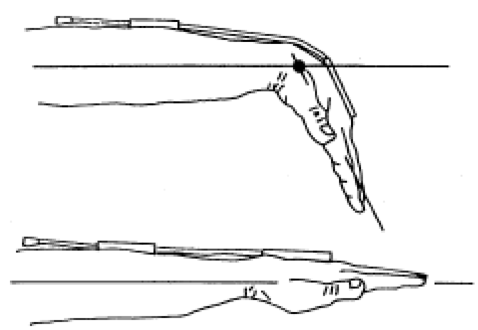


Figure 3.4: Electro-goniometer mounting for measurement of the wrist posture

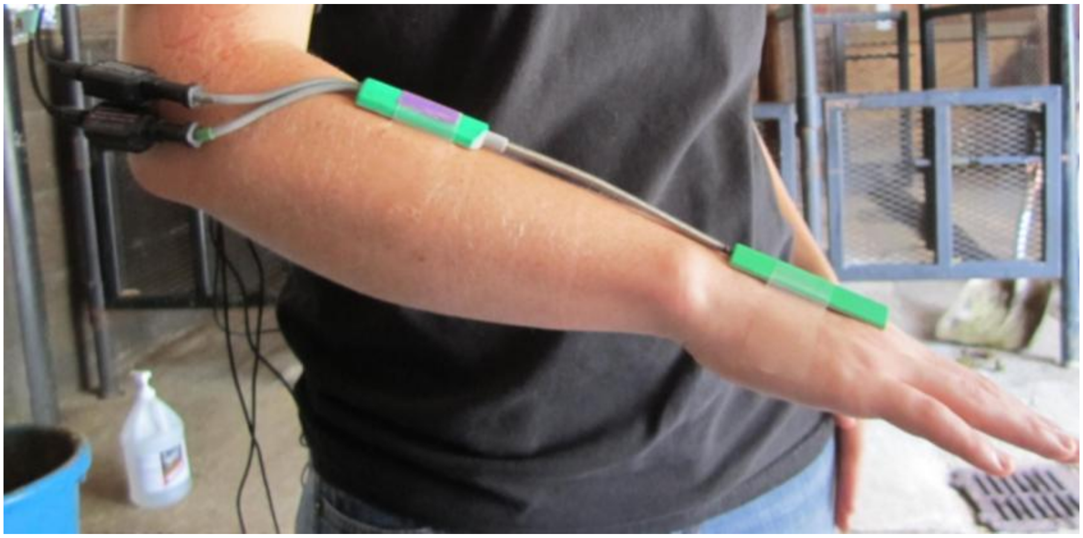


Figure 3.5: Electro-goniometer attached to participant

Hand forces were measured using the Hoggan Health Industries' ergoPAK Force Sensing Resistors (FSRs) with an active area of 0.5 inches. These sensors can be mounted into an accompanying glove with insert pockets on the fingertips and thumb. However, due to the nature in which the data would be analyzed, the sensors were placed in the center of the participant's hand, similar to a study by Nikonovas et al. (2004). The FSRs were taped to the palm using medical tape and covered with a latex glove (see Figure 3.6 for a picture of the sensors mounted on a participant's hand). The maximum force per sensor was 22 lbs. The resolution of force data was 0.1 lbs and the sampling rate was 300 Hz. The four FSRs were connected to the ergoPAK device hub and data were collected using the ergoPAK Data Collection Software.

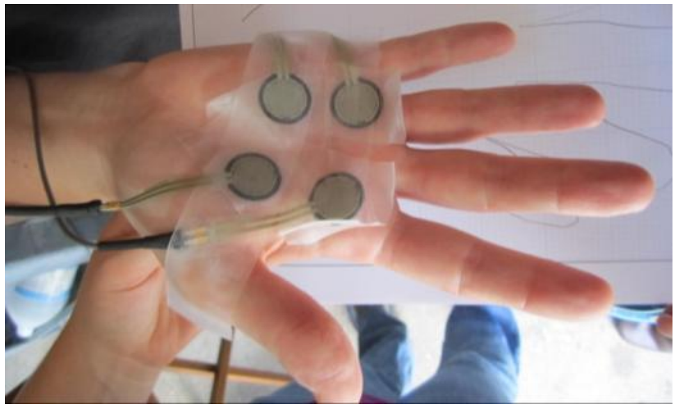


Figure 3.6: FSR's Mounted to Participant's Hand

3.4.3 Response Measures

3.4.3.1 Wrist posture

Wrist posture (flexion, extension, and ulnar deviation) was collected as an input to the Strain Index (Moore and Garg, 1995) measurement technique for identification of risk for distal upper extremity disorders. Further details on this method are provided in Section 3.5.2.1. Wrist postures were broken-out according to subtask (see Section 3.5.2.1 for a list of subtasks). The subtask containing the maximum wrist posture (greatest deviation from neutral) for flexion, extension, or ulnar deviation was identified as being the "worst" subtask and the maximum wrist postures from that subtask were used to determine the inputs into the Strain Index.

3.4.3.2 Force

The forces exerted between a participant's hand and the task object being used (medical equipment, patient, etc.) were measured using the FSRs. The results were used as inputs into the University of Michigan's 3D Static Strength Predictor Program (3DSSPP; Center for Ergonomics, 2007). Further details on this method are provided in Section 3.5.2.2.

The force data were also evaluated on a subtask level (see Section 3.5.2.2 for a list of subtasks). The subtask used for analysis was determined by identifying the most extreme spinal postures from videos. The collected force data were then broken-down into equivalent subtasks and only the data in the time window of the chosen subtask were used for further analysis. Local force maxima (for the subtask) were determined using Matlab. A program was written to identify the highest four peaks in force across sensors for each subtask and each data window. These data points were averaged to determine the mean maximum force for each subtask performance period (Rash & Quesada, 2006). The mean maximum force, in pounds, was used as an input into the static strength modeling program.

3.5 Application of Methods

3.5.1 Phase 1

3.5.1.1 Subjective Screening Tool

A subjective screening tool was used to determine which tasks posed low, moderate, or high risk to the veterinarians. The Industrial Ergonomics Job Screening Tool was developed by the Ergonomic Center of North Carolina (ECNC) and incorporates aspects of validated ergonomic measurement techniques, such as Borg's Perceived Exertion Scales (Borg, 1998) and the Rapid Upper Limb Assessment (RULA; McAtamney and Corlett, 1993) to identify ergonomic risks. The target tasks were assigned low, moderate, or high subjective ratings for the potential risk factors of extreme posture, high force, and repetitive motion. Two ergonomists made independent ratings for each body part including: neck, back, and right and left shoulders, arm/elbow, wrist, and leg. The risk factor ratings were used to calculate a risk priority level for each separate body part. A total job score was then determined by summing the weighted scores from the individual body part ratings. The total score was then categorized into one of three ergonomic risk groups: high, moderate, and low. A low rating was given to any task with a total score of less than 17. A total job score between 18 and 24 resulted in a moderate priority level and any job with a score of 25 or above received a high priority risk rating. The scoring criteria are representative of levels of exposure to work factors (task posture, forces, repetition) that have been associated with the occurrence of specific MSDs or increased rates of injury, in general. The scoring criteria are also reflective of ergonomic risk factor exposure limits used in other validated methods. That said, even if a job is subjectively categorized as a low-risk priority, based on the ECNC tool, it is still possible that certain physical work conditions could lead to injuries.

The inputs (body part ratings on motion, force and posture) of the screening tool were determined by two researchers based on their observations in the field and the videotapes. Results were averaged between raters and across subtasks in order to identify an overall mean job score for each of the 10 tasks. Inter-rater reliability was determined to assess the level of consistency in subjective ratings using Spearman's rank correlation coefficient (Quinn & Keough, 2002).

3.5.1.2 Subjective Risk

Based on the job severity ratings by the ergonomists and frequency of exposure data from the veterinarians, risk scores (Equation 3.1) were calculated for the 10 observed tasks that equine veterinarians thought contributed to the development of WMSDs. The risk scores were to be used as a basis for determining where to focus the quantitative ergonomics data collection (i.e. what tasks to study for Phase 2). The severity of the task was determined based on the total job score results of the ECNC's Job Screening Tool. The frequency of the task was measured in terms of how often a veterinarian was exposed to the task per year.

$$\text{Subjective Risk} = \text{Frequency} * \text{Severity} \qquad \textbf{Equation 3.1}$$

3.5.2 Phase 2

3.5.2.1 Upper Extremity Disorders Risk Assessment: Strain Index

The Strain Index was used to evaluate the risk of developing distal upper extremity disorders with wrist postures from the electro-goniometer being used as inputs, as described below. Previous studies have validated the Strain Index as a method capable of distinguishing between safe and hazardous jobs for distal upper extremity disorders (Garg and Kapellusch, 2009).

The six subjective high risk tasks were broken down according to subtasks. The Strain Index was evaluated for the subtask generating the maximum wrist posture positions as determined by the results of the electo-goniometer. The subtasks used for analysis were as follows: twisting twitch (restraint), using hoof tester (lameness exam), holding equipment (lifting), ultrasound along side of horse (ultrasound), inserting needle (injection), and sweeping (rectal palpation).

The Strain Index was calculated according to Equation 3.2. The intensity of exertion multiplier was determined using a modified Borg CR-10 scale (Borg, 1998). Participants were asked to rate their perceived level of exertion after performing each set of six tasks (see Borg rating scale form shown in Appendix C). The duration of exertion, exertions per minute, and speed of work multipliers were determined from the videotapes of the various tasks. An analyst watched the videos of each task and recorded the task time, tallied the exertions per minute, and subjectively determined speed of work. Regarding the latter multiplier, since the data collection was performed in a controlled environment, and the participants were allowed to perform the tasks at their own pace, the speed of work multiplier was subjectively set to 1.0 for all tasks. This corresponded to a pace described by the Strain Index as being “extremely relaxed” to a “normal speed of motion”. These classifications are based on an observed pace that is below 100% of the MTM-1’s predicted pace (Moore and Garg, 1995). The duration per day multiplier was determined from the results of the veterinarian survey. Finally, the posture multiplier was based on the wrist posture data collected using the electro-goniometer. The flexion, extension, and ulnar deviations were analyzed using the criterion suggested by Moore and Garg (1995), where a multiplier value is determined based on the position of the hand/wrist relative to neutral (calculated in degrees). The multipliers match postures categorized as perfectly neutral, near neutral, non-neutral, marked deviation, or near extreme. The posture generating the greatest multiplier value was used for analysis.

Strain Index (SI) = (Intensity of Exertion Multiplier) x (Duration of Exertion Multiplier) x (Exertions per Minute Multiplier) x (Posture Multiplier) x (Speed of Work Multiplier) x (Duration per Day Multiplier) **Equation 3.2**

Two raters used the Strain Index to independently evaluate each task, based on the data collected in Phase 2. This resulted in at least two Strain Index scores per participant per tasks.

3.5.2.2 Low Back Compression Analysis: 3DSSPP

The force data collected with the FSRs was evaluated using a method similar to Cooper and Ghassemieh (2007), where the forces on the hands were used as inputs to 3DSSPP software to identify the compressive forces on the low back as a result of performing the six high risk tasks. These forces were compared to the NIOSH recommended spinal compressive force limit of 770 lbs to determine which tasks pose risks for low back disorders without interventions. The 770 lbs criterion was determined as a basis for the 1981 lifting equation based on a study by Anderson (1983). He reported compressive forces exceeding this limit resulted in a 40% higher incidence rate of low back pain, as compared to workers in jobs with lower compressive forces (as cited in Waters et al., 1993). This compressive force criterion was also used by NIOSH in developing a revised version of the lifting equation in 1991 (Waters et al., 1993). The criterion has remained consistent for ergonomic evaluation of manual material handling tasks.

The 3DSSPP program provides manikin models that can be manipulated in anthropometry according to the body dimensions of actual workers in jobs under study (see Figure 3.7 for an image of the 3DSSPP software interface with a manikin model). A manikin was manipulated to correspond to the gender, height and weight of the actual participants in the Phase 2 study. Postures were manipulated to match those identified as the most extreme positions in the videos. All task posture pictures were created with a camera line of view as close to perpendicular to the plane of work as possible. The subtasks used for analysis were as follows: holding twitch or rope (restraint), front leg flexion test (lameness exam), grasping equipment from ground (lifting), ultrasound underneath horse (ultrasound), pushing syringe (injection), and sweeping (rectal palpation). Postures were matched to screen shots taken from the videos and by using body angles measured using an on-screen protractor (from Iconico with perceptively correct images of participants in task postures).

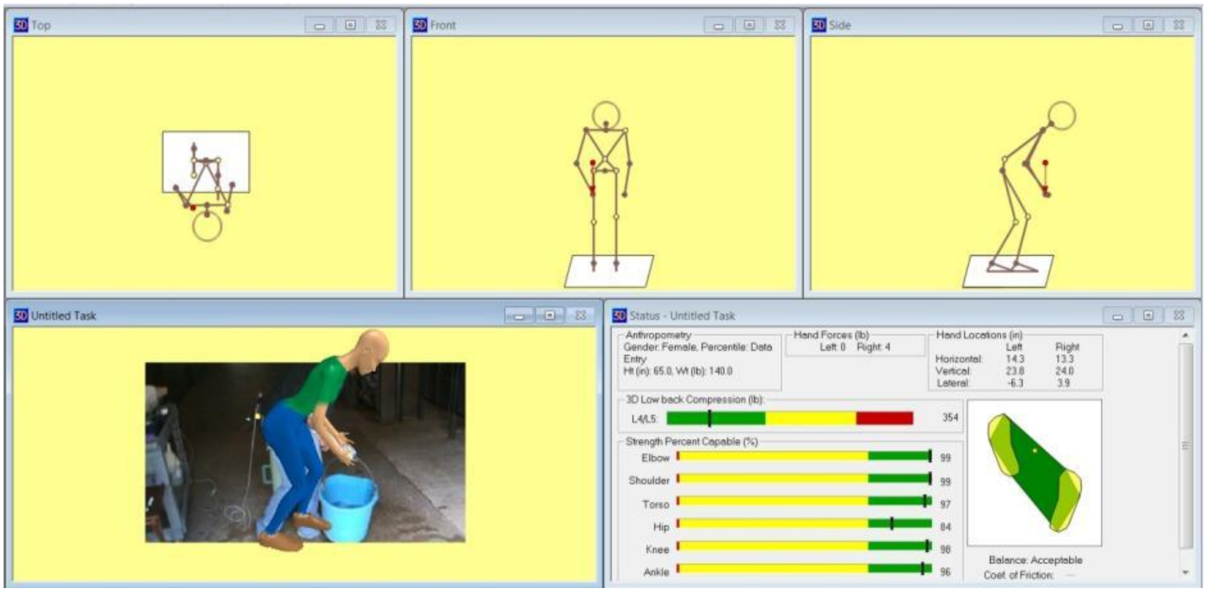


Figure 3.7: Screenshot of 3DSSPP Interface and Output

3.5.2.3 Job Work Mix

Using a typical work mix, the ratio of job demands to worker capabilities (as defined by the 3DSSPP, according to posture position) was determined for the six tasks identified above. A risk score taking into account overall equine veterinarian demand was calculated (Equation 3.3) and the tasks that posed the greatest risks within the work mix were identified as most hazardous.

The job demand was determined by the amount of force required to perform the task, as measured by the data collected with the FSRs (see Section 4.3.2). Worker capabilities were determined by comparison of observed strength with the strength of the 10th percentile of the U.S. female population (The Eastman Kodak Company, 2004). For each task, the forces at the hands were manipulated within 3DSSPP with a manikin posed in the same postures modeled for the low back compression force analysis (see Section 3.5.2.2). It was found that the observed forces corresponded to the 90% strength capabilities of the female population. This was used as a measure of the worker's capability. Work mix was determined by the number of times a task was performed per year, based on the results of the survey (see Section 4.1.3).

Risk due to Job Mix = (Job Demands/Worker Capabilities) x Work Mix **Equation 3.3**

3.6 Hypotheses

For the observational portion of the study (Phase 1), it was hypothesized, based on self-reports from large animal veterinarians (Scuffham et al., 2010a), palpations, ultrasound, obstetric procedures, lameness exams, administration of injections, restraint, positioning, lifting, surgery, and dentistry would receive high subjective ergonomic risk ratings from the ergonomist rater (H1). With respect to specific risk factors contributing to higher risk ratings, these were investigated for a select number of tasks focusing on wrist and back injury.

For Phase 2 of the study, there were three hypotheses formulated. First, based on WMSD prevalence rates identified in previous studies (Scuffham et al., 2010b; Smith et al., 2009) and the results of the subjective screening tool, wrist postures maintained during equine veterinarian tasks were expected to violate predefined ergonomic criteria as defined by the Strain Index (H2). Second, based on injury prevalence rates (Scuffham et al., 2010b; Smith et al., 2009), high risk equine veterinarian tasks, as identified by the subjective screening tool, were expected to expose veterinarians to low-back spinal compressive forces, measured in 3DSSPP, exceeding the recommended NIOSH limit of 770 lbs (H3). Lastly, based on previous literature identifying these specific tasks as being hazardous to large animal veterinarians (Scuffham et al., 2010a; Cattell, 2000; Fourie and Hoffman, 2004; Loomans et al., 2008), the ratio of work demands to veterinarian capacity for a typical work mix was expected to reveal rectal palpations, ultrasound, and lameness exams to pose a higher ratio (and risk of WMSDs), as compared to injections, lifting, and restraint (H4).

4 Results

4.1 Survey Results

The survey was completed by eight veterinarians working at the CVM. Results according to topic are presented below.

4.1.1 WMSDs Reported

Participants were asked to identify, based on the symptom descriptions, any musculoskeletal disorders they felt they might have suffered from, as well as if they had been diagnosed with the disorder by a medical professional. Results are shown in Table 4.1.

Table 4.1: Reported WMSDs of Equine Veterinarians at NCSU CVM

WMSD	Medial Epicondylitis	Carpal Tunnel Syndrome	Thoracic Outlet Syndrome	Low Back Pain
Number of respondents who have reported suffering from the disorder		1	1	1
Number of respondents who have been diagnosed with the disorder	1	1		1
Total	**1**	**2**	**1**	**2**

Survey results revealed at least one equine staff member of the shadowed veterinarians suffered from WMSDs, such as medial epicondylitis, carpal tunnel syndrome, thoracic outlet syndrome, and low back pain. Musculoskeletal disorders not reported by participants are not presented in these results. The complete survey including a full list of the described symptoms can be seen in Appendix B.

4.1.2 Discomfort

Results of the discomfort survey are presented in Table 4.2 along with identification of the affected body parts and severity of the discomfort. Results revealed that the most common area of discomfort was in the neck (4 counts) and the hands/wrist. Other identified areas of discomfort were the back (2 counts), ankle (1 counts), and thigh/knees (1 count). The severity ratings indicated most of the discomfort was described as an ache or pain. One participant reports pain, numbness, and tingling in both the front and back of the neck and another participant identified numbness and tingling in the fingers.

Table 4.2: Results of Discomfort Survey Identifying Areas of the Body Causing Discomfort and the Severity of that Discomfort

Participant	Front			Back		
	Body Part	**Count**	**Severity**	**Body Part**	**Count**	**Severity**
S01	.	.	.	.	.	.
S02	Ankle	1	.	.	.	.
S03	.	.	.	.	.	.
S04	.	.	.	Back	1	Ache
S05	Neck	1	PNT	Neck	1	PNT
S06	Wrist	1	Ache	Wrist	1	Ache
S07	Neck	1	Pain	Neck	1	Pain
	Wrist	1	Ache	.	.	.
	Fingers	1	NT	.	.	.
	Knees	1	Ache	.	.	.
S08	.	.	.	Low Back	1	Pain

Note: NT = numbness and tingling. PNT = pain, numbness, and tingling.

