ABSTRACT

LAMAR, SABRINA LYONS. Investigation of Factors Associated with Prevalence and Severity of Musculoskeletal Symptoms Among the Workers in Clinical Specialties of Radiologic Technology: An Ergonomic and Epidemiological Approach. (Under the direction of Carolyn M. Sommerich.)

Little research has been done to investigate the combination of biomechanical and work organization factors associated with musculoskeletal symptoms among radiologic technologists. This cross-sectional study used a written self-report questionnaire to evaluate levels of job-related psychological stress, exposure to ergonomic stressors, and 12-month and 7-day prevalence of musculoskeletal complaints in radiologic technologists who worked in hospital or clinic-based settings in one health system. Written surveys based on interviews and direct observations of radiologic technologists and adapted from the Job Content Questionnaire and the Nordic Questionnaire were used to elicit information about psychological stress from a control-demands theory approach, work organization factors, categories of work performed, types of equipment utilized, prevalence and severity of musculoskeletal symptoms, and specific personal and health factors. Associations between personal factors, the type of work performed and the presence and severity of musculoskeletal symptoms were explored through statistical analysis. Work stress factors for radiologic technologists sin this study were compared to similar health technologists and nurses from a previously established database of Job Content Questionnaire scores.

RESULTS: Radiologic technologists have a high prevalence of low back symptoms that are likely to interfere with work and leisure activities. Patient positioning was associated with an increased prevalence of low back symptoms. Transporting equipment was associated with an increased risk of experiencing right hand/wrist symptoms and dominant hand/wrist symptoms. Working as a sonographer was associated with increased risk of experiencing

symptoms in the right shoulder, dominant shoulder, right hand/wrist and dominant hand/wrist. Positioning patients was associated with greater risk of experiencing musculoskeletal symptoms in the low back. Technologists in this study were older and had more education than other health care technologists from previous research using the Job Content Questionnaire. They had better scores for decision authority, decision latitude and supervisor support than the other technologists. However, they also had higher levels of physical exertion and psychological demands than the other technologists. They had a similar distribution of males versus females, and scores for created skills, job insecurity, total social support, co-worker support and job dissatisfaction as the other health technologists. Technologists in this study were older than nurses in previous research conducted with the Job Content Questionnaire. They had higher scores for decision authority and reported higher levels for psychological demands than the nurses in previous research.

CONCLUSIONS: This group of radiologic technologists had a very high prevalence of musculoskeletal symptoms that were likely to interfere with work and leisure activities. Tasks related to patient handling and positioning and transporting equipment were associated with higher prevalence of symptoms. Results of this study may provide direction for future research efforts toward quantifying biomechanical exposures for radiologic technologists.

INVESTIGATION OF FACTORS ASSOCIATED WITH PREVALENCE AND SEVERITY OF MUSCULOSKELETAL SYMPTOMS AMONG THE WORKERS IN CLINICAL SPECIALTIES OF RADIOLOGIC TECHNOLOGY: AN ERGONOMIC AND EPIDEMIOLOGICAL APPROACH

by

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DEDICATION

I dedicate this work to my mother, Ann (Dolce) O'Brien. Her dedication to her three children, despite very difficult times that life brought, set the example I followed, in finding the determination to pursue and complete my master's degree. Had she grown up in a time, or in a family culture, that supported the higher education of women, she would surely have surpassed any academic achievements I may accomplish or strive for.

BIOGRAPHY

Sabrina L. Lamar was born on May 27, 1970 and raised in Lombard, Illinois, a suburb of Chicago. She graduated from Willowbrook High School in Villa Park, Illinois in 1988. She earned her degree of Bachelor of Science in Physical Therapy from the University of Illinois in 1993. Shortly, thereafter, Ms. Lamar moved to Durham, North Carolina to work in the Physical and Occupational Therapy Department at Duke University Medical Center. She also obtained her license to practice physical therapy in North Carolina in 1993. Her initial clinical experience at Duke included rehabilitation for hospitalized cardiac, pulmonary, and cancer patients, as well as post-surgical organ transplant recipients. She eventually moved into the clinical outpatient environment where she worked primarily with the orthopedic population, including patients who were recovering from work-related injuries. In 1996, she started working in the Duke Ergonomics Division to complement her clinical work. Her interest in occupational health and ergonomics led her to pursue further study in the area of occupational biomechanics in the Industrial Engineering Department at North Carolina State University. She continued working at Duke University and pursued course work for her master's degree on a part-time basis. Ms. Lamar married Frederick C. Lamar in August 1997. They had two children while she was pursuing her master's degree: daughter, Amira (2001) and son, Aiden Francis (2002). She is the first member of her immediate family to earn a graduate degree.

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Chapter 1

INTRODUCTION

1.1 BACKGROUND AND LITERATURE REVIEW

Research has shown that ergonomic stressors such as repetitive motion, high force, awkward posture and duration of work activity may be related to the development of upper extremity discomfort, musculoskeletal disorders such as tendinitis and carpal tunnel syndrome (Latko, *et. al.*, 1999; Sjogaard and Sogaard, 1998; Armstrong, *et. al.*, 1987; Silverstein, *et. al.*, 1987; Smith, *et. al.,* 1977; Keyserling, 2000a). Weight of object lifted, horizontal reaching distance, awkward posture, and frequency of exertions have been determined to play a significant role in the development of low back pain (Keyserling, 2000b). It is thought that through the various tasks required of radiologic technologists, they may be exposed to these factors, and, therefore at risk for developing work related musculoskeletal disorders.

Radiologic technologists are the medical personnel who perform diagnostic imaging examinations and deliver radiation therapy treatments. There are many areas of practice in which radiologic technologists specialize, including x-ray technology, computed tomography, nuclear medicine, mammography, magnetic resonance imaging, vascular-interventional technology, radiation therapy, ultrasound, or diagnostic radiography (ASRT 1999). Some radiologic technologists work as managers or educators. Certification can be earned in the various areas of clinical specialty and some states require state licensure for an individual to practice. As such, they compose a group of skilled workers who perform a

variety of tasks, operate under a range of work conditions in numerous environments, utilize different types of medical equipment, and engage in direct patient care. According to a 1998 statistic provided by the American Registry of Radiologic Technologists, there are over 221,000 registered radiologic technologists in the United States. National statistics from the U.S. Census Bureau (1998) suggest that approximately 70% of these individuals are female. Existing research implies that the work performed by radiologic technologists involves significant materials, equipment and patient handling resulting in physically intensive work overall.

Radiologic technologists represent a group of skilled heath care workers that has not been extensively investigated by the ergonomics research community. Most of the published ergonomics literature pertaining to health care workers has focused on back pain among nurses. The majority of available ergonomics-related literature directly or indirectly related to the work performed by radiologic technologists has discussed the ergonomic risk factors associated with the use and handling of ultrasound transducers. Some of the research has also incorporated the use of observations to better understand work methods and the use of physical exams to identify signs of musculoskeletal disorders. Investigations comparing ergonomic factors across the various clinical subspecialties of radiologic technology have not been published. Most of the research is based on self-report questionnaires and many investigators did not elicit adequate questionnaire response rates. Therefore, bias associated with non-response, or poor response, may make it difficult to know if the population of "responders" is truly representative of the target population. Questionnaires used in previous studies depended on self-report to define levels of exposure to ergonomic risk factors in the target populations, whereas direct observation, or other quantitative measures may have been

more reliable. A more detailed review of the literature is presented below, grouped by specialty of radiologic technology investigated. This review is also summarized in Table 1.1.

1.1.1 X-Ray Technologists

A few studies of the work of x-ray technologists, in particular, and its impact on musculoskeletal disorders have been published. Through questionnaires and observation methods, Wright and Witt (1993) investigated the prevalence of back pain among radiographers and the various work exposures in the form of methods utilized to perform specific tasks. They received a 49% response rate to their questionnaire. The vast majority of respondents were female (92 of 110). Seventy-two percent of males and 77% of females reported back pain. Age, height, and weight were not significant predictors of back pain. The highest prevalence of back pain was reported among those who worked in general diagnostics. The researchers also compared the methods used by radiographers with back pain to the methods chosen by those who did not report having back pain. They found both groups used similar methods for the following six tasks they observed: carrying cassettes, moving the mobile unit, transferring horizontal patients, retrieving an object from the floor, moving supplies, and moving equipment through a door. Different methods were used for the following four tasks: moving the x-ray tube, moving the Bucky tray, working with wheelchair patients, and placing a cassette under a bedridden patient. This demonstrates that individual strategy is a source of variability for the work performed. This variability may have an influence on the presence of back pain. Alternatively, the variability of techniques employed could be a result of the back pain experienced by the technologists. Since this was a cross-sectional study, there is no way to determine which is the case.

In a field study, Kumar, *et. al.* (2003) investigated the biomechanical loads placed on x-ray technologists during a select number of tasks. The tasks included

- Wearing a lead apron
- Loading a small x-ray cassette into a multiloader
- Loading a larger cassette into a multiloader
- Pushing and pulling an x-ray tube
- Pushing a mobile x-ray unit on the floor
- Pulling a mobile x-ray unit on the floor
- Pushing a patient stretcher in a hallway
- Pushing a wheelchair with a patient in a hallway
- Repositioning a patient horizontally in bed
- Repositioning a patient on side in bed
- Repositioning a patient to an upright seated position
- Repositioning a cassette under a patient
- Slider board transfer of a patient
- Spine board transfer of a patient
- Pulling the spine board
- Lifting a patient from a wheelchair.

Twelve of the sixteen tasks had compressive loads on the L5-S1 intervertebral disc in excess of 1000 N. The following tasks resulted in spinal compressive loads of less than 1000 N: wearing a lead apron, loading small cassettes, loading large cassettes, and pulling a mobile x-ray unit. Questionnaire results indicated that 83% of the female sample had "back problems." Of note is the finding that 67% of all the technologists "mostly liked" their jobs and 17% "always liked" their jobs. This suggests a high degree of job satisfaction among these subjects. Significant joint torques were observed during various activities, such as repositioning and transferring patients and repositioning cassettes under patients. Awkward joint angles were observed, particularly with maneuvering the x-ray tubes which is usually repeated many times per day.

1.1.2 Ultrasound Technologists

Most of the published research involving radiologic technologists has been done with sonographers, also called ultrasonographers. Investigators from various countries, such as the United States, Canada, Australia, the United Kingdom and Italy, have published research related to occupational injuries among sonographers, suggesting their work-related injuries may be an international problem. In an overview provided by Gillian Cattell of the Birmingham Women's Hospital (Cattell, 2001), she suggests that because many other healthcare professionals besides radiographers (radiology technologists) practice sonography to various degrees as part of their job, it may be difficult to determine the total impact of this type of work on health care workers.

In her 1993 study, Vanderpool sought to determine 1) if it was necessary to make modifications to equipment used by cardiac sonographers or their environment, 2) to identify a relationship between carpal tunnel syndrome and other work related musculoskeletal disorders and the work load and techniques of cardiac sonographers, 3) to define ideal work load and techniques for these workers, and 4) to investigate how other personal factors may contribute to the discomfort of cardiac sonographers (Vanderpool, *et. al.*, 1993). Through a questionnaire, they determined that 86% of respondents reported having one or more musculoskeletal symptom. High grip pressure, based on subjective report, while performing cardiac ultrasounds had a positive correlation with carpal tunnel syndrome. Upright posture correlated negatively with physical symptoms and twisted posture correlated positively with physical symptoms. Length of service as a sonographer was not a significant predictor of symptoms in this study. In addition, work environment and procedural technique adopted had minimal predictive value for musculoskeletal symptoms.

In an early study of sonographers, Necas (1996) composed a questionnaire which contained items related to five topics: personal attributes, employment-related information, personal work habits and work environment, musculoskeletal symptomatology information, and information about diagnosed repetitive strain injuries. The questionnaire was distributed by mail to members of the Society of Diagnostic Medical Sonographers in the states of Washington and Oregon. Prior to analyzing the data, a "work habit score" was developed. This was based on the number of positive responses to questions regarding specific work factors including specific work components (e.g. gripping the transducer, applying sustained pressure, etc.). The level of stress the participant experienced in the workplace was judged on a numerical scale from zero to four. The respondents were placed into one of three categories: asymptomatic (no symptoms reported), symptomatic (symptoms reported, but no diagnosis given) and RSI sufferer (diagnosed repetitive stress injury). Necas achieved a 36% response rate from his questionnaire. Eighty-four percent of the respondents were female. The number of respondents in the asymptomatic, symptomatic and RSI sufferer groups was 27, 99, and 23, respectively. He identified a strong positive correlation between the work-habit score and the number of symptoms reported and between the work-habit score and the number of symptomatic anatomical areas reported. The relationship between number of years worked in sonography and the percentage of symptomatic responders was not significant. The number of scans per week was significant for the number of symptoms reported. The author proposes that stress in the workplace seemed to show a positive trend with and increase in musculoskeletal symptoms in this study.

In a study of back pain among echocardiographers, Solanki, *et. al.* (1997) surveyed 266 echocardiographer members of the British Society of Echocardiography about examination

methods, personal characteristics, lifestyle, and prevalence and intensity of back pain. Sixty-nine percent of potential respondents participated in the study. Eighty percent of participants reported back pain. At least some limitation of lifestyle from back pain was reported by over half of the respondents. Length of service was also associated with back pain with those with eleven or more years of service being at greater risk. Most respondents had a high level of job satisfaction. However, presence of average or poor job satisfaction was associated with back pain. Based on results, the main risks for back pain appeared to be use of the traditional echocardiography method and frequent lifting.

Smith, *et. al.* (1997) conducted a survey of cardiac ultrasonographers inquiring about the presence of back, neck, or shoulder pain, treatment rendered, personal factors such as height, age, years of experience, frequency and type of exercise, and job–related factors such as number of scans performed per month, type of equipment used, and use of manual or self-propelled machines. Using univariate analysis, they identified associations between the following factors and musculoskeletal pain: subject height less than 63 inches, performing greater than one hundred scans per month, scan time greater than or equal to 25 minutes, and use of manually propelled machines. One limitation of this study was the response rate; although 220 ultrasonographers responded to the questionnaire, the total response rate was only 51%. Multivariate analysis was not reported. These results suggest that there are various factors to consider, such as workload, type of equipment, and anthropometry. However, it is difficult to make conclusions about the prevalence of musculoskeletal disorders in this group of workers or to make associations among the other factors based on this study, because of the low response rate.

In 1997, the WorkCover Authority of New South Wales conducted a walk-through survey of the occupational health and safety issues presented to sonographers at the Royal Prince Alfred Hospital in Sydney, Australia. Through the survey, they determined that ultrasound tasks were all characterized by prolonged extended reach, prolonged grip, and sustained awkward positions of the arm. The scanning height and the keyboard height were too high for the sonographer in all observed cases. Over 77% of the sonographers who participated in a questionnaire regarding musculoskeletal symptoms reported work-related symptoms, primarily in the shoulder, arm and neck (Gregory, 1998). At the time of his review, Gregory states he had seen the introduction of height adjustable exam tables and seating for the sonographers. He states the use of remote monitors for the patients to view, in obstetrical cases, for example, had improved the ability of the sonographers to avoid severely awkward posture while scanning. He also states he had begun to notice some ultrasound equipment manufacturers introducing adjustable features into the keyboard, alternative "user-friendly" keyboard layouts, adjustable monitors, and units with legroom for the sonographers. He notes that he had yet to observe any improvement in the design of transducers to improve grip.

Mercer, *et. al.* (1997) provide a discussion of the research related to ultrasonographers and report associations between various aspects of the job and symptoms such as eyestrain, muscle strain and injury, carpal tunnel syndrome, stress, and burnout. They attribute muscle strain and injury of the low back to performing ultrasound scans with poor sitting posture or pushing the ultrasound machine. However, scientific justification for their claims is not presented.

Another investigator also used a questionnaire to identify characteristics of work-related injuries among diagnostic sonographers (Wihlidal and Kumar, 1997). They obtained a questionnaire response rate of 61.5% and found that the work-related symptoms could be attributed to increased workload, decreased staff, sustained posture or activity, and poor equipment design.

Schoenfeld (1998) achieved a higher questionnaire response rate. His research was stimulated by his review of the literature (Degani and Solomon, 1997) and a clinical case in which he treated an ultrasonographer for scapho-lunate instability. He attributed her disorder to the repetitive motions and static or awkward muscle positions to which she was exposed while using an ultrasound transducer. Schoenfeld used a questionnaire to explore associations between age, gender, workload and intensity, physical activity, wrist dysfunction, and general medical history. Forty-four of fifty-one questionnaire-recipients responded. Fifty-seven percent of the respondents suffered from between one and four musculoskeletal symptoms and 65% had experienced symptoms of carpal tunnel syndrome at some point during their scanning career. He also found a slightly positive effect for the female gender on prevalence of musculoskeletal symptoms.