4.1.3 Time on Task

There were 8 respondents to this survey among the veterinarians at the CVM and it should be noted that due to individual differences and specialties of practice at the CVM, there is large variability among the veterinarian responses. Results, as shown in Figure 4.1, revealed the task of restraint was performed most often among equine veterinarians on a yearly basis (M = 793.8, SD = 486.6, Range = 0, 1500 times per year). The next most frequent task was the administration of injections, which were performed on average 562.5 ± 608.7 (Range = 0, 1250) times per year. Lifting (M = 418.8, SD = 430.1, Range = 0, 1250 times per year), palpations (M = 387.5, SD = 541.0, Range = 0, 1250 times per year), ultrasound (M = 293.8, SD = 406.6, Range = 0, 1250 times per year), lameness exams (M = 205.5, SD = 211.4, Range = 0, 500 times per year), and surgery (M = 177.5, SD = 147.5, Range = 0, 500 times per year) were performed less often. The tasks that were performed the least frequently at the CVM were obstetric procedures (M = 81.5, SD = 155.6, Range = 0, 400 times per year), dental work (M = 27.8, SD = 27.0, Range = 0, 60 times per year), and positioning (M = 12.5, SD = 35.4, Range = 0, 100 times per year).

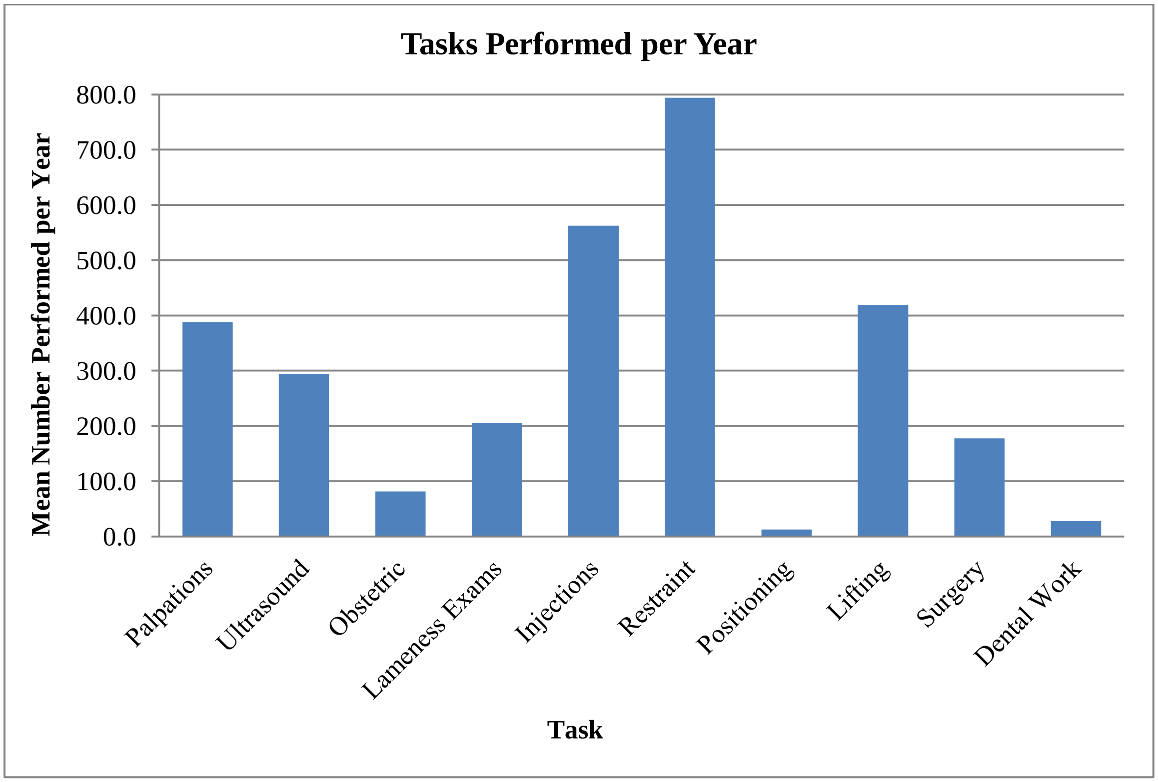


Figure 4.1: Frequency of Tasks Performed per Year

4.1.4 Time on Task per Day

To further quantify the amount of time spent on these tasks, the veterinarians were asked to identify the amount of time per day they spent performing the tasks, based on the assumption of an 8 hour day. Again, individual differences in specialty of practice led to large variability in responses. As with the task frequency survey, 8 veterinarians completed the survey on task time. Aggregate results (see Figure 4.2) showed the greatest amount of time per day was spent performing lameness exams (M = 3.25, SD = 2.82, Range = 0, 6 hrs). Surgery was the only other task performed for more than 2 hours per day (M = 2.88, SD = 1.64, Range = 0, 4 hrs). Restraint (M = 1.75, SD = 1.17, Range = 0, 4 hrs), ultrasound (M = 1.63, SD = 1.30, Range = 0, 4 hrs), palpations (M = 1.25, SD = 1.28, Range = 0, 4 hrs), lifting (M = 1.13, SD = 1.25, Range = 0, 4 hrs), and dentistry (M = 1.0, SD = 1.31, Range = 0, 4 hrs) were all procedures that were performed for at least 1 hour during the workday. Although the number of times the procedure was performed was high, the amount of time spent administering injections was only, on average, half an hour per day (SD = 0.54, Range = 0, 1 hrs). Lastly, obstetric procedures required the least amount of time commitment during the day (M = 0.38, SD = 0.52, Range = 0, 1 hrs).

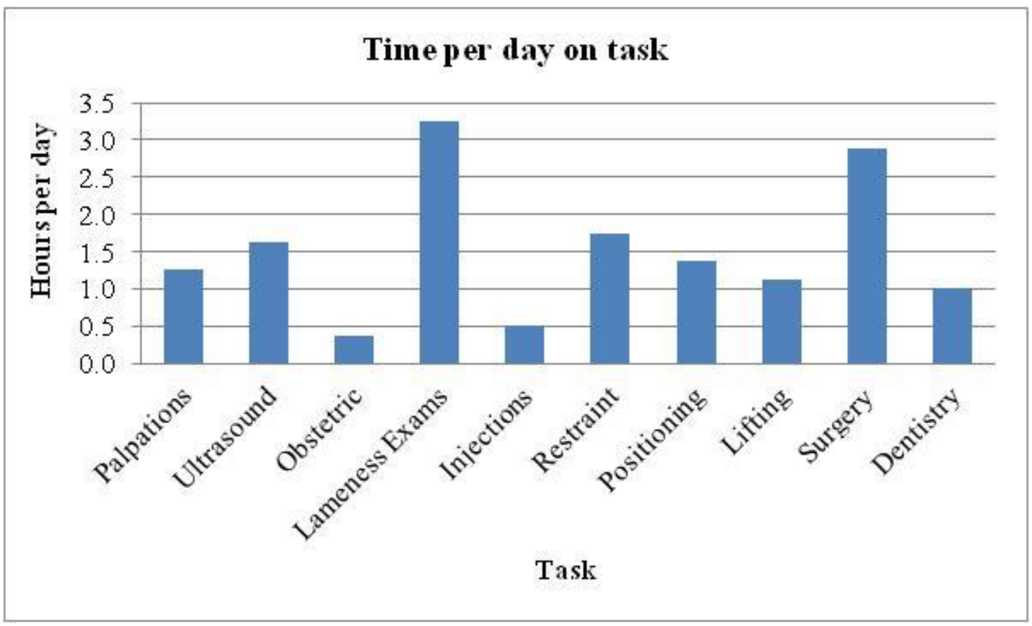


Figure 4.2: Time Spent per Day on Task

4.2 Phase 1 Results

4.2.1 Job Screening Score

The average whole-body job screening scores for the tasks under study are shown in Figure 4.3. Again, the scores were computed by summing weighted individual body part ratings of risk based on low, moderate, or high ratings for posture, force, and motion. Lameness exams received the highest aggregate risk score of 33.8 ± 4.3. All of the ten jobs analyzed received an average score above the level of a low risk job (a score of 16 or below), meaning all jobs were considered to be moderate (a score of 17-25) or high risk (a score > 25). In addition to lameness exams, those jobs receiving high risk scores include: positioning (M= 28.5, SD = 10.4), obstetric procedures (M= 28.5, SD = 5), and scanning/ultrasound (M= 25, SD = 2.7). Jobs receiving a rating of moderate risk were palpations (M= 23.7, SD = 2.6), injections (M= 20.0, SD = 7.3), restraint/handling (M= 22.3, SD = 3.9), lifting (M= 17.2, SD = 2.8), surgery (M= 23.7, SD = 6.4), and dentistry (M= 24.3, SD = 0.4). Inter-rater reliability across all jobs, based on Spearman's rank correlation coefficient analysis (Quinn & Keough, 2002) was 93.9% indicating high consistency between raters.

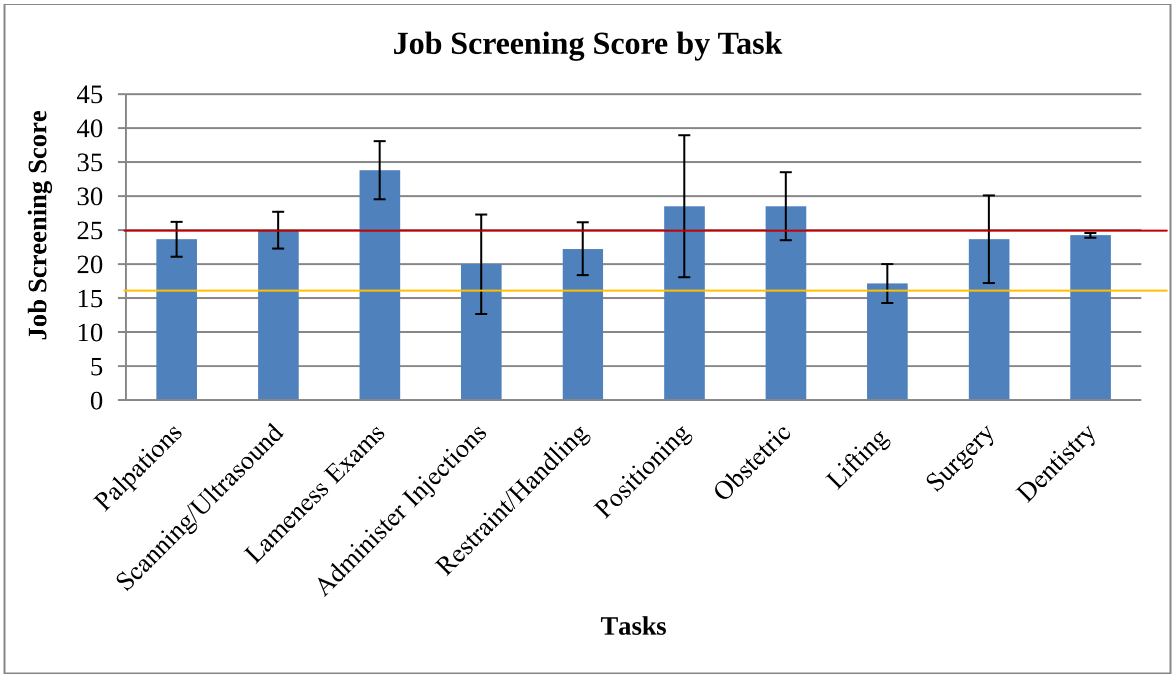


Figure 4.3: Job Screening Score by Task

Note: Upper red line indicates level of high risk (25 and above) and the lower amber line indicates level of moderate risk (17 – 25).

The results of the individual body part ratings showed the hands/wrists most frequently received high ratings across tasks (7 out of 10 tasks). The body parts with the next highest frequency of high risk ratings were the arms, back, and shoulders (5, 5, and 4 out of 10, respectively) The legs were only rated high for 2 tasks and the neck was only deemed high for 1 of the 10 tasks.

4.2.2 Subjective Risk

Taking into account both frequency and severity, results of the subjective risk score analysis revealed the order of highest to lowest subjective risk to be: restraint, administering injections, rectal palpations, ultrasound, lifting, lameness exams, surgery, obstetric procedures, dentistry, and positioning. The top six tasks were identified for further analysis based on these results and their contributions to WMSDs reported in the literature.

4.3 Phase 2 Results

4.3.1 Wrist Posture Results

Wrist posture data in the form of flexion, extension, and ulnar deviation, in degrees from neutral, was determined by the electro-goniometer and used as inputs into the Strain Index (see Figure 4.4). Results revealed the task of restraint to require average wrist postures of 21.04° (S.D. = 22.41°) flexion, 38.97° (S.D. = 21.52°) extension, and 10.26° (S.D = 9.89°) ulnar deviation. The task of lameness required average wrist postures of 27.39° (S.D. = 7.08°) flexion, 42.84° (S.D. = 7.54°) extension, and 31.81° (S.D = 0.92°) ulnar deviation. Lifting equipment required 7.16° (S.D. = 4.65°) flexion, 34.67° (S.D. = 12.29°) extension, and 21.98° (S.D = 11.12°) ulnar deviation. Ultrasounding subjected the participants to average wrist postures of 16.90° (S.D. = 7.16°) flexion, 36.52° (S.D. = 17.19°) extension, and 31.20° (S.D = 7.50°) ulnar deviation. Performing rectal palpations required average wrist postures of 25.20° (S.D. = 13.08°) flexion, 37.63° (S.D. = 23.38°) extension, and 24.28° (S.D = 8.97°) ulnar deviation. Lastly, injections involved average wrist postures of 16.45° (S.D. = 10.83°) flexion, 14.84° (S.D. = 20.85°) extension, and 26.77° (S.D = 9.77°) ulnar deviation.

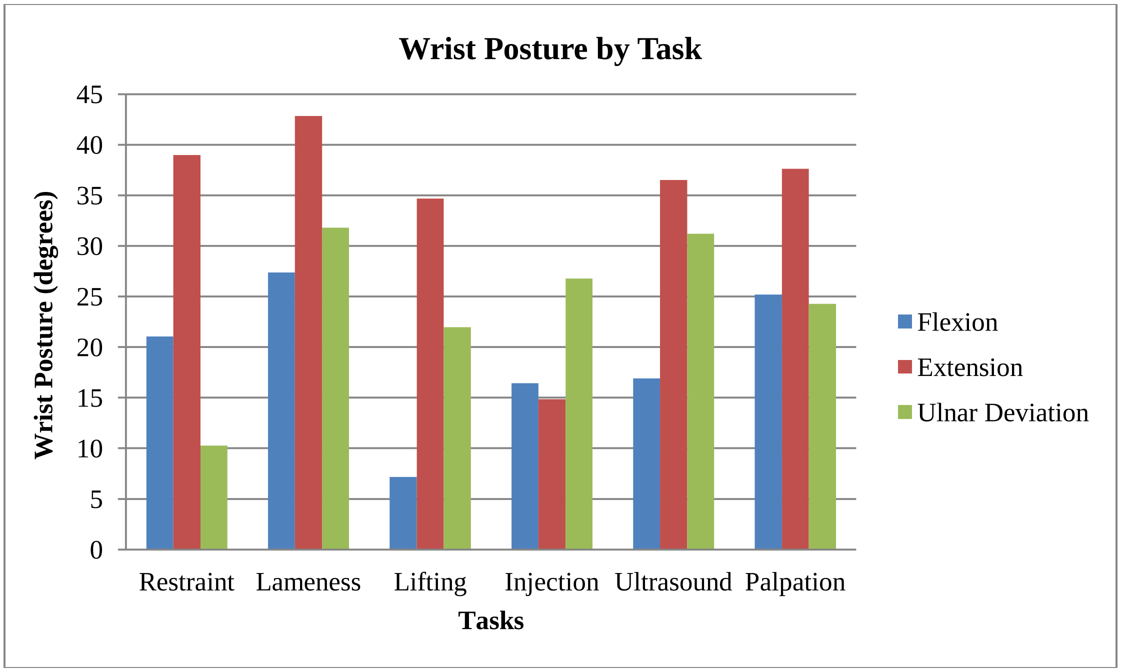


Figure 4.4: Wrist Posture by Task

In general, the most extreme flexion postures were observed for the task of lameness exams (27.39°) and palpations (25.20°). Similarly, the most extreme extension postures were recorded for the lameness exam (42.84°) task. Ulnar deviation was observed to be greatest in the lameness exam (31.81°) and ultrasound (31.20°) tasks. These data and observations were critical to the Strain Index analysis for potential upper-extremity disorders.

4.3.2 Force Sensor Results

Results of the average forces exerted by the veterinarians at the hands are shown in Figure 4.5. The highest forces were exerted when performing an ultrasound (M = 6.41, S.D. = 0.23 lbs-f). Lifting required slightly less force (M = 6.13, S.D. = 3.21 lbs-f). Lameness exams, restraint, and palpations required even less force than lifting (M = 4.18, S.D. = 3.12 lbs-f; M = 3.02, S.D. = 2.68 lbs-f; M = 2.51, S.D. = 1.5 lbs-f, respectively). Finally, injections required the least amount of force on the hands (M = 1.8, S.D. = 1.45 lbs-f).

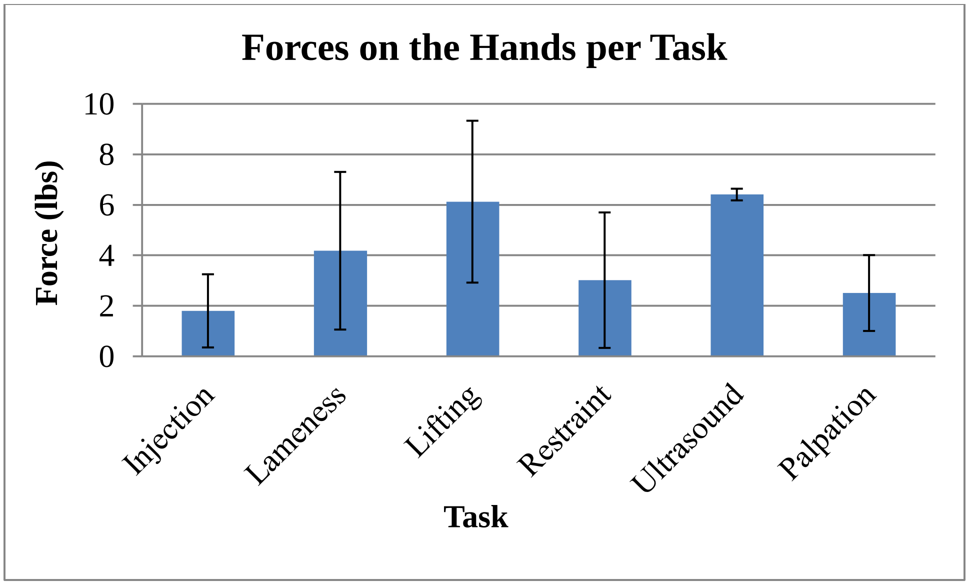


Figure 4.5: Force Exerted on the Hands per Task

4.3.3 Risk for Upper Extremity Disorders

Results of the average Strain Index scores are shown in Figure 4.6. Three of the tasks were considered "probably hazardous" and thus posed a high risk for developing distal upper extremity disorders. Those tasks were lameness exams (M = 22.9, SD = 14.5), lifting (M = 21.6, SD = 14.6), and ultrasound (M = 7.2, SD = 6.4). One task, palpations (M =3.1, SD = 1.6), received a score that indicated an "increased risk for an individual." However, this score was just above the criterion value of 3. The final two tasks were rated as being "probably safe," including: injection (M = 0.6, SD = 0.4) and restraint (M = 2.6, SD = 2.1). Inter-rater reliability for the application of the Strain Index was 87% indicating a high degree of agreement among calculations.

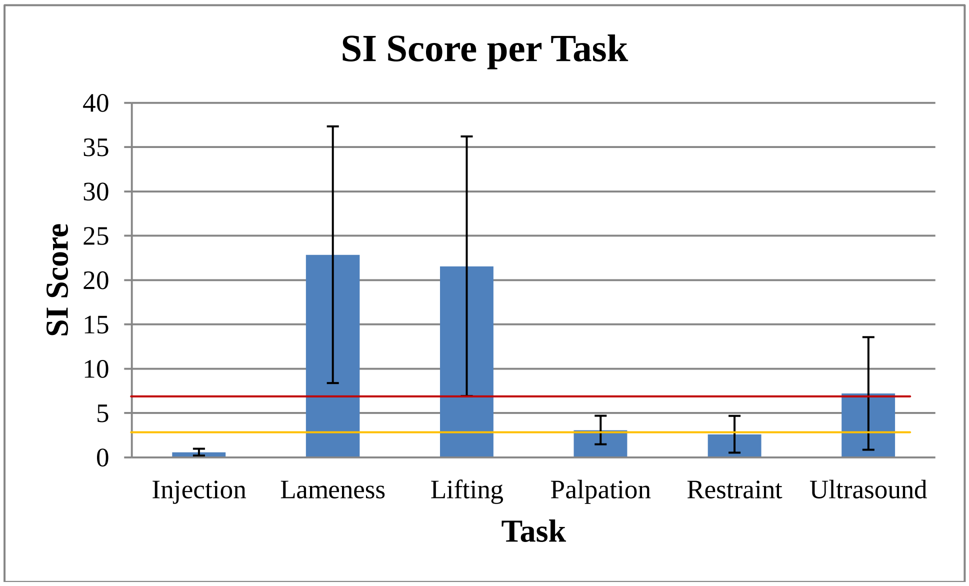


Figure 4.6: Strain Index Results per Task

Note: Upper red line indicates level of hazardous jobs (7 and above) and the lower amber line indicates level of moderate risk (3-7).