Schoenfeld later investigated several factors and their relation to performing ultrasounds in the obstetrics and gynecology environment (Schoenfeld, *et. al.*, 1999). A questionnaire was used to gather information about sonographers' personal factors, age, gender, medical history, wrist dysfunction symptoms and other musculoskeletal problems, workload and intensity, and scanning techniques used. They achieved an 86% response rate for a total of forty-four respondents. Some of the results were limited due to the small number of subjects. However, women experienced more combined symptoms than did men.

Twisting and pushing motions and high grip pressure on the transducer had a positive correlation with carpal tunnel syndrome symptoms. They also found standing to have a positive correlation with increased musculoskeletal stress. They concluded that prolonged and repetitive manipulation of ultrasound transducers might be hazardous for sonographers.

By request of the Safety Manager of the University of Medicine and Dentistry of New Jersey, NIOSH conducted a site visit and Health Hazard Evaluation of the antenatal unit of St. Peter's University Hospital (Habes and Baron, 1999). The safety manager had reported the ultrasound technologists who performed trans-abdominal and trans-vaginal sonograms on pregnant women were experiencing neck, shoulder and arm pain. Their investigation included videotape analysis of several ultrasound procedures and the use of a questionnaire to inquire about musculoskeletal symptoms among the ultrasound technologists. Results of the videotape analysis indicated the trans-abdominal ultrasounds required awkward shoulder posture, sustained application of static force, and various pinch grips while scanning. Wrist posture seemed to depend upon the size of the patient: Work with later term patients required use of greater wrist flexion and extension. Other influencing factors included the position of the equipment in the room, the configuration of the equipment, the shape of the transducer, and the type of patient bed. Awkward shoulder posture, wrist extension, and static gripping were observed in the videotape analysis of the trans-vaginal ultrasound procedures. Five of the six sonographers who participated in the medical questionnaire reported pain or discomfort. These symptoms were located in the neck region, and in the right shoulder, elbow, hand and wrist regions. As a result of their study, Habes and Baron suggest the following interventions to reduce the musculoskeletal risk factors for sonographers at St. Peter's University Hospital. These are: use a height adjustable exam

table and chair; support the elbow when long reaches are required; and consider standing while performing sonograms on late-term patients. They also state the older transducers that are longer and wider are more conducive to proper ergonomic handgrip. In addition, sonographers should request assistance from the patient to optimize their positioning, rather than put the burden of positioning on themselves. It was noted during the observations that the ultrasound equipment is usually located at the head of the patient's exam table. This location contributes to the awkward postures seen during the trans-vaginal exams. Therefore, the authors conclude, an examination room should be arranged specifically for the trans-vaginal sonogram procedures to facilitate use of neutral posture.

Pike, *et. al.* (1999) performed a cross-sectional study of medical sonographers using a questionnaire that addressed five general topics: work experience, general health, and background information; work schedule and tasks; work equipment; problems, pain, and discomfort; and work environment and corporate culture. The questionnaire was mailed to members of a professional society targeting medical sonographers. Less than one thousand of the three thousand questionnaires were returned and used in the analysis. The investigators found that the prevalence of self-reported work-related musculoskeletal symptoms was almost 79%. Respondents attributed their musculoskeletal disorders to manipulating the ultrasound transducer by gripping, applying pressure, using shoulder abduction, and twisting the neck or trunk. Respondents indicated that they take few breaks, but also expressed high levels of job satisfaction and satisfaction with the work culture. A low response rate was obtained and direct observations of work activities were not performed. However, these interesting results suggest that further investigation is necessary

to learn more about this group of workers and the personal and work-related factors that influence the incidence of musculoskeletal disorders among them.

A group of Italian researchers conducted a large questionnaire-based study of the prevalence of musculoskeletal complaints among physicians who operate sonography equipment (Magnavita, *et. al.*, 1999). Two thousand forty-one sonologists responded with completed questionnaires (response rate 76.4%). In this study, most of the respondents were males, working in hospital settings. Over two-thirds of the respondents used ultrasound equipment part-time rather than full time. Even so, over half of the respondents experienced symptoms in their neck and/or back. One-third of them reported having at least one work-related symptom in their upper extremity, mainly in the dominant hand. Age, duration of full-time work with ultrasound devices, the number of days per week working with the devices, and the average time spent for each patient had a significant association with hand/wrist cumulative trauma disorder. Age, duration of full-time work with ultrasound devices, the number of hours per day worked, the number of days per week worked, and the average time spent for each patient had significant associations with neck and back pain. These results are suggestive of a positive association between hours worked in diagnostic ultrasounds and hand and wrist symptoms, as well as neck and back pain.

To date, the largest study of musculoskeletal and psychosocial factors related to tasks performed by sonographers has been conducted by the Employee Health and Safety Services and Health Care Benefit Trust in British Columbia, other parts of Canada and the United States. However, the results of these studies had not been published at the time of this writing. Three professional organizations were used to recruit study participants. These were the British Columbia Ultrasonographers, the Canadian Society of Diagnostic Medical

Sonographers, and the American Registry of Diagnostic Medical Sonographers. A total of 1621 responses was achieved. A high number of respondents reported discomfort in the shoulder (76%), neck (74%), low back (58%), wrist (59%) and hand/fingers (55%). Over 40% of respondents reported experiencing painful work, home or recreation activities as a result of their symptoms. Applying pressure with the transducer and maintaining shoulder abduction were reported as most aggravating to musculoskeletal symptoms. Respondents generally reported a high level of co-worker support and work clarity. They had lower scores (or less desirable scores) for performing repetitive tasks and being able to plan extra work and overtime. Questionnaire results specific to sonographers in British Columbia are reported on by Russo, *et. al.* (2002) discussed later in this summary.

In her published study Christenssen proposed that integrating a stretching exercise program into the work schedule of a group of echocardiographers could reduce the prevalence of signs and symptoms of musculoskeletal disorders (Christenssen, 2001). The stretching exercise program was targeted at the muscles used by the sonographers while working and was adopted in an experimental group over a period of twelve weeks. A control group did not adopt any exercise program during this period. Pre and post questionnaires and symptoms surveys were used to determine the effects of the exercise program. Results did not show any significant differences in prevalence of signs or symptoms in either group. However, the small number of participants and unbalanced number of exams performed by each group were major limiting factors in this study.

More recently, Canadian researchers initiated a comprehensive study of sonographers in British Columbia (Russo, *et. al.*, 2002). In the first phase of the study, a comprehensive questionnaire was administered to over 230 sonographers in British Columbia, which

constituted the majority of sonographers practicing in that province. The questionnaire was comprised of questions that were categorized into one of five categories: personal and health information and work experience, workload and work organization, equipment utilized, musculoskeletal symptoms and work environment and culture. They achieved a response rate of 92%. Participants were divided into two groups: those with high pain or discomfort (HPD) and those with low pain or discomfort (LPD). Almost half (49%) of the respondents fell in the HPD group. Prevalence of any pain or discomfort experienced since beginning work as a sonographer for all respondents was 91%. Factors associated with those assigned to the HPD group according to the results were 1) a greater time scanning during each work day, 2) maintaining static body positioning, 3) performance of obstetrical scans, 4) sharing a workstation with others, and 5) not working with the control panel at a comfortable height. Upper extremity, back and neck were the most commonly reported sites of pain or discomfort. Respondents in the HPD group were more likely to have consulted a doctor or other health professional about their symptoms, received a diagnosis for the symptoms, received treatment for the condition, and filed a WCB claim (Workers' Compensation). Although prevalence of pain or discomfort was high, rates of absenteeism from work or inability to perform normal work activities was very low. However, control over aspects of the work schedule, such as overtime and breaks, was a concern for these sonographers.

The Society of Radiographers recently sponsored a study in which the researcher conducted interviews with 55 sonographers in the United Kingdom (Ransom, 2002). The results of this questionnaire indicate that almost half of the participants were over forty-one years of age. Also, 56.9% of participants had worked as a sonographer for eleven or more years. Eighty-seven percent of them worked full-time as a sonographer. Most of the

symptoms reported were located in the neck, right shoulder and right wrist, or in the "scanning arm." A comparison of dominant versus non-dominant sides was not reported. Only 7.5% had experienced symptoms prior to becoming a sonographer. There was typically a delay between the time the sonographers first experienced symptoms and when they realized they may have a musculoskeletal injury. Many of the sonographers pursued medical evaluation of their musculoskeletal injury(ies). The author describes various experiences and management approaches taken by the general practitioners and occupational health professionals, implying that the health care available to treat these conditions is inconsistent and perhaps uninformed. The author discusses the various levels of support many of the sonographers received from their employer or the trade union. In many of the cases, work site risk assessments were conducted. However, follow-through with recommendations provided in the assessments was not executed in many cases. According to the interviews, the majority of sonographers believed that the three main contributors to their injuries were lack of adjustable features in equipment, awkward posture, and lack of rest breaks. Based on the findings, the investigator suggests that risk assessments should be conducted at regular intervals. Equipment that facilitates working with neutral postures should be provided. They also suggest that shorter, more frequent break schedules be implemented to provide recovery time and reduce the pressure the sonographers are under.