4.3.4 Risk for Low Back Disorders

Results (Figure 4.7) of the low back static strength (3DSSPP) analysis revealed that none of the analyzed tasks violated the NIOSH low back compressive force limit of 770 lbs. The tasks of lifting and performing lameness exams both resulted in the highest low back compressive forces (M = 584.75, SD = 164.31 lbs-f and M= 576.43, SD = 133.30 lbs-f, respectively) compared to all other tasks. An example of the posture positions for these tasks, as modeled in 3DSSPP, were described by the body segment angles shown in Figure 4.8 and Figure 4.9. Screenshots of these postures modeled by the manikin are shown in Figure 4.10 for lifting and Figure 4.11 for lameness exams. Performing ultrasounds (M = 453.25, SD = 132.25 lbs-f) and conducting palpations (M = 363.25, SD = 188.95 lbs-f) yielded lower compressive forces. Again, an example of the posture positions for these tasks, as modeled in

3DSSPP, were described by the body segment angles shown in Figure 4.12 and Figure 4.13. Screenshots of these postures modeled by the manikin are shown in Figure 4.14 for ultrasounds and Figure 4.15 for rectal palpations. Furthermore, the lowest back compression forces were seen in the tasks of restraint (M = 123.38, SD = 68.68 lbs-f) and administering injections (M = 122.0± 14.14 lbs-f).

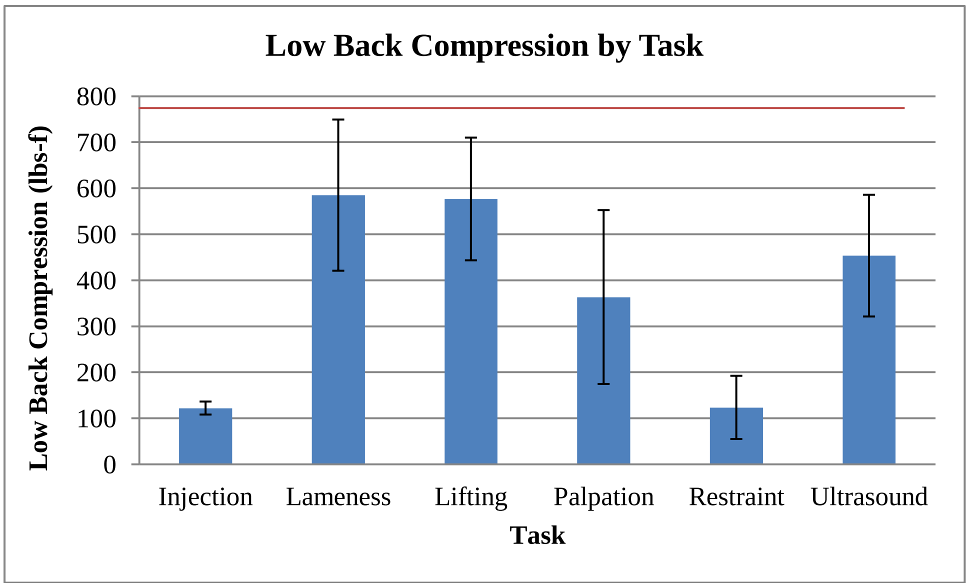
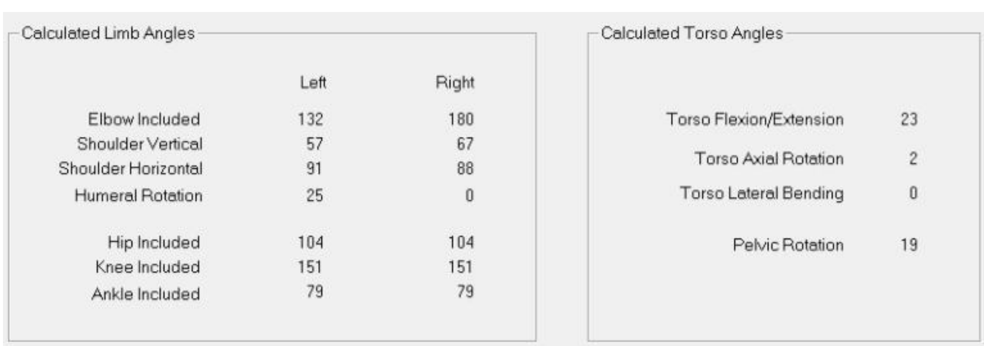


Figure 4.7: Low Back Compression Results

Note: Red line indicates level of NIOSH compression limit



Calculated Limb Angles

	Left	Right
Elbow Included	132	180
Shoulder Vertical	57	67
Shoulder Horizontal	91	88
Humeral Rotation	25	0
Hip Included	104	104
Knee Included	151	151
Ankle Included	79	79

Calculated Torso Angles

Torso Flexion/Extension	23
Torso Axial Rotation	2
Torso Lateral Bending	0
Pelvic Rotation	19

Figure 4.8: Posture Report for Lifting Task

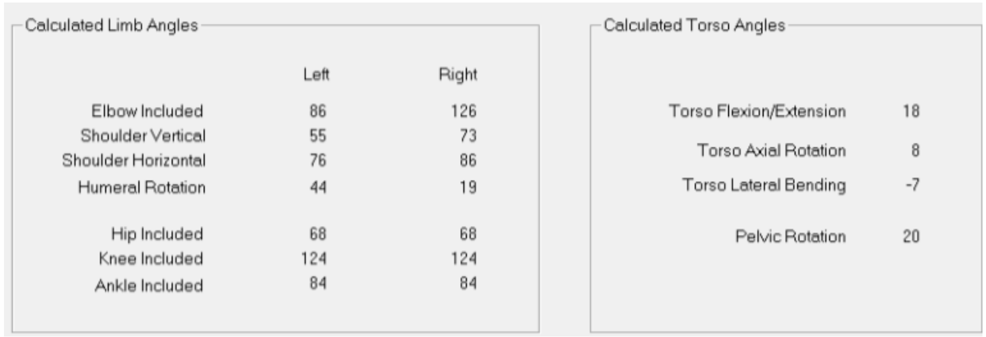


Figure 4.9: Posture Report for Lameness Exam

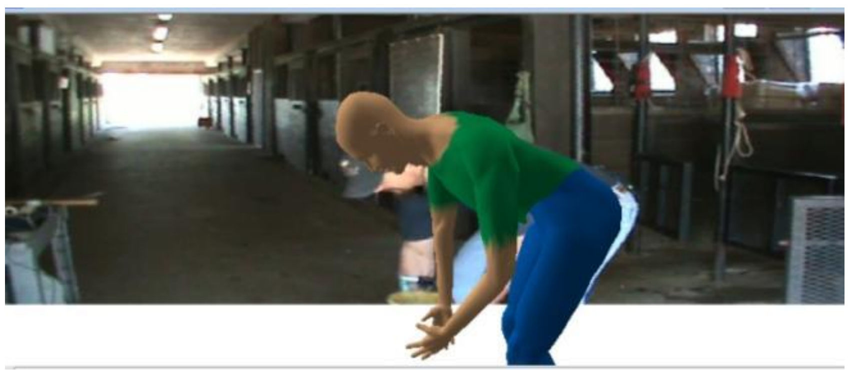
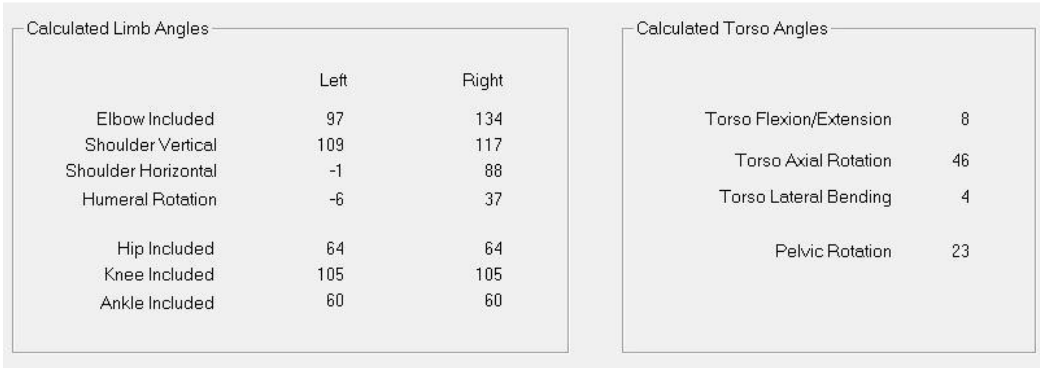


Figure 4.10: Modeled Posture for Lifting Task

Figure 4.11: Modeled Posture for Lameness Exam



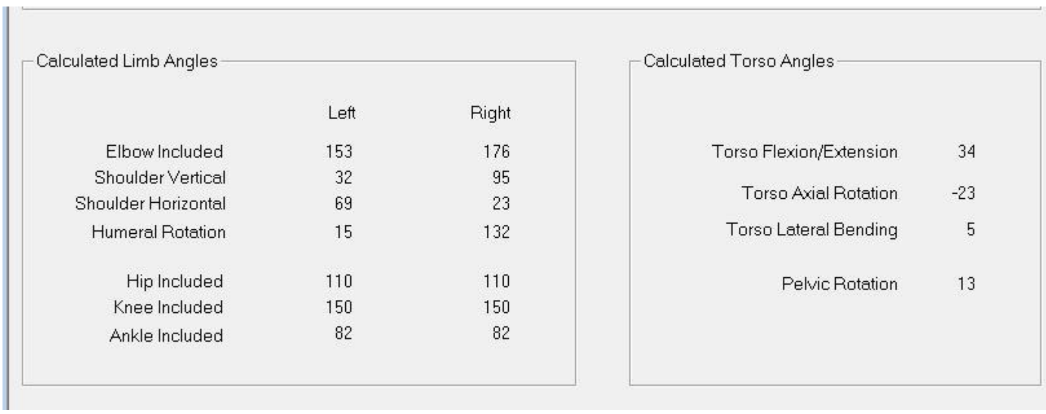
Calculated Limb Angles

	Left	Right
Elbow Included	97	134
Shoulder Vertical	109	117
Shoulder Horizontal	-1	88
Humeral Rotation	-6	37
Hip Included	64	64
Knee Included	105	105
Ankle Included	60	60

Calculated Torso Angles

Torso Flexion/Extension	8
Torso Axial Rotation	46
Torso Lateral Bending	4
Pelvic Rotation	23

Figure 4.12: Posture Report for Ultrasound Procedure



Calculated Limb Angles

	Left	Right
Elbow Included	153	176
Shoulder Vertical	32	95
Shoulder Horizontal	69	23
Humeral Rotation	15	132
Hip Included	110	110
Knee Included	150	150
Ankle Included	82	82

Calculated Torso Angles

Torso Flexion/Extension	34
Torso Axial Rotation	-23
Torso Lateral Bending	5
Pelvic Rotation	13

Figure 4.13: Posture Report for Rectal Palpation Procedure

Figure 4.14: Modeled Posture for Ultrasound Procedure

Figure 4.15: Modeled Posture for Rectal Palpation Procedure

4.3.5 Risk due to Job Mix

The ratio of job demands to worker capacity was integrated with the frequency of exposure data for the analyzed tasks. The tasks with the highest results represent the greatest risks within the typical work mix specified by the participating veterinarians. Risk scores (Figure 4.16) revealed the task of performing ultrasounds (M = 254.96, SD = 5) to contribute most to the potential for developing a WMSDs compared to patient restraint (M = 188.65, SD = 143.13), followed by lifting (M = 91.89, SD = 39.90), palpations (M = 88.14, SD = 31.28), lameness exams (M = 87.74, SD = 63.49), and injections (M = 47.10, SD = 46.72).

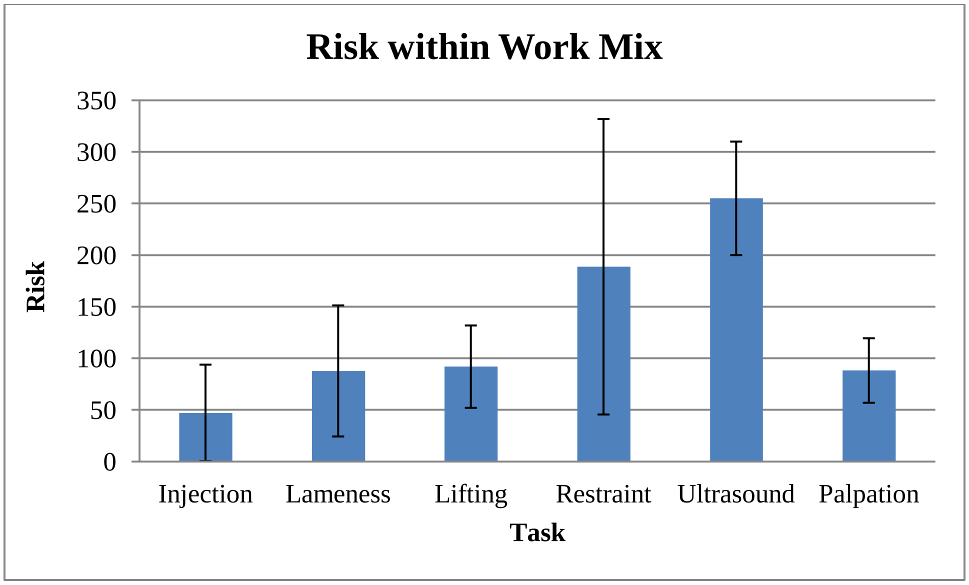


Figure 4.16: Task Risk within Work Mix

5 Discussion

5.1 Phase 1

A survey was distributed among the equine veterinarians at the CVM in order to gain insight into the variability and frequency of veterinarian tasks, as well as body discomfort experienced by veterinarians due to work.

In regard to the amount of time spent per day and number of tasks performed each year, there was substantial variability between respondents (see Section 4.1.3 and Section 4.1.4). There were also differences in the findings of this study compared to previous studies on veterinarian task frequency. These individual differences are attributable to the structure and nature of the facility. As a referral facility, the CVM performs tasks that do not always correlate with those in private practice, which are more limited in scope and repetitive. As a teaching hospital, the veterinarians at the CVM provide certain services based on their area of expertise. The frequency and types of tasks performed vary according to service. This is typically not the case in private practices with one or a few staff veterinarians. Some examples of differences in work mix can be seen in the comparisons between the CVM veterinarian responses and responses from a survey of equine veterinarians in the Netherlands (Loomans et al., 2008). Veterinarians in the Netherlands report performing dental work between a few times per month and a few times per week, whereas equine veterinarians at the CVM only perform such procedures, on average, approximately twice a month. Furthermore, private practice veterinarians typically only perform surgical procedures a few times per year while CVM veterinarians perform surgeries a few times per week. However, there is consistency between the literature and the results of the current survey in regard to injections and palpations being some of the more frequent procedures performed.

Regarding body part discomfort, CVM respondents indicated aches and pains in areas of the body that were consistent with previous reports identified in the literature. Discomfort ratings and reported WMSDs in the current study identified the most affected body parts to be the upper extremities and low back with minor discomfort in the low body. Results from Smith et al. (2009) and Scuffham et al. (2010b) show similar trends in areas affected. In order to test Hypothesis 1, the ECNC job screening tool was also used. It was expected that palpations, ultrasound, obstetric procedures, lameness exams, injections, restraint, positioning, lifting, surgery, and dentistry for equine patients would be high risk tasks for WMSDs as determined by subjective analyst ratings. Results showed only four of the ten tasks (ultrasound, lameness exams, positioning, and obstetric procedures) confirmed the hypothesis with high subjective ratings from the screening tool. The remaining six tasks received ratings of moderate risk.

Differences between the results and Hypothesis 1 could be due to a number of factors. The screening tool used to assess job risk calculates a score for the whole body instead of focusing solely on individual body parts. Therefore, although some tasks may have high risk for individual joints, the overall score could have been lower than expected due to some parts receiving low ratings. For example, the ratings for the task of performing rectal palpations revealed the arm and shoulder to be at high risk for injury; however, the remainder of the body was observed in a neutral posture using minimal force. Therefore, the overall body risk rating was only moderate.

Beyond this, the tasks chosen for analysis in this study were based on previous reports in the literature that identified them as potentially hazardous. However, some of the tasks identified have different versions and methods (requiring varying postures), depending on the specific requirements of the procedure. In order to quantify the risks at a task level and identify as many potential risks as possible, risk scores were averaged across ratings for a number of different versions of the tasks under study. For example, injections could require very different postures if the veterinarian was performing a venous injection in the animal's neck, which requires a neutral posture with raised arms, compared to a hock injection, which requires kneeling and flexed back postures. Higher ratings from riskier versions of a task would be reduced when averaged with safer versions. This intra-task variability (differences in procedure methods) might have also led to high variability in the ratings.

Hypothesis 1 was generated from self reports found in previous literature and although some of the overall risk ratings did not agree, risk ratings of individual body parts were consistent with the literature. The results of the individual body part ratings by ergonomics analysts revealed the hands/wrists to most frequently receive high ratings across tasks (7 out of 10 tasks). The body parts with the next most frequent ratings of high risk were the arms, back, and shoulders. As mentioned previously, in the survey to assess musculoskeletal discomfort, the equine veterinarians at the CVM identified the neck and hands/wrists as being the most common area of discomfort. Similar results are seen throughout the literature on veterinarian tasks with upper extremities (neck, shoulder, and hand/wrist), as well as the lower back, having prevalence rates for musculoskeletal disorders of over 50% (Smith et al., 2009; Scuffham et al., 2010b).

Beyond the screening tool, a subjective risk score was calculated to determine where to focus the quantitative data collection (in Phase 2 of the research). The subjective risk score and risk due to work mix are similar in computation (see Equation 3.1 and Equation 3.3) except that the inputs of severity are different. For the subjective risk rating, the severity is determined by the results of the ECNC's Job Screening Tool; however, the severity component of the risk due to work mix is the ratio of job demand to worker capacity. Results revealed restraint, administering injection, rectal palpations, ultrasounds, lifting, and lameness exams to induce the highest subjective risk of injury for equine veterinarians. Previous literature confirms these results. According to Fourie and Hoffman (2004), 75% of 48 veterinarian sonologists surveyed reported WMSDs. Equine veterinarians from the Netherlands reported lameness exams to be strenuous and demanding with discomforting postures (Loomans et al., 2008). The tasks of manual handling of animals, lifting, and performing rectal palpations have been demonstrated to be associated with WMSDs (Cattell 2000; O'Sullivan and Curran 2008; Scuffham et al. 2010a). Finally, administering injections is one of the most frequently performed tasks for equine veterinarians and vaccination injections can be administered somewhere between a few times per week to almost daily (Loomans et al, 2008).

5.2 Phase 2

5.2.1 Hypothesis 2

Phase 2 of the study involved the collection of quantitative data to help identify which tasks posed the greatest risk of injury to equine veterinarians. It was hypothesized that wrist postures adopted during veterinarian tasks would violate ergonomic criteria as defined by the Strain Index (H2). The most extreme posture angles for flexion were found in the tasks of lameness exams, palpations, and restraint, which all had flexion angles greater than 20°. These represent "non-neutral" postures, according to the Strain Index (Moore & Garg, 1995). Almost all of the tasks, except for administering injections, resulted in average wrist postures greater than 34° in extension, which is categorized as being "fair" based on the Strain Index. Furthermore, the task of lameness exams revealed even greater average wrist extension postures of 42.84° putting it in the category of "marked deviation." Lastly, the tasks of lameness exams, performing injections, and conducting ultrasounds all resulted in ulnar deviations categorized as "near extreme," with postures greater than 25° from neutral.

Results of the Strain Index revealed three out of six tasks analyzed were consistent with the hypothesis. Performing lameness exams, ultrasounds, and lifting were all rated as high risk for distal upper extremity disorders. Common risk factors between these tasks include moderate to extreme wrist extension (11° – 61°) and ulnar deviation (5° - 38°) and high ratings of intensity of exertion (Borg ratings ranging from 2-7). It should be noted that the ratings of exertion using the Borg scale, were higher for the female participant than the male participant. This is consistent with previous findings where, for the same physical exercise, women rated exertion higher than men (Borg, 1998). The larger perceived effort highlights the potential for higher risk for female veterinarians, as defined by the Strain Index.

With respect to rectal palpations, although occasional extreme wrist postures were observed, the intensity of exertion ratings and relatively low average duration of exposure per day led to lower than expected Strain Index scores. However, some specialties (i.e., Theriogenology) required rectal palpations to be performed more frequently than others; therefore, practitioners in those specialties may be prone to a higher risk for distal upper extremity disorders from this task than the average.

Wrist postures adopted while performing the analyzed restraint tasks were often non-neutral but did not extend into the category of "near extreme" compared to the other observed tasks. Also, the intensity of exertion ratings and duration of exposure day remained low. The animals used when collecting the quantitative data were calm and easily controlled. However, more fractious animals would require increased exertion to handle and could increase the risk involved in restraint tasks.

Finally, the task of performing injections was given a rating of “probably safe” for upper extremity disorders. Although contradictory to initial expectation, this was not a surprising result based on the data analysis. While performing injections may require awkward postures occasionally, it was not found to be a strenuous task and was not usually performed for more than 1 hour each day.

5.2.2 Hypothesis 3

The force data collected at the hands were used as inputs to the 3DSSPP. The characteristics of this data for the various tasks under study included averaging the highest four peak forces per participant per task within the subtask time window. The raw force data was averaged across all participants and revealed the tasks of ultrasound and lifting to require the greatest amount of localized force compared to the other analyzed tasks. These higher forces (greater than 6 lbs-f for each task), combined with the awkward postures required by the tasks, led to ultrasound and lifting to be among those with the highest low back compressive forces.

However, contrary to expectations set forth in Hypothesis 3, none of the subjective high risk tasks exposed equine veterinarians to low back compressive forces over the NIOSH limit of 770 lbs. Some of the tasks revealed low back compressive forces near the limit, when analyzed on an individual basis. Yet, when averaged across participants, taking into account variability in individual posture, the compressive force results were lowered to a level that did not equate to high risk. Larger veterinarians and more fractious animals might yield higher forces on the body (particularly with forward flexion of the torso) and increase the likelihood of low back compressive forces exceeding the NIOSH criterion. Furthermore, the low back analyses completed in this study were performed using static snapshots of the most extreme posture positions during a task. However, many of these tasks were not, in fact, static and the accelerations acting on the low back during dynamic movement can increase the required muscle forces (Eastman Kodak Company, 2004). Therefore, the actual forces acting on the veterinarian's body may be higher than those reported here along with the risks of potential injury.

On an individual task basis, the tasks of injection and restraint produced the lowest compressive forces on the back due to the near neutral posture maintained throughout performance. However, these tasks are not always performed in a neutral posture. An injection to the hocks involves crouching and reaching to hocks (see image in Figure 5.1) and restraining a foal involves leaning over to wrap arms around it (see Figure 5.2 for example posture position). These are two examples of when veterinarian tasks could lead to more awkward postures.

Figure 5.1: Example of Veterinarian Posture Position during Hock Injections

Figure 5.2: Example of Veterinarian Posture in Foal Handling

Finally, although the spinal compressive force selected by NIOSH (1981) is 770 lbs for the L5/S1, this may still be too high of a criterion to protect the entire working population. Data has shown compressive forces below this level are associated with increased risk for low back injuries (Waters, Putz-Anderson, & Garg, 1993)

5.2.3 Hypothesis 4

Hypothesis 4 predicted that performing palpations, ultrasounds, and lameness exams would pose a higher risk for WMSDs due to veterinarian's work mix compared to the other tasks. Consistent with the hypothesis, performing ultrasounds did pose the highest risk for WMSDs compared to the other tasks. However, palpations and lameness exams resulted in a lower risk rating than restraint and lifting. It was found that the job demand (amount of force required) for flexion tests, as part of lameness exams, and rectal palpations were much lower than originally anticipated based on reports of the task being strenuous in nature (Loomans et al., 2008) and the assumed forces required in handling the animal. Although it is necessary to maintain a bent and crouched posture when performing flexion tests, the average force required to keep the horse's joint in a flexed position is limited to around an average of 4 lbs. Performing rectal palpations require non-neutral postures for the shoulder but only require on average 2.51 lbs of force. The amount of force exerted by the hands for a rectal palpation has been equated by veterinarians to "searching for something at the bottom of a suitcase full of clothes" (A. Allen, DVM, personal communication, 2011). Also, as previously noted, the number of tasks per year was averaged across different specialties. Equine veterinarians who spend more of their time focusing on rectal palpations and/or lameness exams will be at higher risk than reported here.

Although not initially expected to be of higher risk than other tasks, restraining animals resulted in the second highest risk rating. The ratio of job demand to capacity for restraint remained low (24%); however, the number of times per year this task is performed was high, leading to the high overall risk score.

In general, it is important to note that the observations made during the shadowing and data collection period of this study were completed at one of the highest rated veterinary schools in the United States. Because of the specialized nature of the hospital, the CVM at NCSU may operate in a different and more controlled manner than other private clinics. Consequently, it is possible that the occupational risks encountered by equine veterinarians in the field are greater than the ones identified in this study. Having said that, the CVM may perform some high risk operations that are not performed in private practice due to resource limitations.

6 Conclusion

After reviewing the previous research and results in the area of musculoskeletal disorders among veterinarians, it can be seen that these types of injuries are often more frequent for this specific occupation, when compared to their human healthcare counterparts. A number of studies have been performed to assess the prevalence rates of WMSDs among large animal veterinarians; however, few studies have provided insight into which tasks maybe causing cumulative traumas as well as the magnitude of the risk factor exposure (e.g. postures and forces). The present study focused on ergonomic evaluations of equine veterinarian tasks to identify risk factors and levels exceeding ergonomic guidelines for injury prevention. A summary of the results is shown in Table 6.1 and further discussed below.

Table 6.1: Summary of Study Results

	Analysis Method				
	Phase 1		Phase 2		
Task	**Job Screening Score (Risk Category)**	**Job Order based on Subjective Risk Rating (1 = Highest, 10 = Lowest)**	**Strain Index Score**	**Low Back Compressive Force (lbs)**	**Job Order based on Work Mix Risk Rating (1 = Highest, 6 = Lowest)**
Lameness Exams	33 (High)	6	22.9	576.43	5
Lifting	17.2 (Moderate)	5	21.6	584.75	3
Ultrasounds	25 (High)	4	7.2	453.25	1
Rectal Palpations	23.7 (Moderate)	3	3.1	363.25	4
Restraint	22.3 (Moderate)	1	2.6	123.38	2
Injections	20 (Moderate)	2	0.6	122	6
Obstetric Procedures	28.5 (High)	8			
Surgery	23.7 (Moderate)	7			
Positioning	28.5 (High)	10			
Dentistry	24.3 (Moderate)	9			

A subjective screening tool identified the tasks of lameness exams, rectal palpations, positioning and obstetric procedures as being of high risk to the whole body. However, when combined with data on the frequency of exposure to these tasks, the six tasks identified as having the highest subjective risk (and therefore requiring further quantitative analysis) were restraint, injections, rectal palpations, lifting, ultrasounds, and lameness exams. Further analysis of these tasks revealed those contributing most to risk of WMSDs equine veterinarians overall, as well as for the specific body parts, including the wrists and low back.

Analysis of the Strain Index revealed that lameness exams, lifting, and performing ultrasound procedures were tasks that were hazardous for the development of distal upper extremity disorders. Although none of the average low-back compressive forces observed during these tasks violated the 770lbs criterion identified by NIOSH (1981), the same three tasks (lameness exams, lifting, and ultrasounds) exposed equine veterinarians to the highest low back forces compared to all other analyzed tasks. Finally, these three tasks were among those contributing the highest risk when comparing job frequency, demand, and capacity. Based on these results, it is clear interventions should focus on the tasks of lameness exams, lifting, and ultrasound.

6.1 Recommendations

Ergonomics interventions were formulated to with the intent of mitigating some of the risks posed to equine veterinarians. The recommendations were organized in terms of: (a) interventions at the horse; (b) interventions in the "path" between the horse and the veterinarian (i.e., how the veterinarian interacts with the animal); and (c) interactions at the source of the procedure (i.e., the veterinarian). The interventions were further classified based on the type of control to be applied, including: (a) engineering controls: modifications to the design of the system; (b) administrative controls: modifications to the work process; and (c) PPE: equipment to protect the veterinarian. Therefore, proposed interventions for the tasks of lameness exams, ultrasounds, and lifting are presented in 3 x 3 matrices (types and targets of intervention) and discussed below. All recommendations were reviewed for practicality by an equine veterinarian and any caveats to the interventions are identified.

Interventions to mitigate the risks of performing lameness exams (Table 6.2) should focus on reducing the forces and awkward postures required of veterinarians. To help reduce the amount of time in a sustained awkward posture, an engineering control in the form of a hoof jack could be used to lift the horse’s leg (see Figure 6.1 for example; Equine Innovations, 2010). This intervention may have limited usefulness if the lameness exam requires flexing the fetlock joint versus just holding the horse’s leg passively up in the air. Also, flexion tests, as part of lameness exams, could be conducted on an elevated platform (Figure 6.2) to reduce bending. The platform should have a sloped ramp in order to be able to trot the horse off immediately after the flexion test. Additionally, administrative controls such as restricting the number of lameness exams performed sequentially, training in postures that increase bending at the knees instead of flexion at the back, or requiring flexion tests to be performed in a seated position should be implemented. A stool could be practical for a front leg flexion test but probably would not be tall enough to work for a hock flexion test. Also, it is important to ensure the horse is well-behaved to avoid potential for acute injury (i.e., kicking).

Table 6.2: Lameness Exam Recommendations

	Engineering	Administrative	PPE
Receiver (animal)	1) Use of a hoof jack to lift horse's leg. 2) Perform exam with horse on elevated platform to reduce bending.		
Path		1) Restrict the number of lameness exams performed sequentially. 2) Perform flexion tests while sitting on a wheeled stool, to prevent the need for back flexion	
Source (Veterinarian)		1) Training in performing flexion tests by maintaining a posture that requires a bend at the knee instead of flexion of the back	

Figure 6.1: Example of Hoof Jack

Figure 6.2: Example of Elevated Platform

(Available from: http://www.horseplaygroundequipmentanddesign.com/horseplayground_Products-Bridge.php [Accessed on 23 October, 2011])

Recommendations for the task of lifting are shown in Table 6.3. Engineering controls in the form of buckets with larger diameter handles (Figure 6.3) or two handles would help with coupling issues and distribution of the load. Administrative controls such as filling buckets with water at the destination instead of carrying a full bucket, or using a two-person lift when performing heavy lifting and carrying tasks, should be adopted. If a second person is not available, a cart should be used in lieu of carrying heavy objects by hand. Finally, it is important when lifting to bend down at the knees and avoid excessive forward and lateral flexion at the back.

Table 6.3: Lifting Recommendations

	Engineering	Administrative	PPE
Receiver (animal)			
Path	1) Use buckets with larger diameter handles to help with coupling and awkward wrist postures. 2) Use buckets with two handles to distribute the load.	1) Use a cart to transport equipment over long distances in lieu of carrying by hand. 2) For buckets of water, fill with hose at final destination to limit carrying, if possible.	
Source (Veterinarian)		1) Adopt a two-person lift for heavy lifting and awkwardly shaped objects. 2) When lifting, bend with the legs to reduce the amount of flexion in the back.	

Figure 6.3: Example of Existing Bucket Handle and Handle with Increased Diameter

(Available from: http://www.eaglegriphandles.com/EGH/home.html [Accessed on: 23 October, 2011])

Recommended interventions for conducting ultrasounds are presented in Table 6.4. Engineering controls should be put in place to raise the animal when performing ultrasounds underneath the body or to the lower extremities to mitigate bending by veterinarians. The horse could be placed in lifted stocks (see Figure 6.4 for concept [minus the treadmill component]) or on a raised platform (see Figure 6.2 for example) when conducting these types of tasks. If raising the animal is not possible, administrative controls should be applied, such as requiring veterinarians to sit on a stool (lower the body) or assume a kneeling posture with the aid of knee pads. This is preferable to postures requiring significant flexion of the back. However, kneeling during ultrasounds limits the veterinarian’s ability to move away from the animal quickly to avoid being kicked. Furthermore, if the area to be probed is high on the animal, the veterinarian should stand on a mini step-ladder to prevent working with his/her arm elevated above shoulder level. Another option when working high on the animal is to sit on a raised stool next to the horse, if it is restrained in stocks.

Finally, engineering controls in the form of adjustable monitors or stands (see Figure 6.5 for example) and ergonomic probes would help reduce awkward postures in the neck and wrists of veterinarians. Although some of the ultrasound machines used at the CVM have adjustable monitors, the range of adjustability needs to be increased so screens, or portable machines, can be lifted or lowered to approximately 15° below the eye level of a veterinarian during a procedure (Salvendy, 1987).

Table 6.4: Ultrasound Recommendations

	Engineering	**Administrative**	**PPE**
Receiver (animal)	1) Place animal in lifted stocks to reduce bending.		
Path	1) Investigate ergonomic probe handles to reduce awkward wrist angles 2) Investigate adjustable screens to reduce awkward neck postures. Screens should be able to be lowered to 15° below the eye level of the veterinarian.		
Source (Veterinarian)		1) Adopt kneeling postures when performing ultrasounds underneath the animal. 2) Stand on a mini step-ladder when necessary to maintain shoulder postures below 90° abduction. 3) If conducting ultrasounds underneath animal, or to lower extremities for long periods of time, perform while seated on a stool to lower body position.	1) Use of knee pads when adopting kneeling postures

Figure 6.4: Example of Lifted Stock Concept

(Available from: http://www.horsestocks.com/treadmill.htm [Accessed on 23 October, 2011])

Figure 6.5: Example of Adjustable Stand for Ultrasound Monitor

(Available from: http://www.medicus-health.com/ultrasound-echo-laptop-cart-adjustable-height.aspx [Accessed on 23 October, 2011])

Overall, this study identified risk factors and particularly high risk tasks for WMSDs in equine veterinarian work as well as specific risk factors within tasks. The study also provided some quantification of veterinarian exposures to such risks in terms of posture positions and force. These findings provide an applicable guide for prioritizing and developing control measures within this domain.

6.2 Limitations

Caution should be taken in interpreting and applying the results of the current research due to certain limitations. One of these limitations was the small number of participants analyzed during Phase 2 of the research. Due to the availability of equine veterinarians at the CVM and the resources for this study, only two participants were observed during the Phase 2 data collection. Also, as previously mentioned in Section 3.1.1, the types and frequencies of tasks performed at the CVM may not be representative of those seen in private practice. Therefore, the results of this study may not be generalizable to all equine veterinarian operations and practitioners. Furthermore, as part of the initial job screening, scores for different versions of a task (sometimes requiring varying postures) were averaged together to identify an overall task screening score. One example can be found in differences in posture in variations of the injection task. A sedative injection to the horse's neck requires a more neutral posture than a series of hock injections. For an injection to the animal's neck, the veterinarian maintains a neutral posture with some flexion of their shoulder and minimal neck extension. However, injections to the hocks require veterinarians to bend the knees and kneel, forward-flex the back, and extend the arms to reach. All of these body postures lead to higher subjective ratings of risk for those body parts when compared to sedative injections at the neck. Further separation and analysis of the tasks on a version-by-version basis may provide greater accuracy in assessment of the specific task risks (with the potential limitation of a smaller sample size).

In addition, there were limitations with the equipment used during portions of the study. The goniometer sensor used for the wrist was larger than the size recommended by current manufacturers. This was due to a malfunction of the recommended goniometer during the data collection period. The results of the goniometer data could therefore be subject to ±5% error between the two goniometer axes measured over a range of ± 60°. Additionally, forces collected using the FSRs may have been lighter than actual forces exerted by a participant on a task basis. In order to use the forces as inputs into 3DSSPP, the FSRs were placed in the palm of the hand beneath a glove. This placement allowed the sensors to compress by a certain amount before registering a force. Another limitation of the sensors was that they only covered a small portion of the hand. If, during performance of the task, a participant used a portion of his/her hand not covered by a sensor, the force measurement results would be lower than the actual task force.

6.3 Future Research

Future research in this area should focus on addressing some of the limitations of the current study. In particular, more participants should be studied to gain further sensitivity and reliability in the quantitative analysis. Also, future analyses should be broken-up to identify risk factors according to equine service, as it was found that day to day work varies between veterinary medical services. Furthermore, work should be done to identify differences in risk factors between referral facilities and those seen in private practice.

When compared to small animal practices, the types of procedures performed in large animal veterinary work can differ substantially. Procedural differences are largely due to size and anatomy differences among the animals. When the results of the present study are compared with results of prior ergonomic analysis on small animal veterinarian tasks (Rogers et al., 2011), only restraint tasks were considered high risk for both types of practice. Restraint is performed frequently in both large and small animal care and task repetition is one of the main risk factors. However, in large animal work there is often equipment to aid the veterinarian in restraining the animal (e.g., harnesses, ropes, twitch, etc.); whereas, in small animal practices, the task is often performed manually. Veterinarians must lean over an animal and, therefore, the restraint involves more awkward postures. Although the overall risk score was considered high for this task in both types of practice, the differences in equipment and procedure due to patient size reveal the importance of separate ergonomic analyses.

The current research only focused on the anatomical areas of the wrist and low back in quantitative ergonomics analysis. Future studies should look into risk factors for other body locations. Previous research has identified MSD prevalence in almost every joint of the body for veterinarian tasks. The rates for the neck and shoulders are also particularly high. Methods of quantitative risk factor exposure for these body parts need to be carefully determined. This is a challenging ergonomics research problem in and of itself. More research is needed to further identify the tasks leading to WMSDs in other locations. Finally, any proposed or otherwise identified interventions should be empirically tested to ensure they mitigate the risks involved in equine veterinarian work.