Specific to the work of cardiac sonographers, McCulloch, *et. al.* (2002) developed and distributed a questionnaire to assess the demographics, musculoskeletal health, work place ergonomics, and workloads of cardiovascular sonographers. Eighty-two percent of respondents reported some level of discomfort. Sixty-seven percent of the respondents reported major or disabling discomfort. Both the number of studies performed each day and

the length of time of those studies were significant factors related to the presence of symptoms. In addition to these results, the authors share suggestions to assist cardiac sonographers with reducing awkward postures while scanning.

A number of papers and articles in sonography-related trade journals, on sonography-related Web sites and in bulletins for professional societies for sonographers discuss the extent to which sonographers are affected by work-related musculoskeletal disorders (Baker and Murphey, 2001; Baker and Murphey (www.soundergonomics.com retrieved on 3/25/2002); Murphey and Coffin, 2002a; Murphey and Coffin, 2002b; Hancock, 2003), The majority state that a range of 80% of sonographers experience work related musculoskeletal disorders in their career and that many of them must leave the field of sonography or stop working altogether. The authors attribute the problem to a variety of sources, such as lack of adjustable chairs and ultrasound equipment and the resulting awkward postures, grip force required to maneuver the transducers, and weight and inflexibility of the transducer cables. These authors propose various modifications such as adjustable chairs and patient stretchers, improved equipment design to include multiple adjustments on ultrasound machines, light weight transducers with flexible cables, and improved placement and adjustability of the monitors, and easy access to accessories. Administrative controls such as arranging a sonographer's schedule so a variety of exams are performed rather than all the same type, allowing for stretching in the work place and sufficient break time, and educating sonographers about proper scanning techniques are also recommended. Educational tools and ergonomic checklists have been proposed to assist individual sonographers with preventing musculoskeletal disorders. One example of such a tool is the "Mock Laboratory Assessment of Scanning Ergonomics" proposed by Julie Arnold Hancock (2003) in which

the author proposes a fictitious situation in which one is responsible for the ergonomic evaluation of scanning at a healthcare facility.

Dodgeon and Bernard (www.soundergonomics.com retrieved on 3/25/2002) propose the following solutions to reduce the prevalence of musculoskeletal symptoms among sonographers in the UK. The equipment and work surfaces should be fully adjustable. The monitor height and tilt should be adjustable to promote neutral neck posture while scanning. The size of the transducer should promote a power grip and maximize grip strength. Sonographers should take shorter and more frequent rest breaks to promote recovery from muscular work.

1.1.3 Other Clinical Specialties

Miller and O'Brien (1991) distributed questionnaires to groups of radiation therapists at eleven radiation oncology departments in New York State. Sixty-two percent of the therapists responded to the questionnaire. Nineteen of twenty-eight respondents were female. Eighty-nine percent of the female respondents reported having experienced low back pain, and 55.5% of the male respondents reported the same. Length of employment in radiation therapy was longer for therapists who reported having low back pain than for those who did not. In this study, age and length of time as a staff therapist were associated with report of low back pain. The authors suggest various strategies to prevent low back pain for radiation therapists, such as: storing equipment at waist level to prevent bending at the waist while lifting, locating treatment consoles at waist level, providing mechanical assist devices for patient transfers and positioning, providing regular training in body mechanics for lifting, and providing on-site fitness centers and stress management workshops.

In a case study report, Ruess, *et. al.* (2003) describe the finding that four of twelve staff radiologists in one department reported upper extremity symptoms within a period of several months. In response to the trend of reported symptoms, the entire group of staff radiologists was surveyed regarding type of work performed, length of time working in that area, number of hours worked per week and over the weekends, administrative responsibilities and research activities conducted. An ergonomic assessment of the department was also conducted. Standard neuromuscular evaluation of the four symptomatic radiologists was conducted. They revealed the symptomatic radiologists were the only staff members with active research duties, spent more total work hours using a keyboard, and had some of the more administratively demanding jobs. Although they also spent significantly more time performing sonography, they did not report experiencing symptoms while performing sonography. Therefore, the investigators concluded that sonography was not a significant contributor to their conditions. Rather, they concluded that prolonged computer use and poor office ergonomics were primarily responsible.

Moore, *et. al.,* (1992) conducted a survey of practicing radiologists and sonographers to determine the role of wearing lead apron shielding in the prevalence of occupational back pain. Sonographers were included as a control group to represent workers with little to no use of lead aprons. Age, frequency of lead apron use and longevity of lead apron use were considered. Fifty-two percent of those who used lead aprons frequently reported experiencing back pain compared to 46% of those who used lead aprons infrequently. This difference was not statistically significant. Other factors were also not statistically significant leading the authors to conclude that wearing a lead apron is not a significant factor in the development of back pain.

Ross, *et. al.*, (1997) reported a study of the prevalence of spinal disc disease among interventional cardiologists. They compared the prevalence of musculoskeletal symptoms among interventional cardiologists with that of orthopedists and rheumatologists. Physician groups were selected based on the average number of hours per day they used lead apron shielding and the number of procedures performed per day. The group of interventional cardiologists wore lead aprons more frequently than physicians did in the other two groups. Results showed that axial skeleton complaints were more common among the interventional cardiologists. In addition, the interventional cardiologists had the greatest frequency of lost workdays due to back or neck pain. This study is pertinent to radiology technologists in that many of the clinical subspecialties of radiologic technology, such as vascular technology and general radiology, also require use of lead shielding. Use of lead shielding at work may have an impact on the prevalence of back and neck pain among these workers. However, authors of this study did not control for other work exposures that may influence the prevalence of

spinal disc disease among members of the three groups. In addition, the diagnosis of spinal disc disease was poorly defined.

1.1.4 Research Related to Patient Handling

Radiologic technologists are involved with direct patient care, which requires transferring and positioning patients for procedures. Patients arrive to radiology in wheelchairs or on stretchers and must be transferred to another stretcher or gurney, or assisted to a standing position for their diagnostic testing. These types of activities have been shown to be associated with occupational injuries among nursing staff. For example, in a landmark study of low back pain among nurses, Owen (1989) distributed questionnaires to 1000 nurses from a database of approximately 40,000 licensed nurses in Wisconsin (USA). Just over half were returned (567) and usable (503). Sixty-two percent (62%) reported no back pain (Group 1). Thirty-eight percent (38%) of the respondents reported low back pain (Group 2). Over 65% of Group 2 nurses reported back pain episodes in the previous year. A total of 49% of Group 2 reported lost workdays due to occupational low back pain. Moving or lifting a patient in bed was perceived to have precipitated the low back pain in 61% of the 519 low back pain episodes reported in the past year. Moving a patient from bed to chair and chair to bed accounted for 17.7% of these episodes. Specific units were identified as having excessive low back pain episodes compared to others.

In their longitudinal study of risk factors related to neck and shoulder pain in hospital nurses, Smedley, *et. al.* (2003) found that 34% of nurses reported at least one episode of neck or shoulder pain in a thirteen month follow-up period. They observed an increased risk of neck and shoulder symptoms among nurses who frequently assisted with patient mobilization

to walk, or in a wheelchair, bed, hoist, trolley or commode, or who washed or dressed patients while seated in a chair or on a commode.

Marras, *et. al.* (1999) performed biomechanical evaluations of several types of patient transfer techniques adopted by nursing staff and found patient handling, in general, to present significant risks for low-back injury. As a result, they recommended the use of mechanical assistive devices during patient transfers.

It is likely that the patient handling requirements and techniques employed by radiologic technologists are similar to those adopted by nursing staff. Therefore, these workers may be exposed to similar patient-handling related hazards as nursing staff in hospitals and have increased risk of injury.