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APPENDICES

Appendix A: HTAs and Location Maps

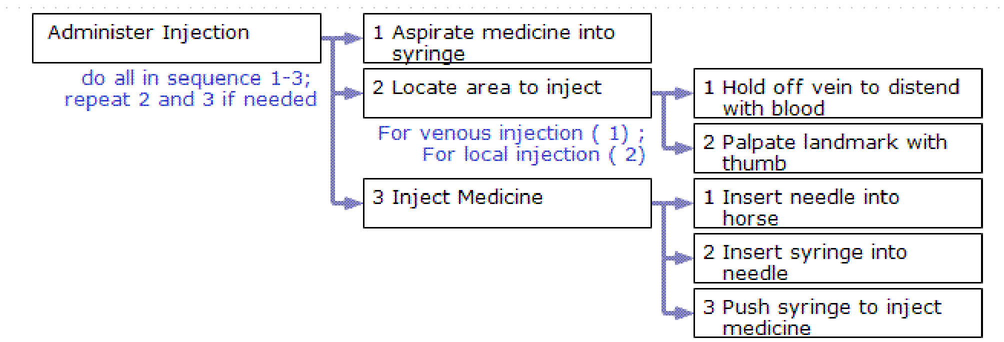


Figure A.1: Injection HTA

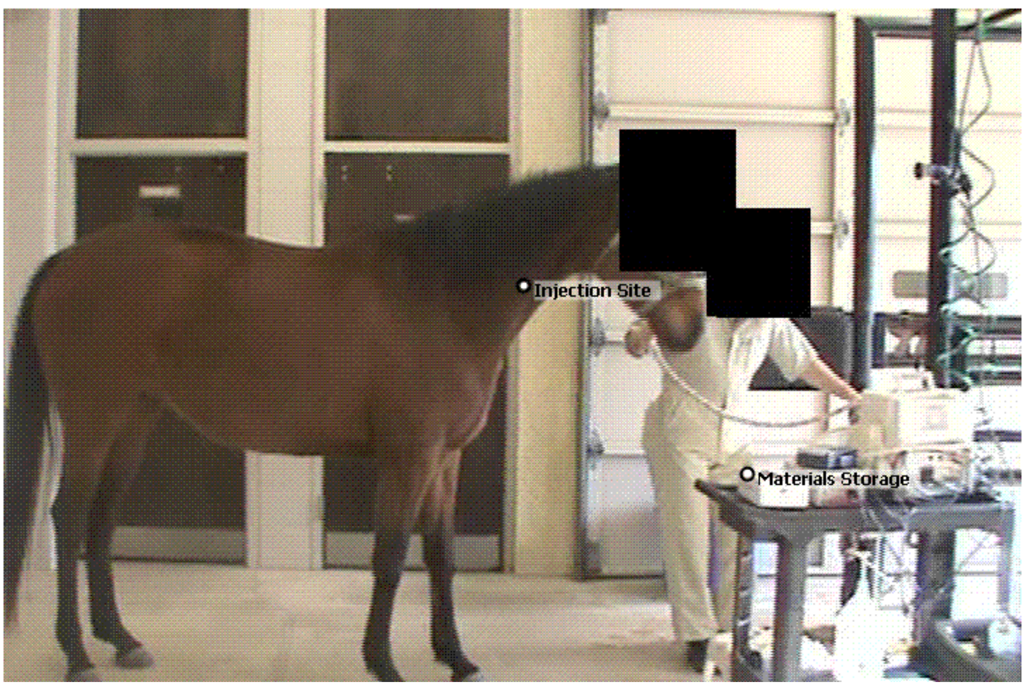


Figure A.2: Injection Location Map

Appendix A: HTAs and Location Maps

Figure A.3: Injection Counts Location Map

Figure A.4: Injection Transitions Location Map

Appendix A: HTAs and Location Maps

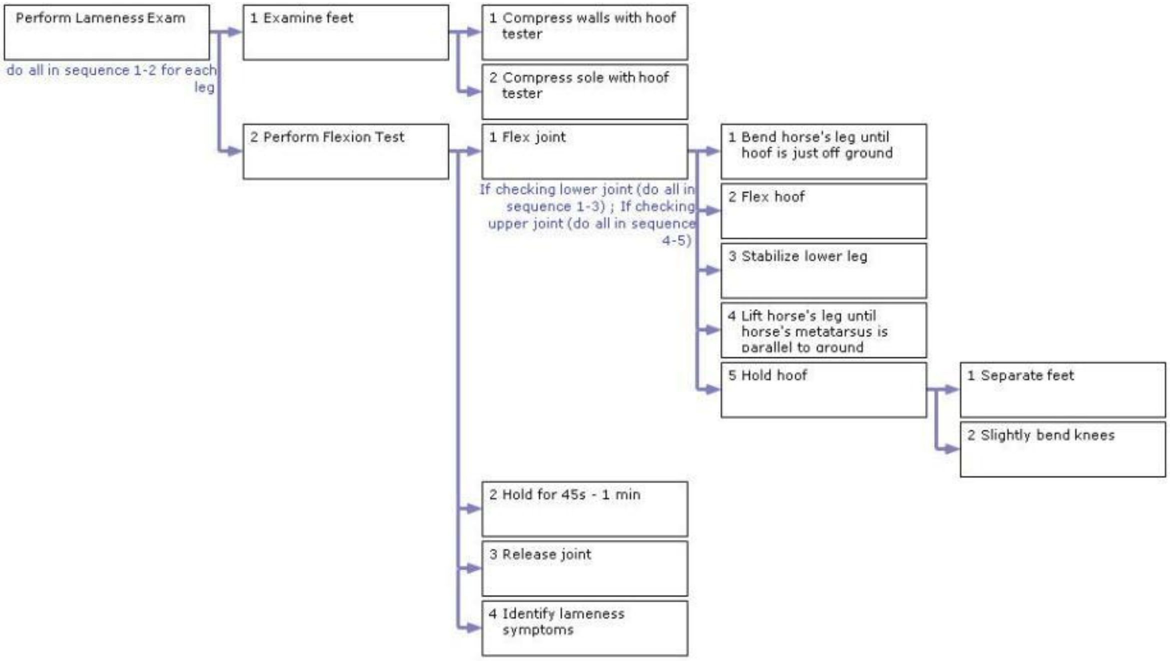


Figure A.5: Lameness Exam HTA

Figure A.6: Lameness Exam Location Map

Appendix A: HTAs and Location Maps

Figure A.7: Lameness Exam Counts Location Map

Figure A.8: Lameness Exam Transitions Location Map

Appendix A: HTAs and Location Maps

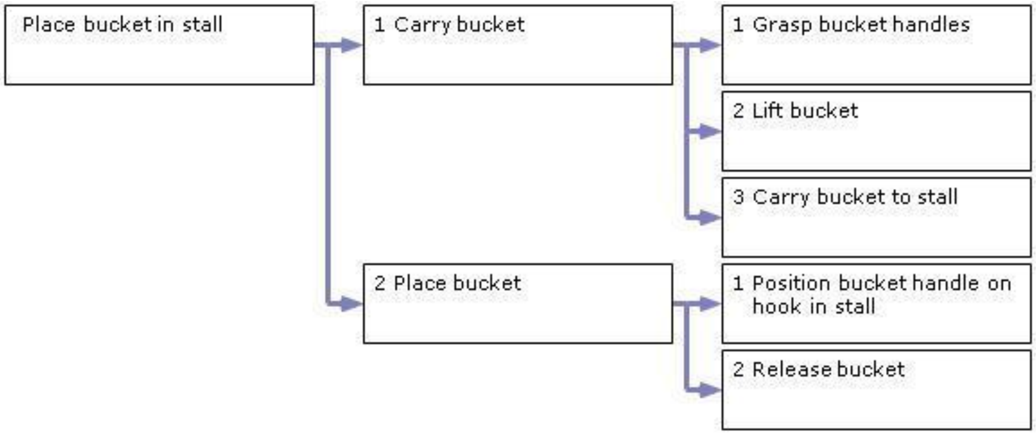


Figure A.9: Lifting Bucket HTA

Figure A.10: Lifting Bucket Location Map

Appendix A: HTAs and Location Maps

Figure A.11: Lifting Bucket Counts Location Map

Figure A.12: Lifting Bucket Transitions Location Map

Appendix A: HTAs and Location Maps

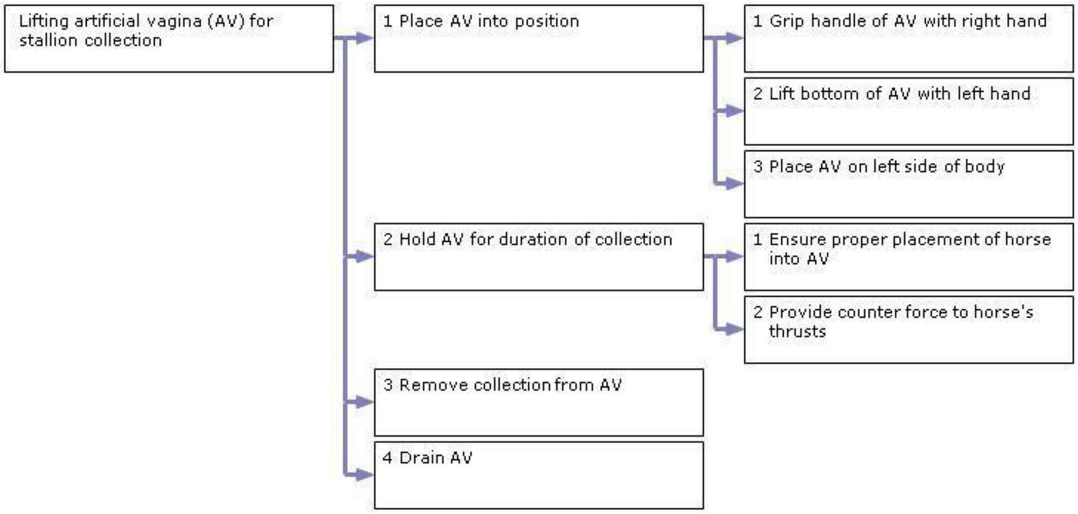


Figure A.13: Lifting AV HTA

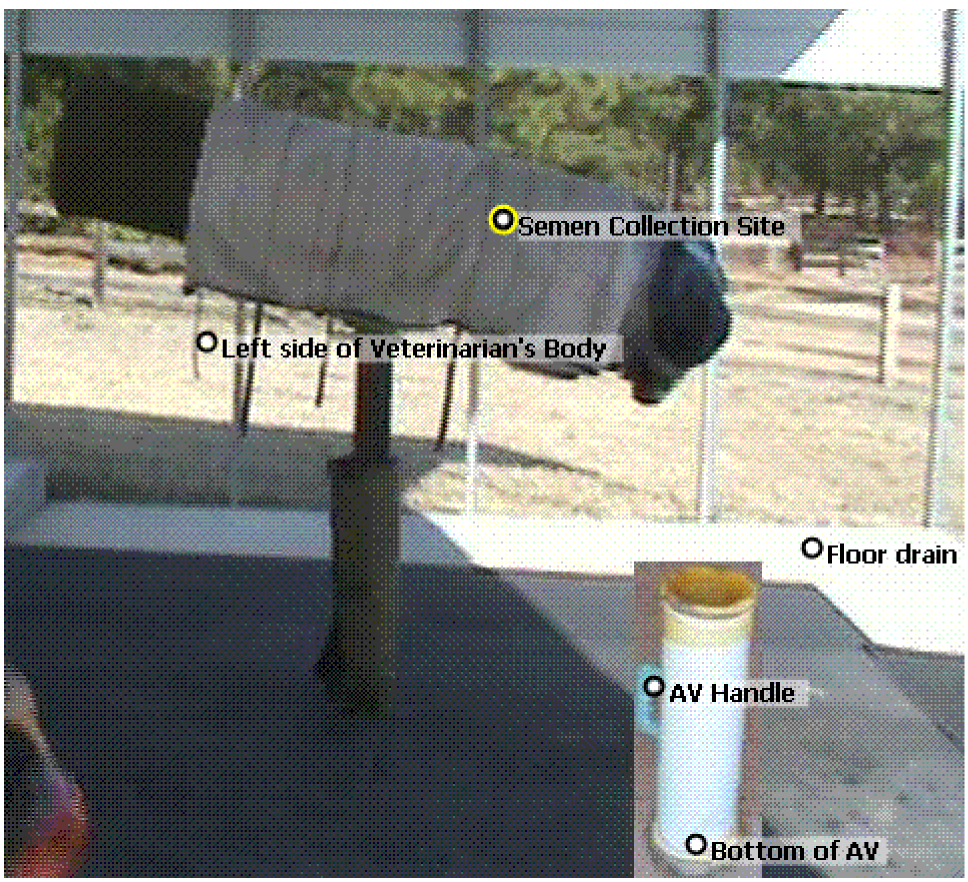


Figure A.14: Lifting AV Location Map

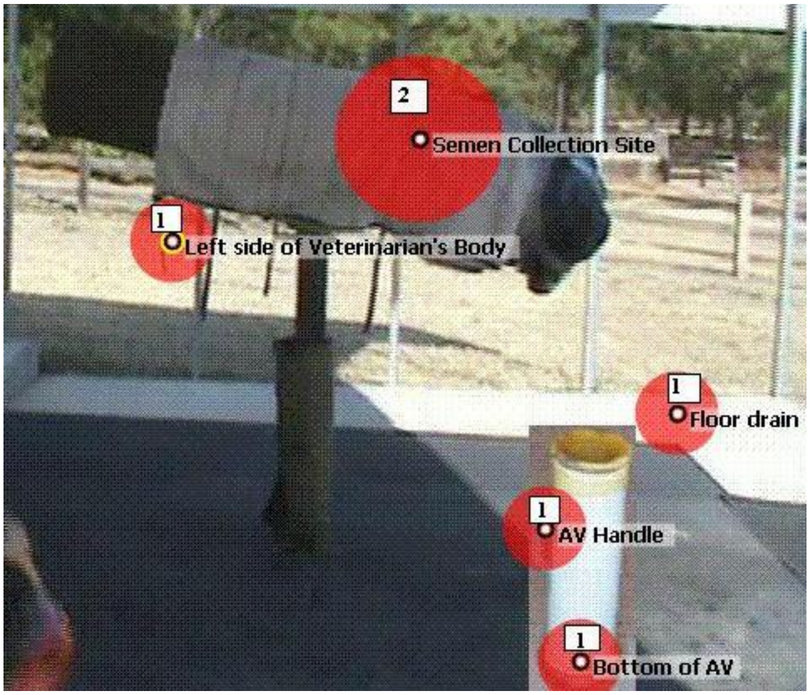


Figure A.15: Lifting AV Counts Location Map

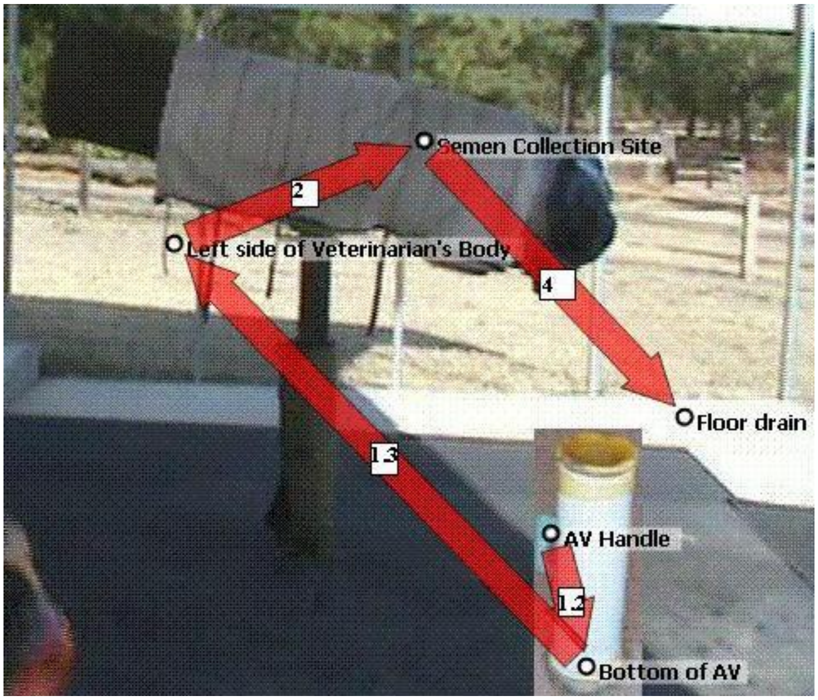


Figure A.16: Lifting AV Transitions Location Map

Appendix A: HTAs and Location Maps

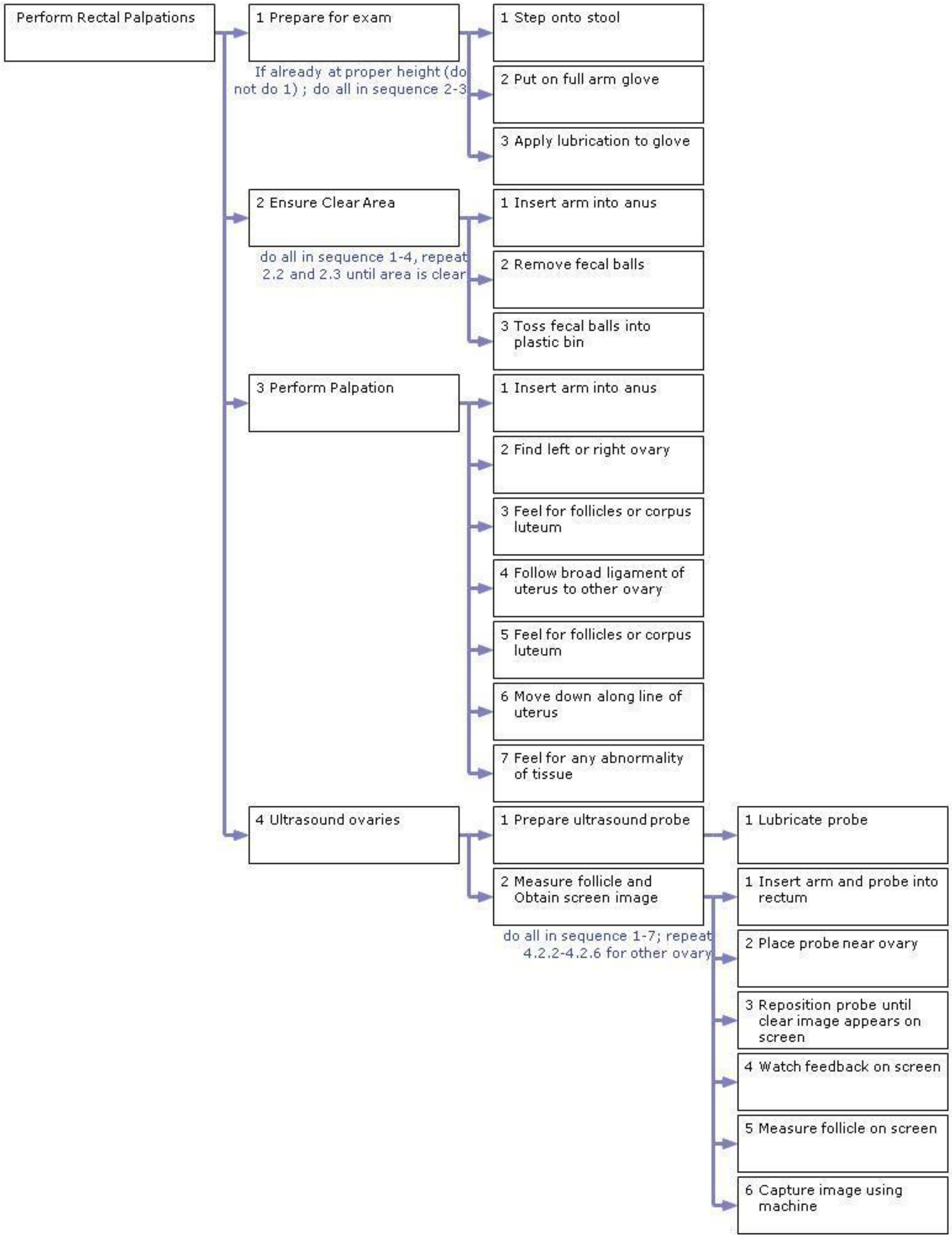


Figure A.17: Rectal Palpation HTA

Appendix A: HTAs and Location Maps

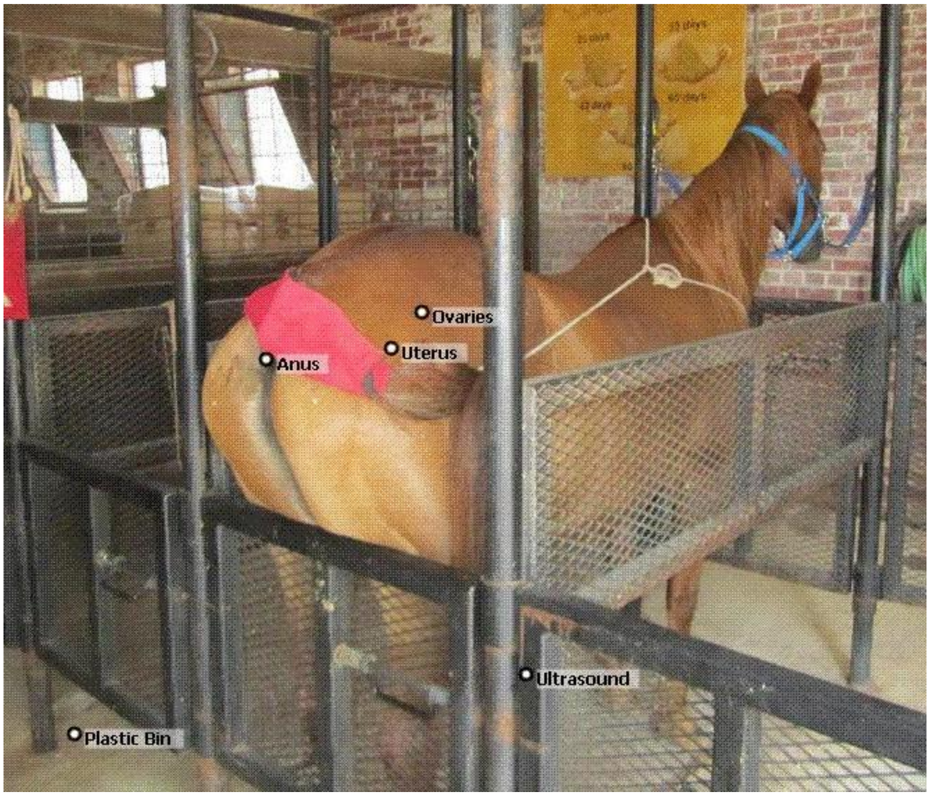