1.1.5 Work Organization Factors

The importance of work organization factors in the development of work-related musculoskeletal disorder has been reported (Bongers, *et. al.,* 1993). In general, review of previous research on work organization factors and musculoskeletal disorders suggests that there is a positive relationship between performing monotonous work, having poor social support at work, certain personality traits, and presence of emotional problems, with the incidence of back trouble. According to Bongers, *et. al.* (1993) there is a likely association between monotonous work, time pressure, poor work content, high work load, and stress symptoms or perceived stress at work, and the development of neck and shoulder pain. Lack of control at work, monotonous work, time pressure, high perceived workload, high job demands, low control, poor social support, and presence of stress symptoms were related to developing musculoskeletal problems in locations other than the neck, back, and shoulders.

Most of the studies reviewed by Bongers, *et. al.* relied on self-report of physical loads at work. They suggest that future research use objective measures to quantify physical loads. Bongers, *et. al.* specifically suggest that special attention be paid to work organization factors such as demands, control, and social support.

In their 1999 study, Van der Weide, *et. al.* (1999) aimed to identify the prognostic factors for chronic disability from acute low-back pain of occupational origin. They used questionnaires to collect information about demographics, perception of work conditions, low-back pain characteristics, pain intensity, functional disability, general health perception and health locus of control. Questionnaires were administered to patients with acute low back pain through occupational health services for a number of universities and health care facilities. Specific conditions were met for patients to be eligible for participation and the participants were followed for twelve months. Many psychosocial and work organization factors were associated with functional disability after 12 months. Specifically, these included not enjoying work, social isolation, emotional effort at work, lack of variation at work, work temp and quantity and physical effort. Work tempo and quantity, problematic relations with colleagues, and lack of variation in work were strong prognostic factors for time required to return to work after their injury.

Hoogendoorn, *et. al*. (2001) investigated the relationship between psychosocial work characteristics and low-back pain and the role of psychological strain variables in that relationship. They looked at a population of 861 workers from 34 companies in the prospective study. Workers in the study had no back pain at baseline. Annual questionnaires related to the occurrence of back pain were administered annually over a three-year period. Results suggested that workers with high quantitative job demands, high conflicting

demands, low supervisory support and low co-worker support had a higher risk of low-back pain.

Collins, *et. al.* (1998) studied job satisfaction in a group of mammography technologists. Through questionnaires, they identified working relationships among mammography technologists, and between mammography technologists and the radiologists with whom they worked as the most important variables related to their job satisfaction. Questionnaires were sent through the U.S. mail and only 1,503 of the 5000 questionnaires were returned to the investigators. A relatively low response rate was achieved (30%).

Other literature, described previously in this summary, suggests that most workers in the field of radiologic technology report relatively high levels of job satisfaction despite the stress they experience from inadequate staffing and increased workload. However, because of the associations among job culture, job satisfaction, and musculoskeletal symptoms, these are important factors to include when investigating musculoskeletal symptoms among radiologic technologists.

1.1.6 Summary of Prior Research

Previous research suggests that radiologic technologists are a worker group composed primarily of women that may be characterized by their high level of job satisfaction, and high rates of musculoskeletal discomfort. Although radiologic technologists are educated in similar settings and educational programs, as the technologists move on to specialize in their fields, it is likely that the work they perform once employed varies greatly depending on the clinical subspecialty they select. The effect of the clinical subspecialty in which a technologist works, on the prevalence and severity of musculoskeletal symptoms, has not

been determined. There appears to be variability in their work exposures based on clinical specialty. Sonography seems to have the potential for involving upper extremity intensive work, while other areas, such as general radiography, may involve more equipment and materials handling and awkward posture that results from the necessity to access and position equipment. Areas such as computed tomography and magnetic resonance imaging are computer intensive, but have not received much attention from the research community. All of these areas require direct patient contact and, in many cases, patient transfers and positioning. Most of the existing research pertaining to radiologic technologists has focused on sonographers. It has been primarily questionnaire-based and symptoms-focused. In most cases, response rates to questionnaires have been less than what is typically accepted as adequate. The National Institute for Occupational Safety and Health (NIOSH) used a 70% response rate as a criterion for consideration when analyzing studies regarding musculoskeletal disorders and workplace factors (NIOSH, 1997). Additionally, many of the researchers recruited participants for their studies by mail using membership databases from professional societies. Often times, members of these societies are not necessarily practicing professionals. Rather, they may be retired or inactive in their careers. Both of these conditions may affect questionnaire responses.

There is a need to investigate the differences in the physical requirements and exposures between the subspecialties of radiologic technology and the factors that influence the prevalence of musculoskeletal symptoms in this group of workers with standardized methods. If this information were available, it may assist or drive improvements in the more hazardous areas. As such, a research study was designed and conducted in order to investigate the associations between the clinical specialty within radiologic technology,

personal characteristics, physical work exposures, equipment used, and work organization factors of workers as they relate to prevalence and severity of musculoskeletal symptoms among radiologic technologists in a variety of specialty areas within a large health system. The next section of this document describes earlier, reactive investigations of reported musculoskeletal injuries of radiologic technologists within the health system that was the locus of this research study. The remaining sections, then, describe the conduct and results of the research study, a discussion of the results and proposed future directions for research and intervention.

Table 1.1 Summary of prior research

Author	Year	Study Population	Methods	Findings	Comments
Collins, J., *et. al.*	1998	1503 registered mammography technologists	25-item questionnaire administered by mail demographics, career objectives, job satisfaction results compared to similar 1987 study	83.1% partly or very satisfied with their job	30% response rate Did not look at relationship between MSDs and job satisfaction
Habes and Baron, NIOSH	1999	Two types of ultrasound procedures performed in an antenatal ultrasound clinic; Six sonographers	Direct observation and videotaping of trans-abdominal and trans-vaginal ultrasound procedures, medical evaluation Grip force for ultrasound transducer estimated with force meter	Right shoulder flexion and abduction, sustained static forces, various pinch grips used while maneuvering transducer Size of patient influenced wrist posture Equipment location caused twisting of the neck, flexion and abduction of the left shoulder, and left elbow extension Shape of transducer influenced grip type Pain in neck, right upper extremity reported by sonographers Typical pressure =4lbs, Peak grip pressure = 8.5lbs.	Health Hazard Evaluation conducted by NIOSH Limited sample for medical evaluation Did not consider other types of ultrasound examinations
Kumar, S., *et. al.*	2003	Seven x-ray technologists (1 male, 6 females)	Strength testing Videotaping of "most strenuous" occupational tasks	Compressive forces at L5-S1 range from 8N to 8335N depending on task Patient handling tasks were associated with the highest compressive forces Resultant moment on limb joints frequently exceeded mean population strength 83% of female subjects reported back problems	Small sample size

Table 1.1 (continued)

Magnavita, N., *et. al.*	1999	2041 Italian physician sonographers (73.5% male)	Questionnaire related to demographics, employment, scanning techniques and work factors, musculoskeletal symptoms, physical activity Mailed to recipients identified through a professional society	2/3 respondents only used ultrasound part-time 1/3 of respondents were experiencing one or more work-related symptoms at the time of their response (mostly affecting the dominant hand) 20% did not have any work-related symptoms 54.3% experienced pain in the neck or back age, duration of full-time, hours worked per day and days worked per week were related to prevalence of symptoms upright posture correlated negatively; twisted posture and uncomfortable transducer design correlated positively with symptoms	76.4% response rate Sample non-representative of all sonographers
McCullough, M., *et. al.*	2002	295 sonographers (75% cardiac sonographers)	14-item questionnaire pertaining to demographics, ergonomics and workloads; Mailed to subscribers of three trade journals	82% report some type of discomfort; 67% report major or disabling discomfort 48% sought medical treatment Scanning time >30 minutes and increased number of studies per day correlated (+) with discomfort	No mention of response rate, male versus female, impact of performing a variety of ultrasound work
Miller, S. and O'Brien, J.	1991	28 (19 female) radiation therapists at 11 different departments in New York State	Questionnaires mailed to and administered through chief radiation therapists; questions related to demographics, work and symptoms of low back pain	75% had experienced low back pain; 89% of females and 55.5% of males; Significant factors were age and time spent as a staff therapist Higher stress levels associated with low back pain radiating to below the knee.	62.2% response rate small n
Moore, B., *et. al.*	1992	236 radiologists (11% female)	23-item questionnaire mailed to members of professional societies for radiologists; Questions related to demographics, work issues, back pain and lead apron use	58% had experienced back pain; 92.4% reported at least some use of lead apron No association shown between lead apron use and development of low back pain	34% response rate vague definition of back pain

Table 1.1 (continued)

Necas, M.	1996	149 sonographers (85% female)	Pilot study - Questionnaire mailed to members of states' professional societies; Demographics, employment, work habits and environment, symptoms, medical history Developed "work habit score"	Trend in increasing weight, number of years worked, hours per week worked and number of scans per week among RSI sufferers Work habit score (+) correlation with number of symptoms reported and number of symptomatic areas 66% experienced symptoms females account for 90% of reported symptoms Having less than three 10-minute breaks (+) correlation with number of symptoms 15% diagnosed with RSI trend to increase RSI with years worked in ultrasound	
Pike, I., *et. al.*		983 American registered sonographers (85% female)	125-item pilot questionnaire demographics, employment, workload and scheduling, equipment and symptoms distributed to random sample of 3000 registered sonographers	81% experienced pain since working as a sonographer, but 96% rated their personal health status as good or excellent.	32.8% response rate Only descriptive statistical analysis reported.
Ransom, E.	2002	55 sonographers in the United Kingdom (96.4% female) who reported work related musculoskeletal symptoms	Interviews conducted in person at sonographers' places of work or in their homes	Symptoms mainly in neck, shoulder, right wrist and back Over 61% had had workplace risk assessments completed (most in reaction to symptoms reported) Self-reported association of symptoms to poor ergonomics, poor posture, lack of rest breaks, poor equipment design, large patients and lack of awareness	

Table 1.1 (continued)

Ross, A., *et. al.*	1997	714 physicians (cardiologists, orthopedists, and rheumatologists)	16-item questionnaire mailed to members of professional societies and physician directories for cardiologists, rheumatologists and orthopedic surgeons Demographics, incidence of back pain or sciatica before and after specialty training, employment and work factors, lead apron use and types used	Cardiologists reported relatively greater use of lead aprons per day than the rheumatologists or orthopedic surgeons Axial skeleton complaints were more frequently reported by the cardiologists (21.3% versus 13.6% and 11%, respectively)	29.7% response rate Does not control for other factors or specific pathology of lumbar spine
Ruess, L., *et. al.*	2003	4 radiologists with complaints of upper extremity symptoms	Physical examination by an occupational therapist and work evaluation completed by industrial hygienist	Increased work hours and research activities associated with symptoms of carpal tunnel syndrome and cubital tunnel syndrome Sonography determined to not be a factor	Small n Low exposure to sonography
Russo, A., *et. al.*	2002	211 sonographers in British Columbia	125-item questionnaire mailed to sonographers in B.C. Categories of questions include demographics, work experience, health, work issues, equipment, and work environment	91% reported pain or discomfort (primarily in upper extremity, back and neck); 49% in high pain and discomfort group; Significant factors include time per day spent scanning, maximum time in one body position; number of obstetrical exams; shared workstation, height of control panel (-); Overall neutral or positive perception of the work environment	92% response rate
Schoenfeld, A., *et. al.*	1999	44 obstetric and gynecologic sonographers (77% female)	Questionnaire related to demographics, work intensity and scanning technique, musculoskeletal symptoms, general medical history	57% experiences between one and four symptoms Significant factors for symptoms include gender (male experienced fewer symptoms), number of scans (+) and length of scan (+) with incidence of multiple symptoms; upright posture (-), twisted posture (+); Twisting and pushing wrist motions correlated with carpal tunnel syndrome	81% response rate Targeted specialty area of practice

Table 1.1 (continued)

Smith, A., *et. al.*	1997	115 American cardiac ultrasonographer members of professional society	22-item questionnaire Categories include demographics, workload, scanning conditions, type of patient	80% experienced back, neck or shoulder pain 47% sought medical treatment Sonographer height (-) Number of studies per month (+) Scan time (+)	51% responded (of 220, subset of 1600) respondents from 98 different laboratories
Solanki, M., *et. al.*	1997	183 British cardiac sonographer member of professional society (81.4% female)	Questionnaire related to occupational, personal and lifestyle issues and back pain	80% experienced back pain trend toward increase incidence of BP with increased years of experience intensity of back pain (+) correlation with study duration, interference with work, limitation of lifestyle 99% good or average job satisfaction rating average or poor job satisfaction (+), lifting occasionally or frequently (+), traditional method of scanning (+), related to risk of back pain	69% response rate
Vanderpool, H., *et. al.*	1993	101 registered cardiac sonographers (72% female)	Questionnaire related to demographics, workload, techniques, medical history, physical activity, symptoms	1-4 CTS symptoms experienced by 57% Men experienced fewer combined symptoms Trend of longer examinations resulting in more frequent symptoms (+) correlation between CTS symptoms and high grip pressure (-) correlation between upright posture and physical symptoms	47% response rate
Wihlidal, L. and Kumar, S.	1997	96 sonographers (86.5% female) in Alberta	27-item questionnaire mailed to sonographers; related to demographics, exercise, employment and work issues, work-related symptoms and consequences of these	88.5% reported work related symptoms Significant factors: gender, age (-), height (-), weight (-), job satisfaction (-)	61.5% response rate possible healthy worker effect majority female
Wright, D. and Witt, P.	1993	Members of state's professional association (83.6% female)	Questionnaires mailed to radiographers Demographics, incidence of back pain; drawing and descriptions used to describe work tasks	72% of males and 77% of females reported back pain; Increased prevalence of back pain among those who worked in general diagnostics; Similar work methods used by those with and those without back pain for six tasks; Different work methods used for four tasks	Random sample of 226 members (13% of organization) 49% response rate

1.2 BACKGROUND AND PRIOR INVESTIGATIONS OF REPORTED MUSCULOSKELETAL INJURIES OF RADIOLOGIC TECHNOLOGISTS WITHIN THE STUDIED HEALTH SYSTEM

Duke University Health System has a large nine hundred bed hospital and many outpatient clinics and employs approximately 200 radiologic technologists. During the years 1997, 1998 and 1999, a total of 105 on-the-job injuries were reported in the radiology department. Record review of the reports indicated that 79 of 105 (75%) may have been associated with poor ergonomics. Forty-seven of the 79 (59%) were reported by radiologic technologists of various seniority levels and specialties. This suggests that 45% of the total number of injuries reported during that period were ergonomic related and involved a radiologic technologist. The Duke Ergonomics Division has had opportunities to respond to reports of musculoskeletal injuries that may have resulted from ergonomic factors such as use of awkward posture, repetition, excessive force, local mechanical stress, or a combination of these. All of their interventions were in response to injuries reported. The following discussion of their observations, conclusions, and proposed interventions of jobs performed by radiologic technologists offers further support for the need for formal ergonomics research related to radiologic technologists.

1.2.1 Portable Equipment

Radiology technologists are responsible for obtaining x-rays with portable equipment for patients who are too ill to be transported to Radiology for examination. The process of obtaining a roentgenogram with the portable equipment while a patient lies supine in bed

requires that the radiologic technologist slide a large film cartridge underneath a patient. The use of force to position the patient and to slide the cassette underneath the patient is common. It has been observed that technologists tend to use awkward back and shoulder postures and forceful grip while performing this task. Several reports of back and upper extremity injuries, that employees attributed to placing x-ray cassettes under patients, stimulated closer investigation of the task and the equipment involved. It was determined that there was significant friction between the x-ray cassette and the mattress ticking during cassette placement. Awkward back, shoulder, and grip postures were attributed to not having sufficient coupling (handles) on the cassette. As a result, a multi-disciplinary team including radiologic technologists, clinical engineers, and ergonomists developed a low friction cassette holder with a handle. Although the device did not eliminate the need to re-position patients, it made the task easier by reducing the force required to place the cassette under a patient, and provided a handle which could be gripped with a power grip rather than a pinch grip. The equipment-related improvements made to this task may reduce the occurrence of upper extremity injuries; however, further studies are necessary to determine if ergonomic stresses have truly been reduced or eliminated from the task and if there are other task elements to which the musculoskeletal injuries may be attributable (James, *et. al.*, 1999).

1.2.2 Ultrasound

Radiologic technologists are responsible for performing diagnostic ultrasound examinations on pregnant women. Employees have reported discomfort in the low back and upper extremities that they attribute to the awkward postures and sustained gripping required while scanning and the fast work pace. Duke ergonomists observed these tasks and

confirmed the use of sustained grip, awkward back, neck, shoulder and wrist posture during scans. The grip forces or postures were never quantified, compared to other clinics, nor were formal analyses of frequency or duration of the exposures completed. Equipment modifications were recommended, but few, if any, were ever implemented due to budgetary constraints or lack of support to address these issues.