Figure A.18: Rectal Palpation Location Map

Appendix A: HTAs and Location Maps

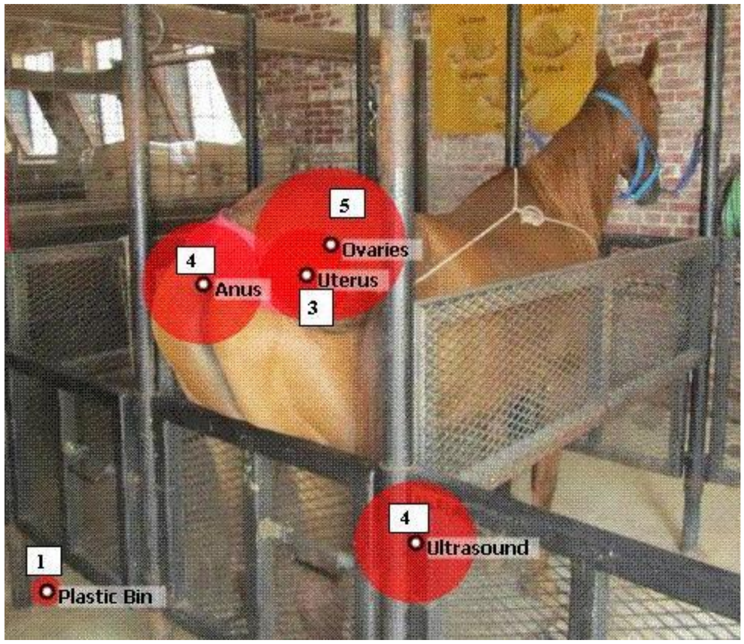


Figure A.19: Rectal Palpation Counts Location Map

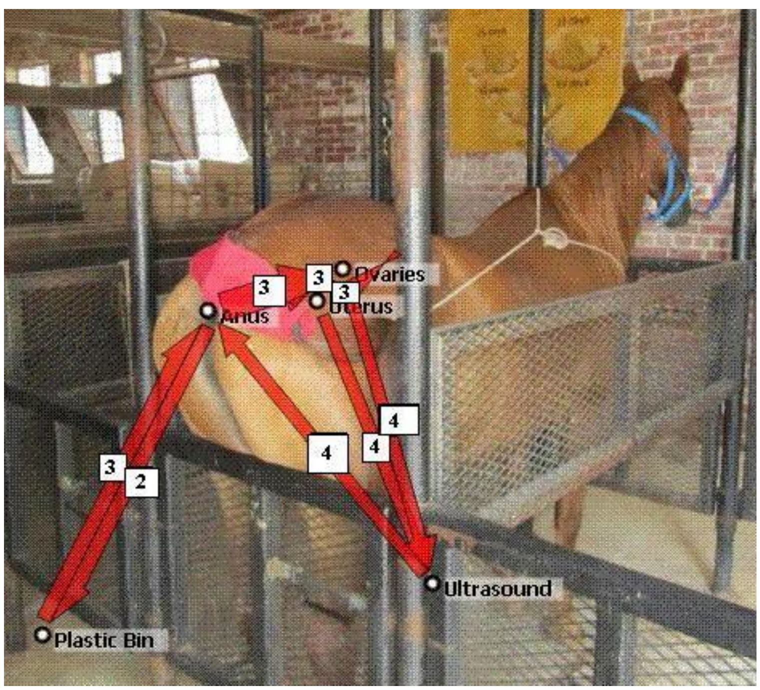


Figure A.20: Rectal Palpation Transitions Location Map

Appendix A: HTAs and Location Maps

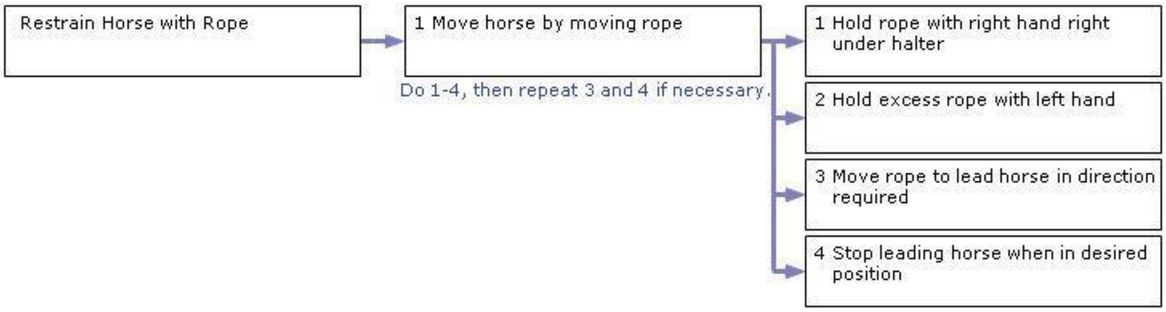


Figure A.21: Restraint with Rope HTA

Figure A.22: Restraint with Rope Location Map

Appendix A: HTAs and Location Maps

Figure A.23: Restraint with Rope Counts Location Maps

Figure A.24: Restraint with Rope Transitions Location Maps

Appendix A: HTAs and Location Maps

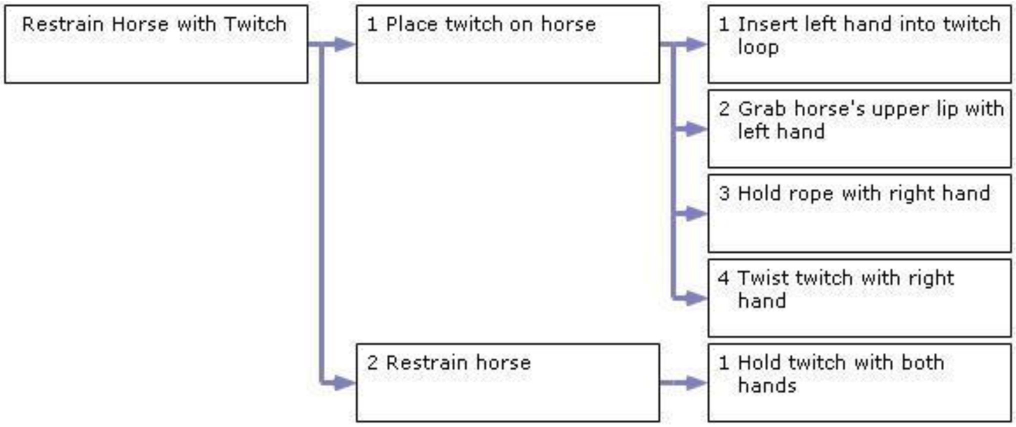


Figure A.25: Restraint with Twitch HTA

Figure A.26: Restraint with Twitch Location Map

Appendix A: HTAs and Location Maps

Figure A.27: Restraint with Twitch Counts Location Map

Figure A.28: Restraint with Twitch Transitions Location Map

Appendix A: HTAs and Location Maps

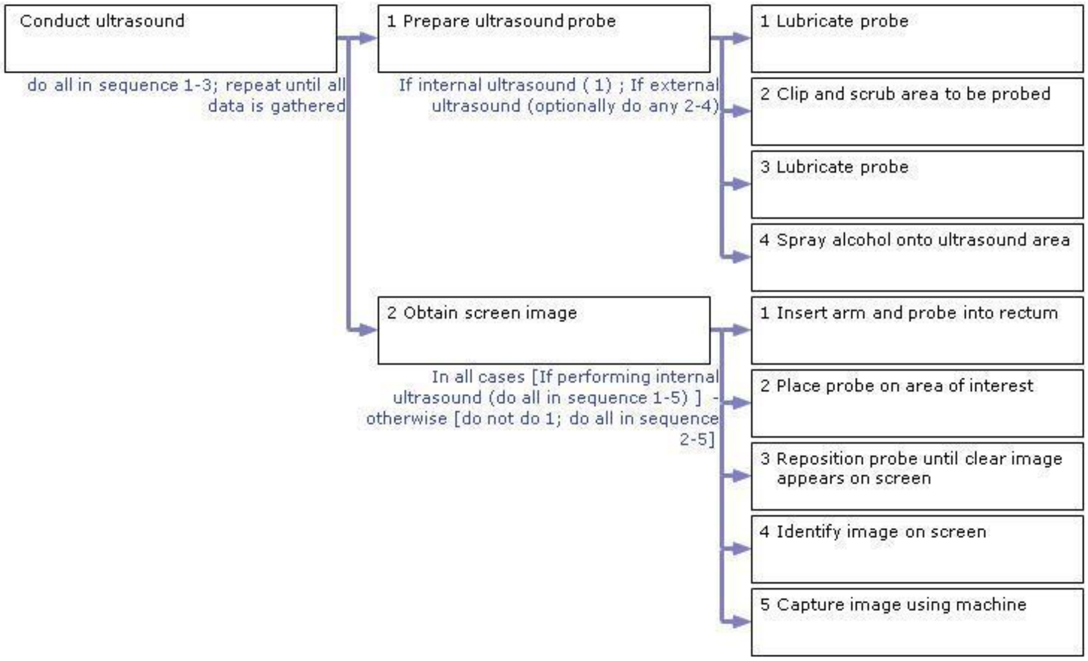


Figure A.29: Ultrasound HTA

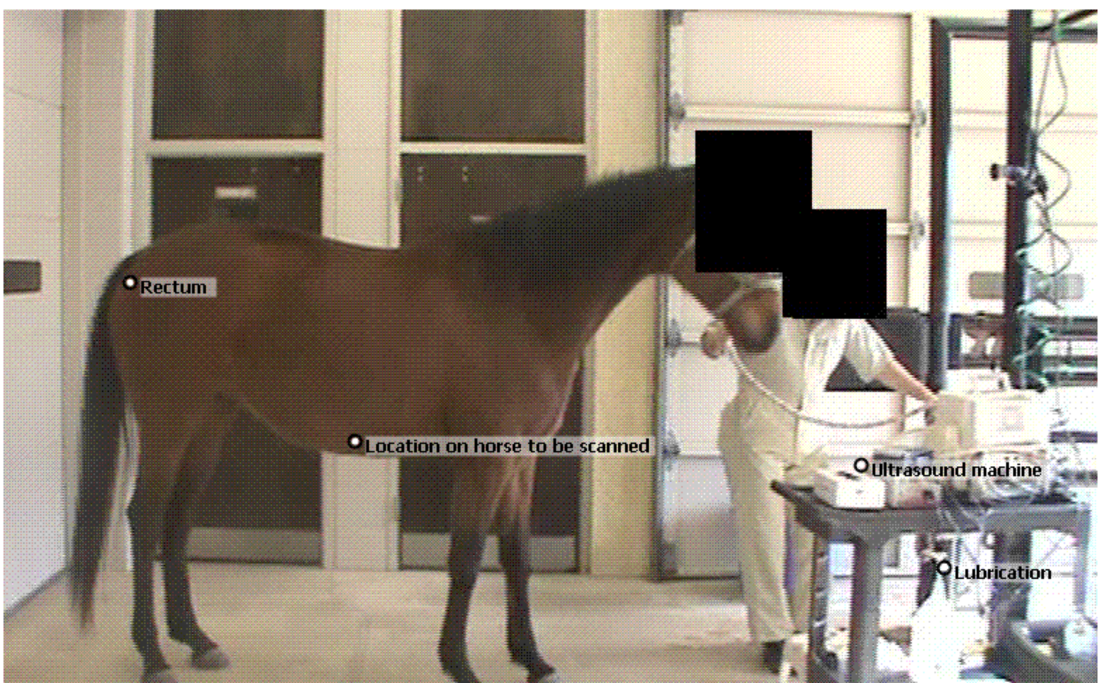


Figure A.30: Ultrasound Location Map

Appendix A: HTAs and Location Maps

Figure A.31: Ultrasound Counts Location Map

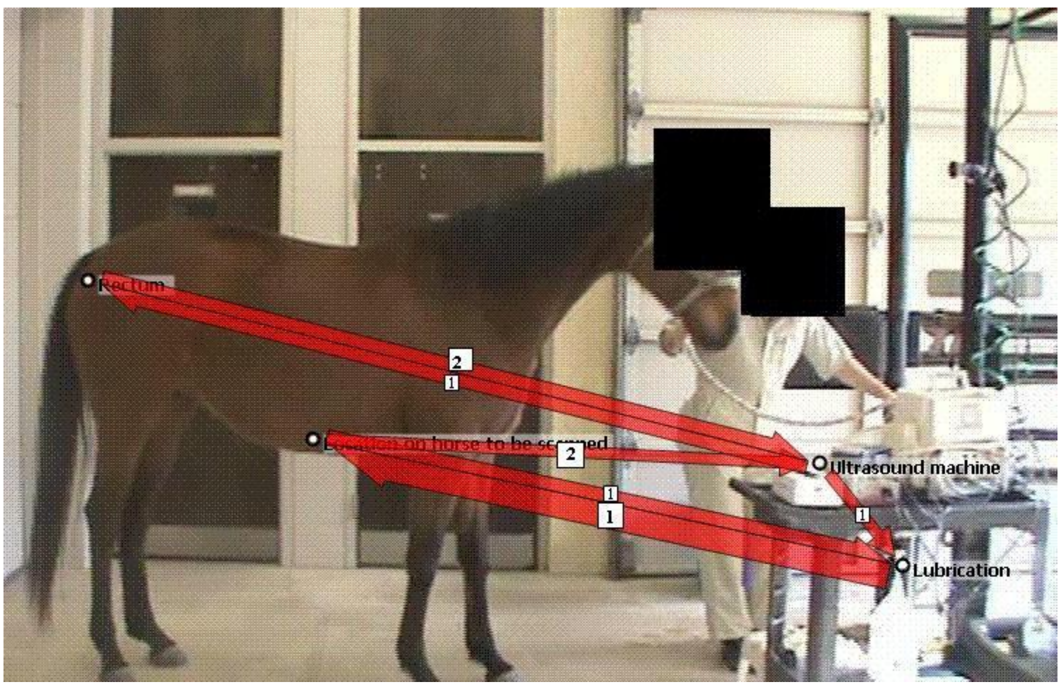


Figure A.32: Ultrasound Transitions Location Map

Appendix A: HTAs and Location Maps

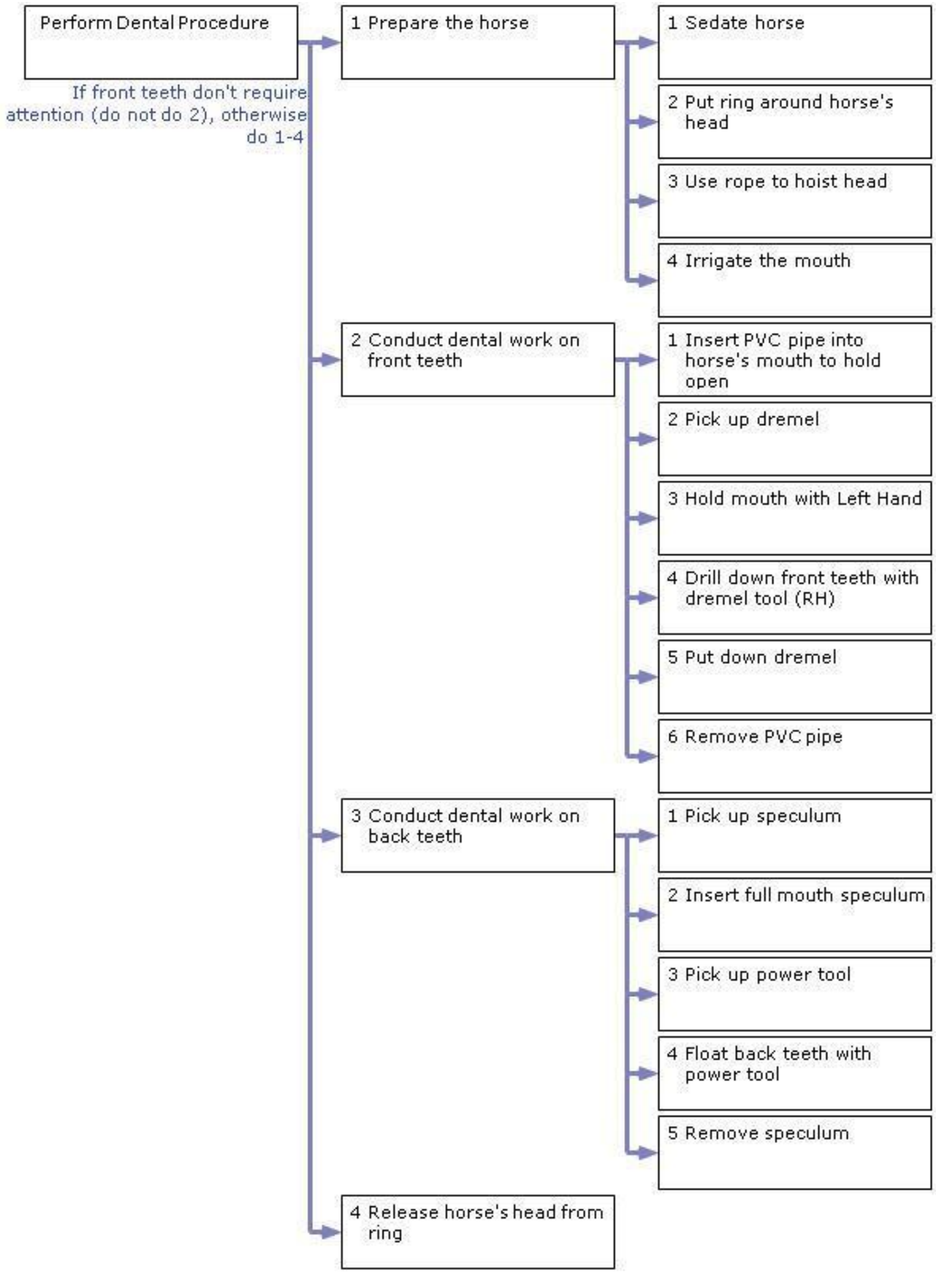


Figure A.33: Dental Work HTA

Appendix A: HTAs and Location Maps

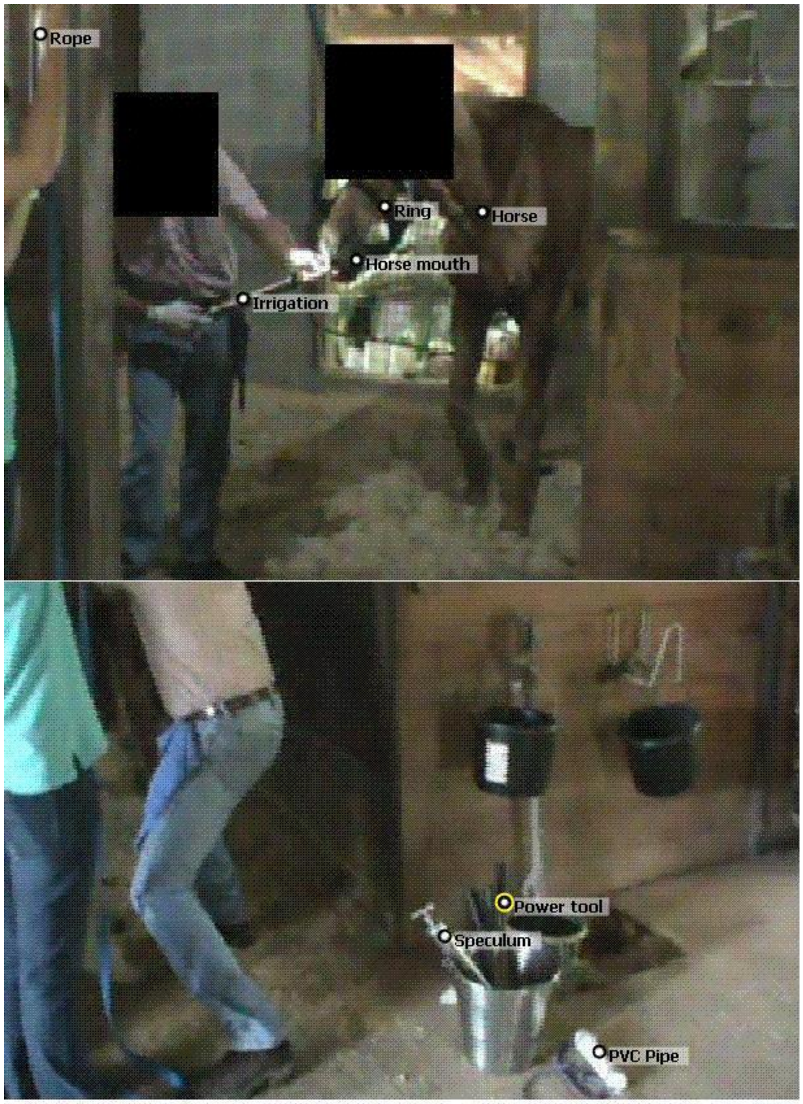


Figure A.34: Dental Work Location Map

Figure A.35: Dental Work Counts Location Map