1.2.3 Video Display Terminals

Many radiologic technologists work with desktop computers and other types of video display terminals. Duke ergonomists report that several of the technologists have required computer workstation evaluations and modifications due to musculoskeletal pain in the neck, shoulder, and wrists. Many of the recommendations involved simple modifications to the workstation layout or the purchase of inexpensive accessories. However, radiologic technologists do not represent a traditional group of office workers. Many of them are likely to change from clinical work to office work, or perform a combination of both, without having any basic knowledge of safe work techniques applicable to office workers. They may be at greater risk of developing work-related musculoskeletal disorders as a result.

1.2.4 Summary of Past Efforts within the Studied Health System

Duke University Health System is a large health system with representative areas of most specialties of radiologic technology. The technologists who work there account for a high percentage of ergonomic-related occupation injuries within their department. Use of portable x-ray equipment and placement of portable x-ray cassettes under patients has been associated with use of excessive push and pull force and awkward posture by the

technologists. Ultrasound exams have been associated with awkward upper extremity posture and sustained forceful grip during exams. Though recommendations have been proposed, they have generally been met with non-compliance in regards to implementation of the modifications. Concepts of office ergonomics apply to most radiologic technologists due to the high prevalence of computer interaction to perform exams or document procedures.

1.3 SUMMARY

Previous research suggests that radiologic technologists who work as sonographers have a high prevalence of musculoskeletal symptoms in the neck and upper extremities. Females gender has been associated with an increased risk of symptoms in some studies. Longevity in the profession, number of hours worked, duration and number of exams performed and various equipment features have also been associated with higher prevalence of symptoms in some studies, but not all. General radiology technologists and radiation therapists also have a high prevalence of low back symptoms, and have demonstrated a high level of variety in the strategies they use to perform work tasks. Patient handling activities have also been implicated as a possible source for musculoskeletal symptoms.

Most f the previous research on radiologic technologists has been questionnaire-based and used mass mailings to recruit participants, or was conducted with very small groups. Work exposures and prevalence of musculoskeletal disorders or symptoms has not been explored and compared among most of the various clinical specialties within radiologic technology. For example, computed tomography technologists, mammography technologists, interventional technologists and magnetic resonance technologists have not been included in subject populations for most studies. Similarly, standardized measures of

work organization and job stress factors have not been employed to compare the radiologic technologists of today with other health care workers.

1.4 SPECIFIC AIMS

The specific aims of this project were:

1. to determine the prevalence and severity of musculoskeletal complaints among radiologic technologists who work within a large health system;
2. to characterize work exposures and their variability in the same group of radiologic technologists;
3. to describe levels of occupational stress and related work organization issues in this group of radiologic technologists and compare to similar work groups;
4. to explore associations among the following factors:
   a) type of clinical specialty and prevalence, severity and location of reported musculoskeletal symptoms;
   b) occupational task exposures and prevalence, severity and location of reported musculoskeletal symptoms;
   c) frequency of use and type of equipment and prevalence, severity and location of reported musculoskeletal symptoms;
   d) personal factors (age, sex, and race) and their effect on the associations listed just above.

1.5 HYPOTHESES

The following hypotheses were proposed:

1. There will be a difference between the reported prevalence and severity of musculoskeletal complaints among the different clinical specialties. Sonographers will have greater prevalence and severity of hand and wrist complaints than other specialties because of the previous studies of sonographers and location of musculoskeletal symptoms. Those working in general radiology will have greater prevalence and severity of back complaints than other specialties (due to the requirements for arranging or adjusting equipment).
2. Work that involves more frequent patient transfers or positioning, pushing or pulling equipment, lifting equipment, transporting objects or equipment, or transporting patients will be associated with higher reported prevalence and severity of musculoskeletal complaints in the back and neck regions of the body than other types of work (because these work exposures are often associated with awkward postures in the back and neck and use of excessive forces). Work that involves more frequent gripping or manipulation of objects or tools will be associated with higher reported prevalence and severity of musculoskeletal complaints in the hand and wrist regions of the body than other types of work (because this type of work is typically associated with awkward hand and wrist posture , static posture and excessive grip force).
3. Technologists who frequently use equipment to assist with patient transfers will have lower prevalence and severity of musculoskeletal complaints in the back and neck regions of the body than other types of work. This is based on a growing body of literature that suggests that using equipment reduces risk of back injury among nurses.
4. Equipment that requires use of sustained grip, such as ultrasound transducers, will be associated with higher prevalence of hand/wrist symptoms. Equipment used in general

radiology will be associated with higher prevalence of shoulder symptoms due to over head reaching required to maneuver the equipment.

5. Older workers will have lower prevalence of musculoskeletal symptoms than younger workers will (potentially due to a healthy worker effect).
6. Women will have a higher prevalence of musculoskeletal symptoms than men will, (consistent with previously described trends in prevalence of musculoskeletal disorders).
7. Levels of occupational stress and other work organization issues based on a control-demands model will be similar to those of other health care personnel who perform direct patient care, such as nurses and other radiologic technologists.

1.6 GOALS OF THIS STUDY

Results of this evaluation may be used toward the following goals:

1. To identify and improve specific areas of practice for radiologic technologists that may cause or contribute to musculoskeletal symptoms;
2. To identify and improve specific work tasks performed by radiologic technologists that may cause or contribute to musculoskeletal symptoms;
3. To identify areas needing improved design of equipment that are found to be associated with higher incidences of musculoskeletal complaints.
4. To identify additional research questions pertaining to radiologic technologists or refine existing questions. Specifically to guide future research in determining which clinical specialties within radiologic technology are most likely to be associated with musculoskeletal injuries, and how similar are these workers to other health care workers.

Chapter 2

RESEARCH STUDY: DESIGN AND METHODS

2.1 QUESTIONNAIRE DEVELOPMENT AND CONTENT

A two–part questionnaire with 214 items plus sections unique to each clinical subspecialty, and an additional section on equipment used was developed. Part 1 included four sections: General information about work characteristics, categories of work performed, equipment used, and a specialty-specific section on detailed work characteristics. Seven fill-in-the-blank questions related to work location, clinical specialty, length of the shifts covered, number and type of patients seen each day. Multiple choice responses were used for questions related to categories of work performed, such as analysis of exams, pushing or pulling equipment, transferring patients, etc. Check boxes were used for participants to indicate the frequency they used specific pieces of equipment ranging from "many times per day" to "not at all." The sections for each clinical specialty were based on the information collected in observation sessions and interviews, described below. Three separate question lists were developed for (a) magnetic resonance and computed tomography, (b) diagnostic ultrasound including general, vascular, fetal diagnostic, and (c) diagnostic radiologic including general, vascular, orthopedics, urology, gastroenterology, and mammography: These sections varied in length depending on the variety of tasks performed by the groups as defined. A combination of check boxes and fill-in-the-blank responses were used for these sections.

2.1.1 Development of Part 1 of the Questionnaire

In order to develop specific and concise questions about work exposures in Part 1 of the questionnaire, but elicit the necessary information about the various clinical areas involved, a series of direct observation sessions was conducted by this investigator. Informal interviews with technologists and their supervisors were also conducted around the observation sessions. The results of these sessions are summarized in Table 2.1. This process enhanced the understanding of the diversity between the tasks that different groups perform, tasks or factors the technologists suspected of contributing to symptoms, the pace of work in each area and issues related to equipment used. For example, most of the technologists interact with patients, but not all of them perform patient transfers. Most of them use the computer for documentation, but some groups use the computer extensively during their diagnostic procedures. Radiologic procedures performed with a pediatric population are different, in some cases, than the same procedures with adult patients, in terms of physical demands, time requirements, and equipment used. Equipment available to technologists varied, even within similar clinical specialties. For example, technologists only had access to one model of portable x-ray unit, but several models of general x-ray machines and fluoroscopy machines. Some of the variability in equipment used was a result of patient population served, vendor of choice when equipment was purchased, and physicians' preferences.