Appendix A: HTAs and Location Maps

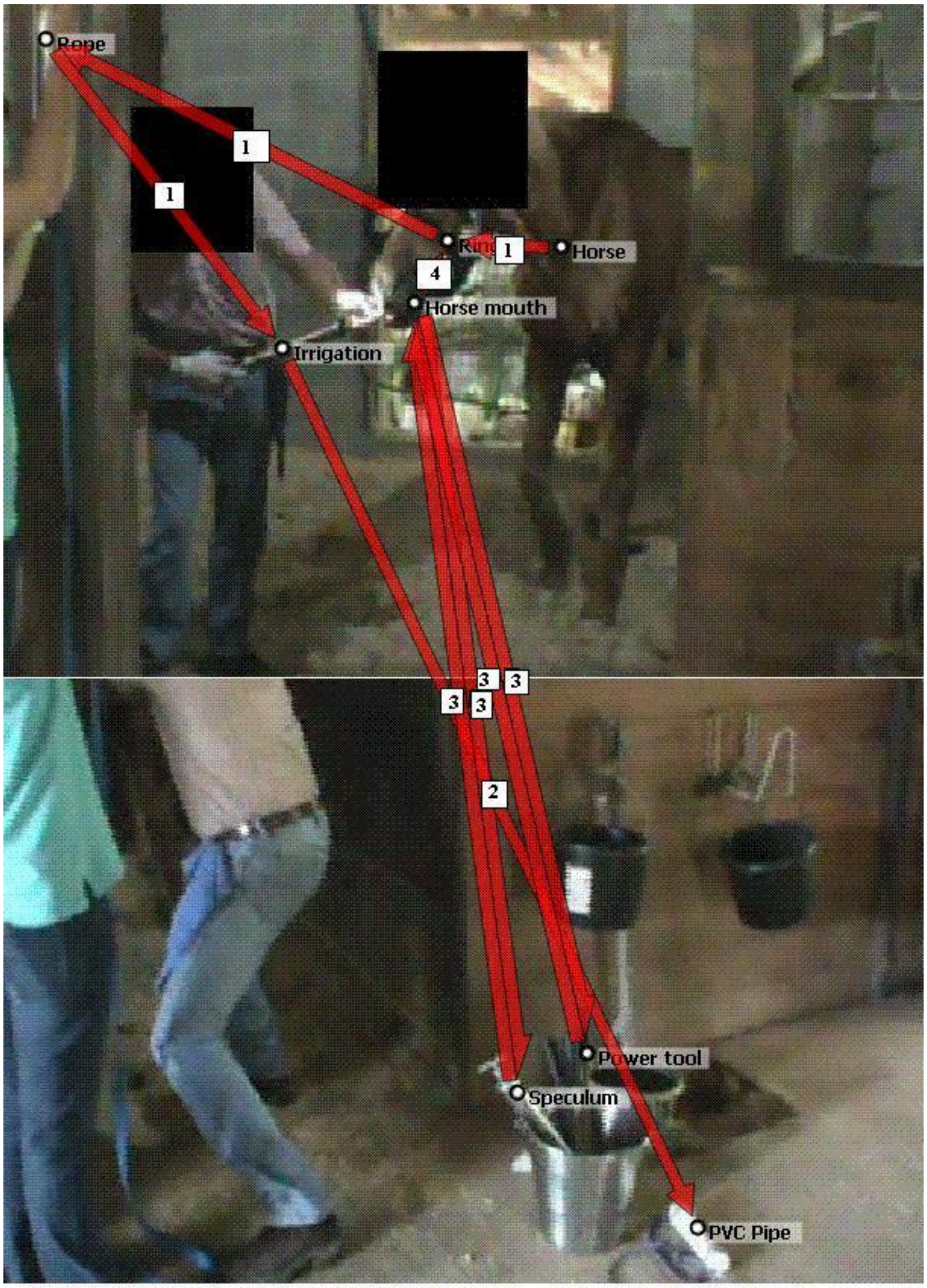


Figure A.36: Dental Work Transitions Location Map

Appendix A: HTAs and Location Maps

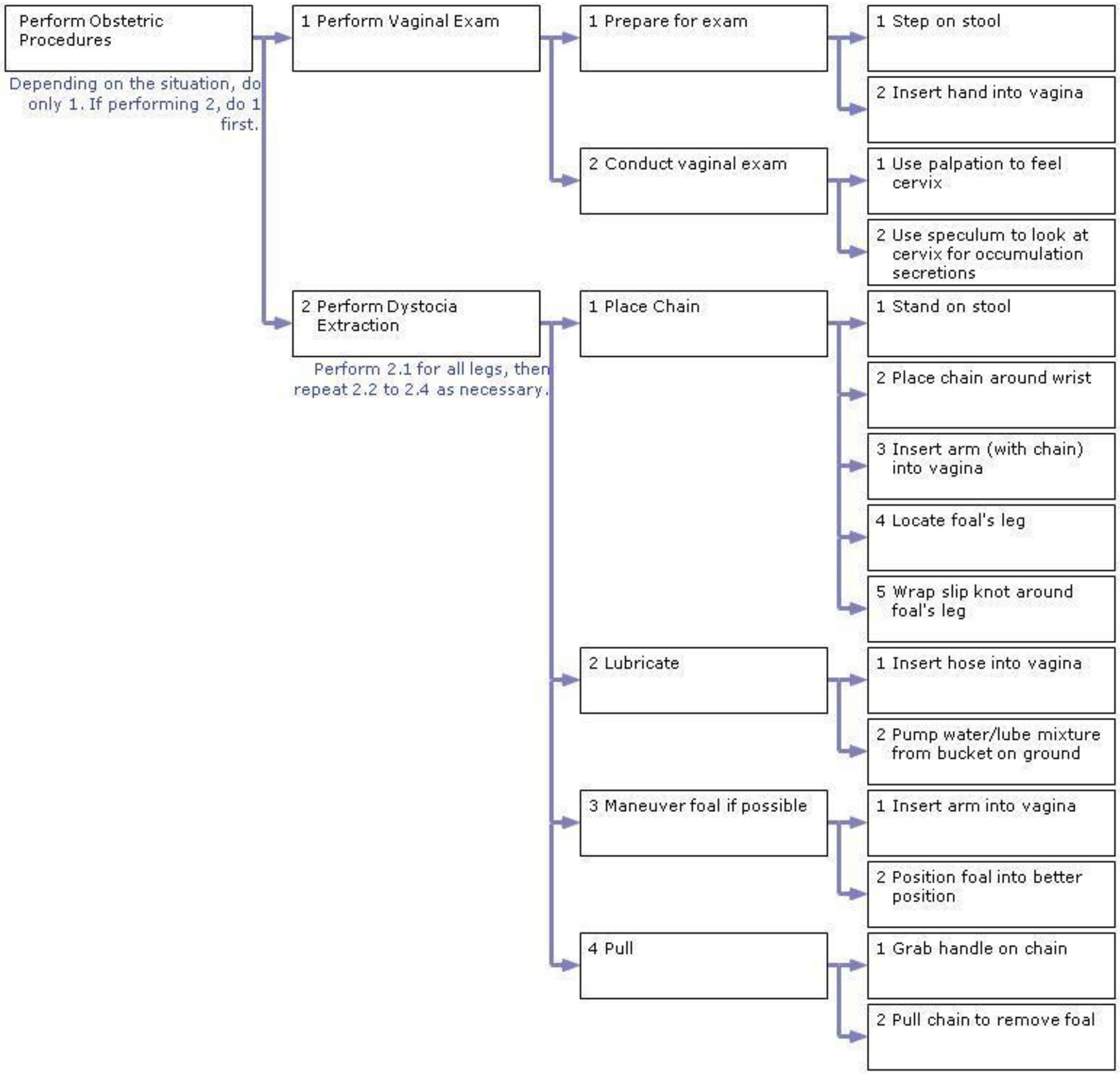


Figure A.37: Obstetric Procedures HTA

Appendix A: HTAs and Location Maps

Figure A.38: Obstetric Procedures Location Map

Note: This location map is only for step 1 from the Obstetric HTA (Figure A.3).

Appendix A: HTAs and Location Maps

Figure A.39: Obstetric Procedures Counts Map

Figure A.40: Obstetric Procedures Transitions Map

Appendix A: HTAs and Location Maps

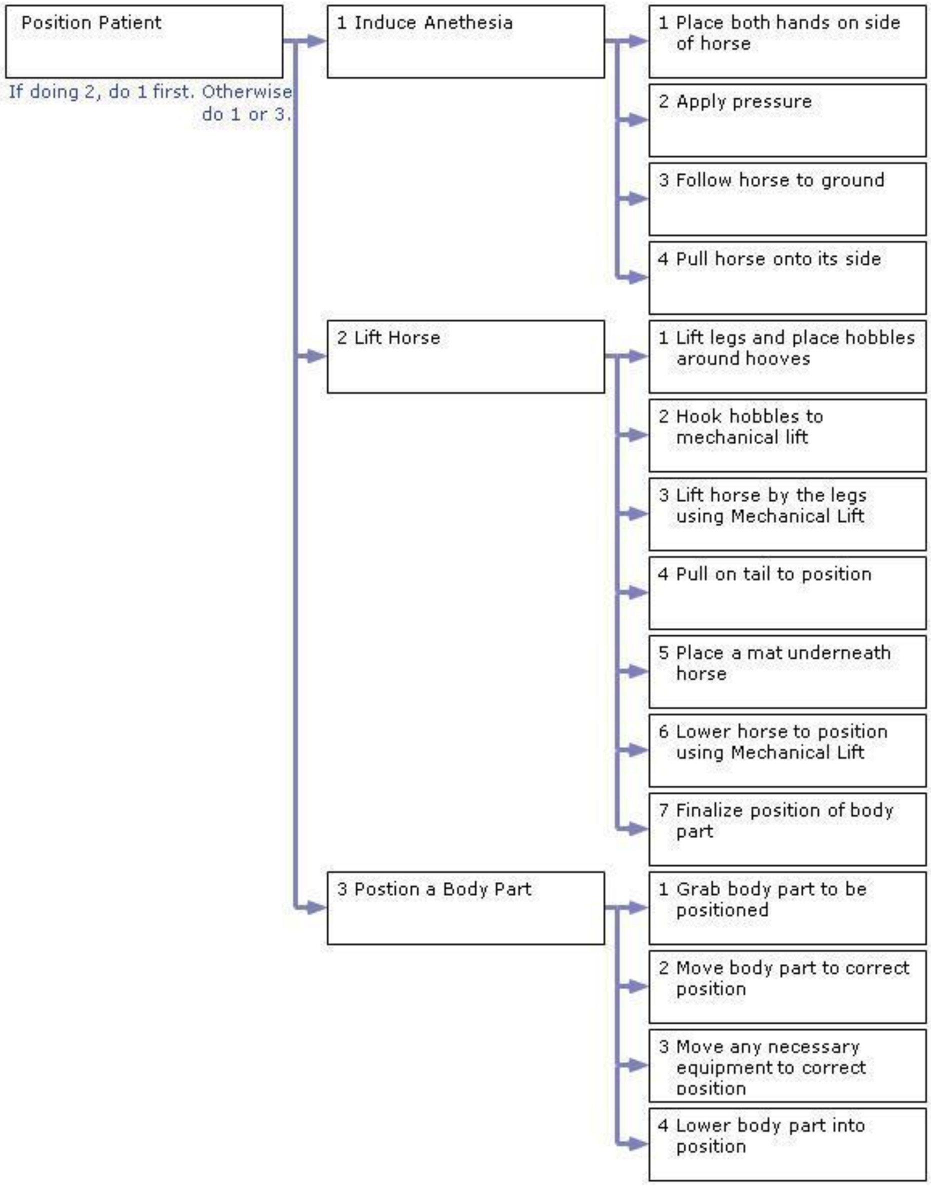


Figure A.41: Positioning HTA

Note: This is the HTA for a couple of positioning tasks. There are numerous other positioning tasks performed at the CVM as well.

Appendix A: HTAs and Location Maps

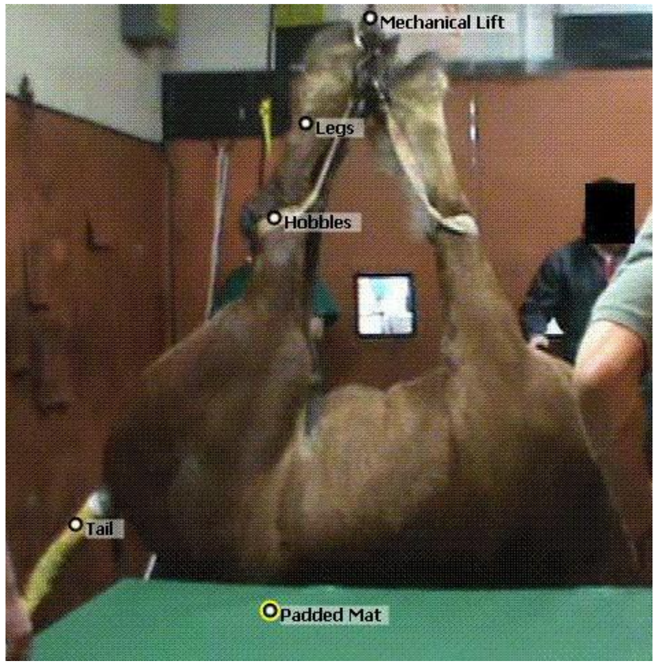


Figure A.42: Positioning Location Map

Note: This location map is only for step 2 from the Positioning HTA (Figure A.).

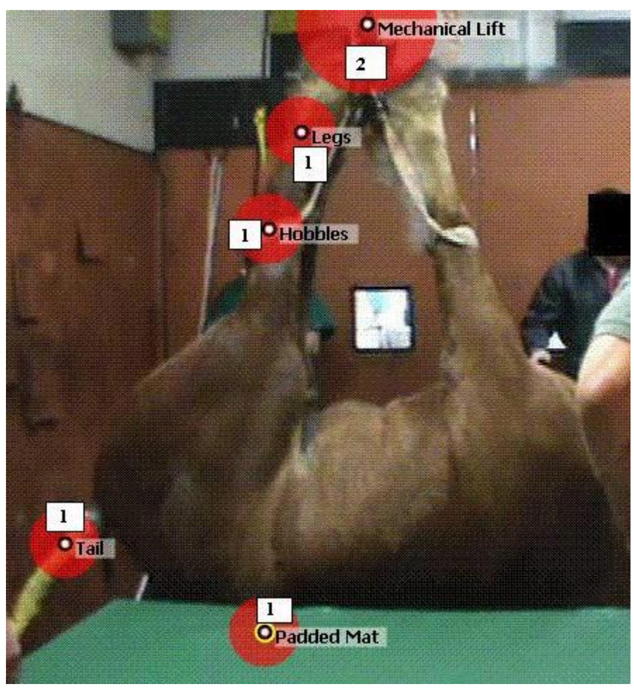


Figure A.43: Positioning Counts Location Map

Appendix A: HTAs and Location Maps

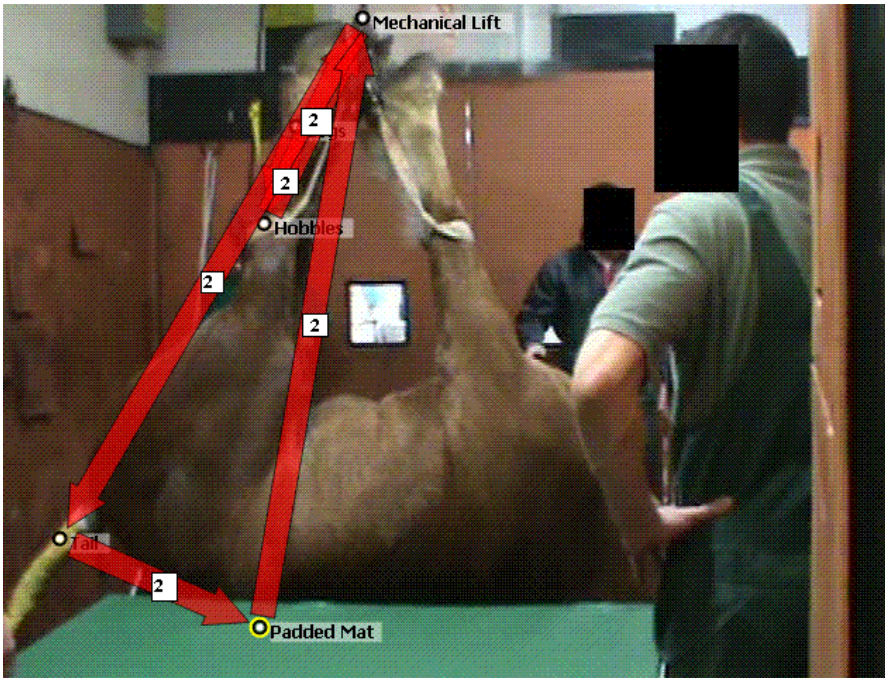


Figure A.44: Positioning Transitions Location Map

Appendix A: HTAs and Location Maps

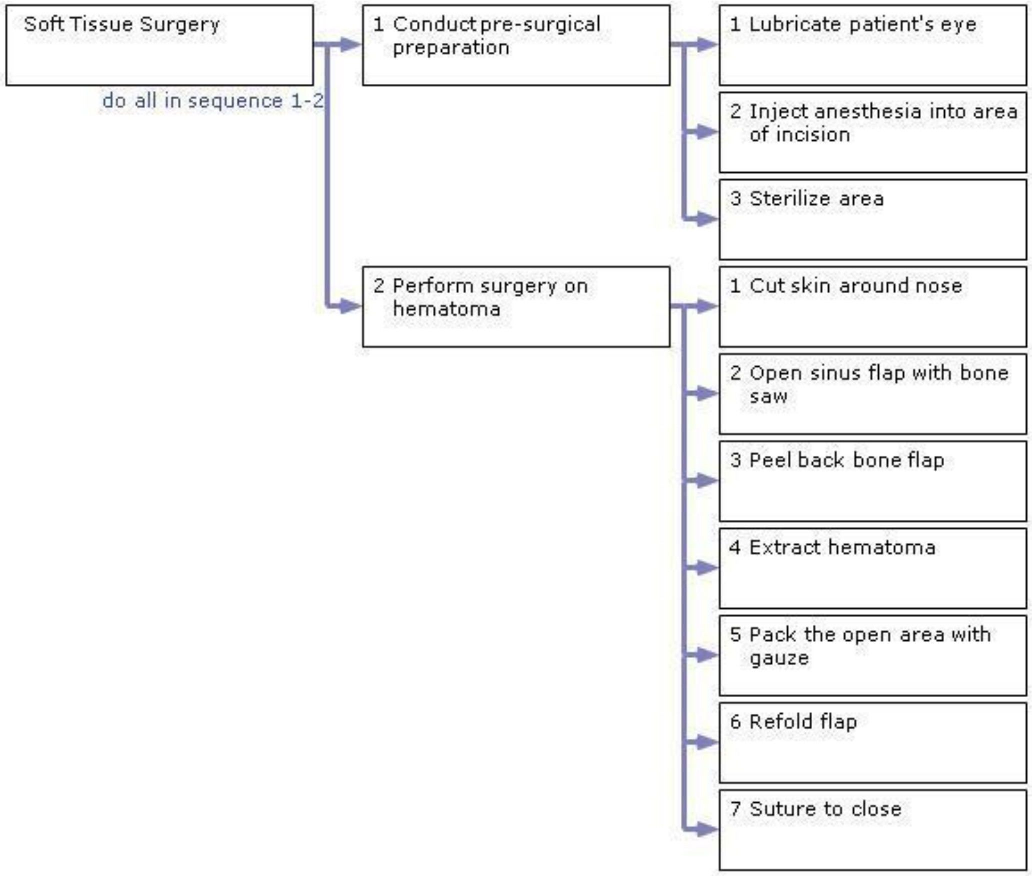


Figure A.45: Surgery HTA

Note: This is the HTA for one type of soft tissue surgery. There are numerous other surgical tasks performed at the CVM as well. Some tasks may be similar across different surgeries while others may be different.

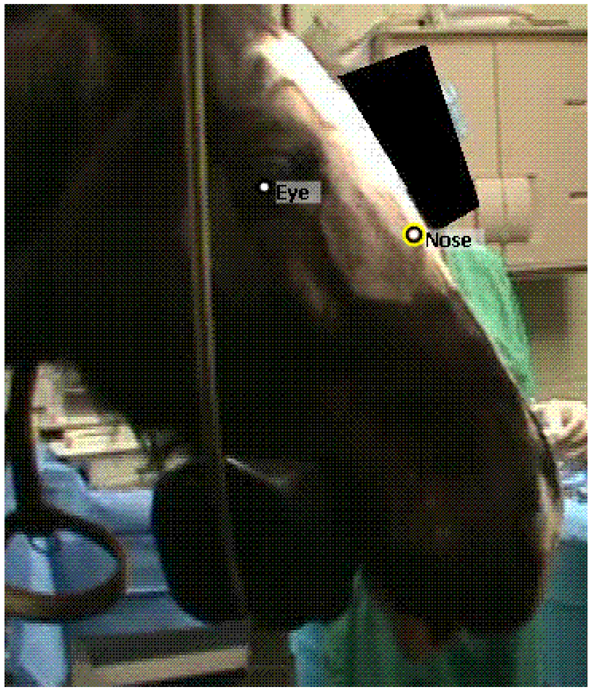


Figure A.46: Surgery Location Map

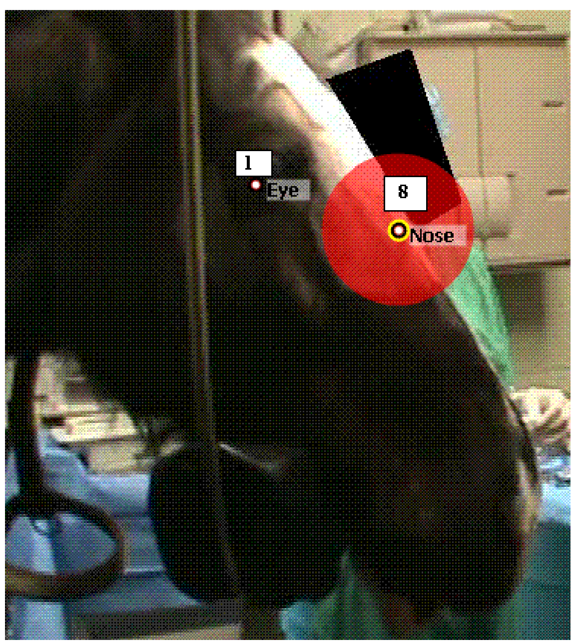


Figure A.47: Surgery Counts Location Map

Appendix A: HTAs and Location Maps

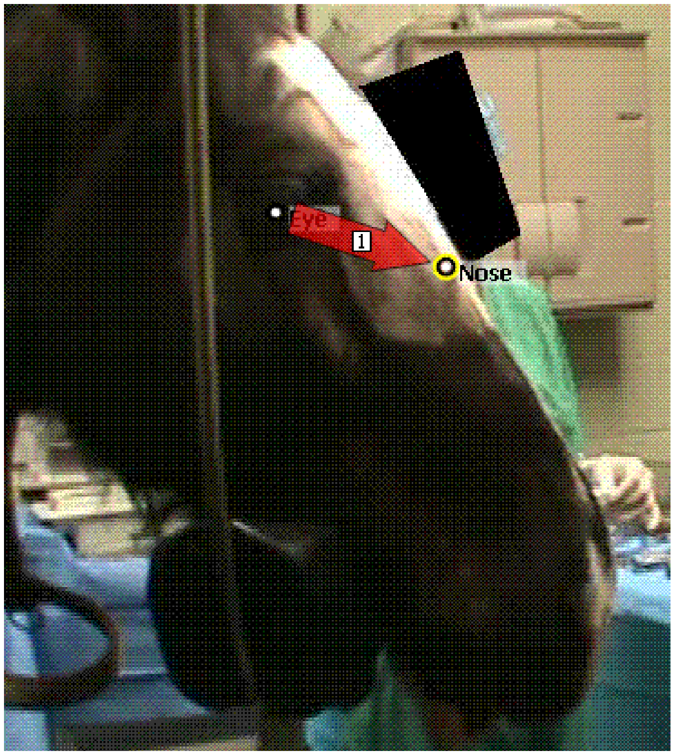


Figure A.48: Surgery Transitions Location Map

Appendix B: Discomfort and Task Frequency Survey

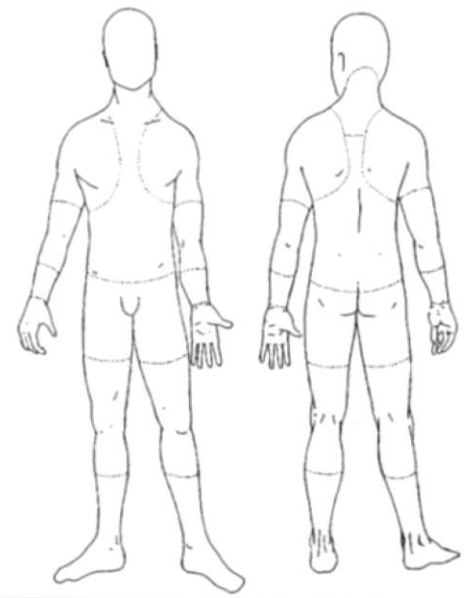
Name (optional): ______________________ Age: ______

Sex: ❑ Male ❑ Female

Work Location: ______________________

Job: ______________________ Shift: ______________

Supervisor: ______________________



Front | Back

- Time on **THIS** Job:
  - ❑ Less than 3 months
  - ❑ 3 mo. to 1 year
  - ❑ Greater than 1 year to 5 years
  - ❑ Greater than 5 years to 10 years
  - ❑ Greater than 10 years
- How often are you <u>mentally</u> exhausted after work?
  - ❑ Never ❑ Seldom
  - ❑ Often ❑ Always
- How often are you <u>physically</u> exhausted after work?
  - ❑ Never ❑ Seldom
  - ❑ Often ❑ Always
- Have you had any pain or discomfort during the last year that you believe to be related to your work?
  - ❑ No **(If NO, stop here)**
  - ❑ Yes

If **YES**, carefully shade in the areas of the drawings (above right), there may be more than one, which bother you the **MOST**. For each area that you shade in, label what kind of discomfort you experience there as follows:

P → Pain
NT → Numbness /Tingling
PNT → Pain/Numbness /Tingling
A → Ache
B → Burning
SW → Swell
ST → Stiffness
O → Other
Describe (______________)

Appendix B: Discomfort and Task Frequency Survey

Please complete the column for each body part that bothers you   Name *(optional)*__________________ ID #__________

	Neck	Shoulder	Elbow/forearm	Hand/wrist	Fingers
• 1 *Which side bothers you?*	☐ Left ☐ Right ☐ Both	☐ Left ☐ Right ☐ Both	☐ Left ☐ Right ☐ Both	☐ Left ☐ Right ☐ Both	☐ Left ☐ Right ☐ Both
• 2 *What year did you first notice the problem?*	________	________	________	________	________
• 3 *How long does the problem usually last?*	☐ A Less than 1 hour ☐ B 1 hr - 24 hrs ☐ C > 24 hrs - 1 week ☐ D > 1 week - 1 month ☐ E > 1 month - 6 months ☐ F More than 6 months	☐ A ☐ B ☐ C ☐ D ☐ E ☐ F	☐ A ☐ B ☐ C ☐ D ☐ E ☐ F	☐ A ☐ B ☐ C ☐ D ☐ E ☐ F	☐ A ☐ B ☐ C ☐ D ☐ E ☐ F
• 4 *How many separate times have you had the problem?*	☐ A Constant ☐ B Daily ☐ C Once a week ☐ D Once a month ☐ E Every 2-3 months ☐ F More than 6 months	☐ A ☐ B ☐ C ☐ D ☐ E ☐ F	☐ A ☐ B ☐ C ☐ D ☐ E ☐ F	☐ A ☐ B ☐ C ☐ D ☐ E ☐ F	☐ A ☐ B ☐ C ☐ D ☐ E ☐ F
• 5 *What do you think caused the problem?*	________ ________	________ ________	________ ________	________ ________	________ ________
• 6 *Problem in the last 7 days?*	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
• 7 *According to the scale of 0–5 shown, how would you rate this problem right now?*	0 = no discomfort 5 = unbearable discomfort Rating = ☐	0 = no discomfort 5 = unbearable discomfort Rating = ☐	0 = no discomfort 5 = unbearable discomfort Rating = ☐	0 = no discomfort 5 = unbearable discomfort Rating = ☐	0 = no discomfort 5 = unbearable discomfort Rating = ☐
• 8 *Have you had medical treatment for this problem?*	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
• 9 *Days of work lost in the last year due to this problem*	________ days	________ days	________ days	________ days	________ days
• 10 *Days of light or restricted duty in the last year due to this problem*	________ days	________ days	________ days	________ days	________ days
• 11 *Have you changed jobs because of this problem?*	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
• 12 *Please comment on what you think would improve your symptoms*					

Appendix B: Discomfort and Task Frequency Survey

Please complete the column for each body part that bothers you Name (optional)__________ ID #__________

	Upper back	Low back	Thigh/knee	Low leg	Ankle/foot
• 1 *Which side bothers you?*	☐ Left ☐ Right ☐ Both	☐ Left ☐ Right ☐ Both	☐ Left ☐ Right ☐ Both	☐ Left ☐ Right ☐ Both	☐ Left ☐ Right ☐ Both
• 2 *What year did you first notice the problem?*	______	______	______	______	______
• 3 *How long does the problem usually last?*	☐ A Less than 1 hour ☐ B 1 hr - 24 hrs ☐ C > 24 hrs - 1 week ☐ D > 1 week - 1 month ☐ E > 1 month - 6 months ☐ F More than 6 months	☐ A ☐ B ☐ C ☐ D ☐ E ☐ F	☐ A ☐ B ☐ C ☐ D ☐ E ☐ F	☐ A ☐ B ☐ C ☐ D ☐ E ☐ F	☐ A ☐ B ☐ C ☐ D ☐ E ☐ F
• 4 *How many separate times have you had the problem?*	☐ A Constant ☐ B Daily ☐ C Once a week ☐ D Once a month ☐ E Every 2-3 months ☐ F More than 6 months	☐ A ☐ B ☐ C ☐ D ☐ E ☐ F	☐ A ☐ B ☐ C ☐ D ☐ E ☐ F	☐ A ☐ B ☐ C ☐ D ☐ E ☐ F	☐ A ☐ B ☐ C ☐ D ☐ E ☐ F
• 5 *What do you think caused the problem?*	______ ______	______ ______	______ ______	______ ______	______ ______
• 6 *Problem in the last 7 days?*	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
• 7 *According to the scale of 0-5 shown, how would you rate this problem right now?*	0 = no discomfort 5 = unbearable discomfort Rating = ☐	0 = no discomfort 5 = unbearable discomfort Rating = ☐	0 = no discomfort 5 = unbearable discomfort Rating = ☐	0 = no discomfort 5 = unbearable discomfort Rating = ☐	0 = no discomfort 5 = unbearable discomfort Rating = ☐
• 8 *Have you had medical treatment for this problem?*	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
• 9 *Days of work lost in the last year due to this problem*	______ days	______ days	______ days	______ days	______ days
• 10 *Days of light or restricted duty in the last year due to this problem*	______ days	______ days	______ days	______ days	______ days
• 11 *Have you changed jobs because of this problem?*	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
• 12 *Please comment on what you think would improve your symptoms*					

Appendix B: Discomfort and Task Frequency Survey

Description of Musculoskeletal Disorder	Symptoms	Please check if you feel you may suffer or have suffered from this disorder	If you suffer from this disorder, please indicate which work task you believe led to these symptoms	Disorder Names	Have you been diagnosed with this disorder by a medical professional?
Inflammation of the tendon	Localized pain and discomfort			Tendonitis	
Tendon sheath (covering) inflammation caused by excessive secretion of synovial fluid (tendon lubricant)	Localized pain and discomfort, motion-induced pain			Tenosynovitis	
Persistent pressing of inflamed sheath on the tendon	Localized pain and discomfort, motion-induced pain			Stenosing tenosynovitis	
Stenosing tenosynovtis affecting tendons of the thumb on the back side of the wrist	Localized pain and discomfort, motion-induced pain in thumb or wrist			De Quervain's Disease	
A cyst created by the excessive secretion of synovial fluid	Localized pain and discomfort, motion-induced pain usually around hand or foot.			Ganglion cyst	
Irritation of tendons of the finger extensor muscles which attach on the outside of the elbow	Localized pain and discomfort over the outside of the elbow			Lateral epicondylitis (tennis elbow)	
Irritation of tendons of the finger flexor muscles which attach on the inside of the elbow	Localized pain and discomfort over the inside of the elbow			Medial epicondylitis (golfer's elbow)	
Thickening of shoulder tendons	Localized shoulder pain and discomfort, motion-induced pain, functional impairment			Rotator cuff tendonitis	
Entrapment/pinching of the median nerve	Pain, numbness, and tingling of areas of the hand supplied by the median nerve			Carpal tunnel syndrome	
Entrapment/pinching of the ulnar nerve	Pain, numbness, and tingling of areas of the hand supplied by the ulnar nerve			Guyon tunnel syndrome	
Compression of neurovascular bundle as it passes between the neck and shoulder	Pain, numbness, and tingling in the fingers of the hand; arm numbness; weakened wrist pulse			Thoracic outlet syndrome	

Appendix B: Discomfort and Task Frequency Survey

Description of Musculoskeletal Disorder	**Symptoms**	**Please check if you feel you may suffer or have suffered from this disorder**	**If you suffer from this disorder, please indicate which work task you believe led to these symptoms**	**Disorder Names**	**Have you been diagnosed with this disorder by a medical professional?**
Vasospasm due to cold and/or vibration	Finger blanching, pain and numbness, and eventual loss of sensation and the control of the hand			Vibration syndrome (Raynaud's phenomenon, vibration white finger)	
Inflammation of the subacromial or subdeltoid bursa, located between the rotator cuff and the coracoarcromial ligament in the shoulder. It hinders the free movement of tendons and limits the joint mobility in the shoulder	Pain, swelling, tenderness, and limitation of motion of the shoulder			Subacromial bursitis	
Inflammation of the olecranon bursa, that lies over the point of the elbow	Pain, swelling, tenderness, and limitation of motion of the elbow			Olecranon bursitis	
Inflammation of the bursa that lies over the patella at the knee	Pain, swelling, tenderness, and limitation of motion of the knee			Prepatellar bursitis	
Spinal awareness/sensitivity	Pain, numbness, tingling in lower back			Low Back Pain	

Appendix B: Discomfort and Task Frequency Survey

Time Spent on Specific Tasks

Please indicate how many procedures you perform for each of the listed categories.

We understand that the kinds of procedures you perform can depend on the time of year and the service you are under. Therefore, please identify how many procedures you do according to the most appropriate time frame. Please try to quantify your workload down to the lowest appropriate category possible. I.e., if you do 5 palpations everyday please indicate that under the "Per Day" category. However, if you only do this procedure a few times a year, please indicate that number under the "Per Year" category. If you feel like you need to further quantify the number of tasks performed, please indicate in the "Comments" section below.

	Estimated Frequency			
	Indicate estimate in one column only for each procedure			
Procedure	**Per Day**	**Per Week**	**Per Month**	**Per Year**
Palpations				
Scanning/Ultrasound				
Obstetric				
Lameness Exams/Foot Work				
Administration of Injections/Venipuncture				
Restraint/Animal Handling				
Positioning				
Lifting (Patient/Carrying Equipment, etc)				
Surgery				
Dental Work/Dentistry				
Other				

If you marked "Other," please identify to which tasks you are referring:

Appendix B: Discomfort and Task Frequency Survey

Portion of Day Spent Performing Tasks

Assuming an 8-hour day, how much time per day do you spend performing these tasks?

	Estimated Time per Day				
Procedure	**0-1 hr**	**1-2 hrs**	**2-4 hrs**	**4-6 hrs**	**6-8 hrs**
Palpations					
Scanning/Ultrasound					
Obstetric					
Lameness Exams/Foot Work					
Administration of Injections/Venipuncture					
Restraint/Animal Handling					
Positioning					
Lifting (Patient/Carrying Equipment, etc)					
Surgery					
Dental Work/Dentistry					
Other					

Comments:

Appendix C: Borg Scale Questionnaire

Borg Scale of Perceived Exertion

We want you to rate your perceived (P) exertion, that is, how heavy and strenuous the exercise feels to you. This depends mainly on the strain and fatigue in our muscles and on your feeling of breathlessness or aches in the chest. But you must only attend to your subjective feelings and not to the physiological cues or what the actual physical load is.

1 is "very light" like walking slowly at your own pace for several minutes
3 is not especially hard it feels fine, and it is no problem to continue.
5 you are tired, but you don't have any great difficulties
7 you can still go on but have to push yourself very much. You are very tired.
10 This is as hard as most people have ever experienced before in their lives.
• This is "Absolute maximum," for example, 11 or 12 or higher

Restraint

0	Nothing at all	"No P"
0.3		
0.5	Extremely Weak	Just noticeable
1	Very Weak	
1.5		
2	Weak	Light
2.5		
3	Moderate	
4		
5	Strong	
6		
7	Very Strong	
8		
9		
10	Extremely strong "Max P"	
•	Absolute maximum	Highest Possible

Appendix C: Borg Scale Questionnaire

Administering injections

0	Nothing at all	"No P"
0.3		
0.5	Extremely Weak	Just noticeable
1	Very Weak	
1.5		
2	Weak	Light
2.5		
3	Moderate	
4		
5	Strong	
6		
7	Very Strong	
8		
9		
10	Extremely strong "Max P"	
•	Absolute maximum	Highest Possible

Rectal palpations

0	Nothing at all	"No P"
0.3		
0.5	Extremely Weak	Just noticeable
1	Very Weak	
1.5		
2	Weak	Light
2.5		
3	Moderate	
4		
5	Strong	
6		
7	Very Strong	
8		
9		
10	Extremely strong "Max P"	
•	Absolute maximum	Highest Possible

Appendix C: Borg Scale Questionnaire

Ultrasound

0	Nothing at all	“No P”
0.3		
0.5	Extremely Weak	Just noticeable
1	Very Weak	
1.5		
2	Weak	Light
2.5		
3	Moderate	
4		
5	Strong	
6		
7	Very Strong	
8		
9		
10	Extremely strong “Max P”	
•	Absolute maximum	Highest Possible

Lifting

0	Nothing at all	“No P”
0.3		
0.5	Extremely Weak	Just noticeable
1	Very Weak	
1.5		
2	Weak	Light
2.5		
3	Moderate	
4		
5	Strong	
6		
7	Very Strong	
8		
9		
10	Extremely strong “Max P”	
•	Absolute maximum	Highest Possible

Appendix C: Borg Scale Questionnaire

Lameness exams

0	Nothing at all	“No P”
0.3		
0.5	Extremely Weak	Just noticeable
1	Very Weak	
1.5		
2	Weak	Light
2.5		
3	Moderate	
4		
5	Strong	
6		
7	Very Strong	
8		
9		
10	Extremely strong “Max P”	
•	Absolute maximum	Highest Possible