Table 2.1 Task descriptions and associated hazards for each work group[1]

Work Group	Tasks	Tools/Equipment Used	Hazard	Variable Factors
All	Notes: Minimal writing required; Aides available to assist with heavy work in most areas; extended reach often required for patient positioning or to access and adjust equipment components; most assist with management of soiled linens			
	Position patients Transfer patients Transport patients Empty dirty linen bags	Stretchers, Beds, Gurneys	Forceful exertions Awkward posture	Ability of patient Height/size of technologist Rotation schedule/variety of work Number of exams per day Duration of each exam Availability of assistance to help with patient mobility Availability of assistance Age of equipment Automated features of equipment Digital versus analog exam format Rotation schedule Variety of equipment used
	Access patient information Document procedures	Computers	Prolonged static posture Awkward posture to access keyboard and mouse/trackball Prolonged gripping of mouse Repetitive motion for keying	
CT	*Perform CT scan* Notes: Highly likely to push beds and stretchers; 60-70% of exams performed with contrast			
	Patient transfers and positioning Interface with computer to operate CT equipment	Keyboard Trackball/mouse Patient vehicle CT gurney	Prolonged standing	Computer interface design Type of pointing device

Table 2.1 (continued)

MR	*Perform MRI scans* Notes: Fixed height stretchers; 60-70% of each exam is computer-oriented; Exams vary in length from 30 minutes to 2 hours; Special doors in MRI are very heavy			
	Interface with computer to operate MR equipment	MRI scanner Computer interface	Awkward and static posture while interfacing with computer Prolonged standing	
	Pushing MRI doors open		Push force required Awkward posture while pushing/pulling	
IV	*Attend interventional and vascular radiology procedures* Notes: Assist with patient preparation and set-up of equipment; Procedures vary in length from 30 minutes to 10 hours; May be required to mop or empty trash; Limited patient re-positioning; "Cassetteless" operation; Also utilize ultrasound			
	Preparation of procedure room Cleanup of procedure room Positioning monitors for procedure Use of ultrasound equipment* Documentation of procedure	C-arm equipment Ultrasound Overhead banks of multiple monitors Lead apron/vest shielding	Prolonged standing Awkward posture while using the computer Awkward and static neck posture to view banks of multiple monitors (poorly positioned) Forceful pushing and pulling Increased weight through axial skeleton from lead vest/apron Pressure over shoulder girdle from weight of vest/apron	Type of scanner used Patient arriving in wheelchair versus stretcher Use of anesthesia for patient Type of lead protection selected

Table 2.1 (continued)

MM	*Obtain mammograms* Notes: Consistent exam procedure- series of 4 images; Also utilize ultrasound; Automated equipment set-up; Software requires high volume of "clicking" for menu selection; lightweight cassettes used			
	Transport and develop cassettes	Mammography imaging equipment	Awkward posture to position mammography equipment and patient Forceful and awkward gripping posture to carry cassettes. Weight of cassettes	Number of monitors in overhead bank Weight of trash bags when changed Computer arrangement varies from room to room Digital versus standard films Cassette size Number of cassettes used and carried
	Attend breast biopsy procedure (approximately one hour each) – primarily responsible for obtaining informed consent and preparing patient	Biopsy imaging equipment	Awkward back and shoulder posture to access controls for equipment Prolonged standing	
RT	*Perform radiographic exams* Notes: Most variable area of practice: includes general, orthopedics, pediatrics, urogenital, and gastrointensital (inpatient and outpatient)			
	Maneuver x-ray tube over patient	Upright or table Bucky x-ray tube Lead apron shielding	Force used to maneuver x-ray tube and Bucky Overhead reaching to access x-ray tube Forward bending and twisting to access x-ray tube	Orientation of Bucky Tension/ resistance in mechanical parts Digital versus standard films Cassette size Number of cassettes used and carried
	Transport x-ray cassettes Install and remove x-ray cassettes Develop film		Forceful grip and awkward posture to carry cassettes Weight of cassettes	
	Portable X-ray exams Transport equipment Patient positioning before and after bedside exams	Portable x-ray machine	Push force required to push machine and to position film under patient Push/pull force to move furniture may be required	

Table 2.1 (continued)

US	*Perform ultrasound exams* Notes: Adjustable stretchers and stools available; gloves worn during all exams			
	Sitting or standing Manipulate ultrasound transducer Interface with ultrasound control panel View monitor	Ultrasound machine Patient stretcher Chair/stool Remote monitor (in some cases) Gloves	Prolonged sitting Prolonged standing Leaning forward over legs in sitting position Forward bending in standing position Extended reach to access equipment and patient Prolonged grasping of transducer Force applied through transducer Rotated neck posture	Size of patient (due to obesity or pregnancy) Position of patient Type of exam Scan head used Fit of gloves Sitting versus standing position Location of sonographer relative to the patient (and head of bed, versus at foot of bed)
	Bedside ultrasound exams Transport ultrasound equipment Patient and bed positioning before and after bedside exams		Push force required to push machine and to position patient Push/pull force to move furniture may be required Awkward and static posture to access patient	
	Non-stress test Placement of electrodes Monitor output on screen	Computer interface and monitoring electrophysiological response of fetus.	Awkward posture may be used to place electrodes on patient	

[1]Based on interviews and direct observations
*Refer to Ultrasound section for details

2.1.2 Development of Part 2 of the Questionnaire

Part 2 of the questionnaire addressed work organization issues, musculoskeletal symptoms and personal medical histories using modified versions of the Job Content Questionnaire (Karasek, 1979; Karasek, *et. al.,* 1985) and the Nordic Questionnaire (Kuorinka, *et. al.*, 1997) for musculoskeletal discomfort. Additional questions about patient population and health issues potentially related to musculoskeletal disorders that could be easily formatted for multiple choice response were also included in Part 2 out of convenience for data entry. Part 2 of the questionnaire was entirely multiple choice and participants responded on an Opscan sheet (bubble sheet) for this section of the questionnaire. Most of the multiple-choice responses provided four or five choices, or they required, "yes," or, "no," responses. Body diagrams with shading in areas to illustrate body regions were located in the top right corner on pages pertaining to musculoskeletal symptoms.

2.1.2.1 Questions Pertaining to Work Organization and Occupational Stress

The Job Content Questionnaire, developed by Karasek (1979), and Karasek, *et. al.* (1985), is based on a demand-control-support model of occupational stress. Although the tool was originally developed to identify stress factors related to cardiovascular disease, it addresses the psychosocial factors deemed by Bongers *et. al.* (1993) to be most important in the development of musculoskeletal disorders. The questionnaire has been successfully used to determine associations between work organization stress factors and other endpoints, including musculoskeletal pain (Kristensen, 1995), and may be effective in demonstrating a relationship between work organization factors, health, and quality of life (Kristensen, 1995). Although demographic information is covered in the questionnaire, it primarily addresses

five main categories: job decision latitude, psychological demands, job physical demands, job insecurity, and social support at work.

2.1.2.2 Questions Pertaining to Musculoskeletal Symptoms

The use of musculoskeletal symptom questionnaires is a well-accepted method to identify potential ergonomic problems in the work environment. Jonsson and Ydreborg demonstrated the method to be effective through using questionnaires and comparing the results to actual work exposures for a diverse group of workers (Jonsson and Ydreborg, 1985). The Nordic questionnaire (Kuorinka, *et. al.,* 1987) is one such tool used to elicit information about symptoms. Developers of the questionnaire established the reliability of the questionnaire. The questionnaire uses a graphical representation of the posterior aspect of a human silhouette divided into nine regions as a reference. The nine regions are neck, shoulders, upper back, elbows, low back, wrists/hands, hips/thighs, knees, and ankles/feet. Subjects may indicate the presence of symptoms in either or both body hemispheres. The questionnaire allows subjects to indicate whether any symptoms have been present within the last twelve months and within the last seven days. Severity of symptoms, if present, is identified by subjects indicating the degree to which the symptoms interfered with their level of function at work, at home or with leisure.

2.1.3 Pre-Test of Questionnaire

One general radiologic technologists from Duke Hospital, one sonographer in the community, and one general radiologic technologist from a different health care facility within the Duke University Health System were recruited to comment on the content,

language and level of confidence in responses to questions in Part 1. Their feedback was considered and incorporated in the final draft of the questionnaire

Prior to finalizing the questionnaire, it was pre-tested. Several radiologic technologists completed the questionnaire on a trial basis to

- ensure that questionnaire content was applicable to the participating facility
- weed out questions that seemed ambiguous or too complicated
- ensure that participants could be confident about the responses they would provide
- ensure that questions of a personal nature did not seem offensive to the participant (and act as a deterrent to participation)
- determine an estimated length of time required to complete the questionnaire
- ensure a high level of comfort with utilizing the Opscan form for responses, and
- confirm the accuracy of technical language used in the questionnaire.

See Appendix 1 to review instructions for the questionnaire trials and the questions asked after the questionnaire trials.

2.2 METHODOLOGY

This study utilized a cross-sectional design to investigate the prevalence and severity of musculoskeletal symptoms, levels of occupational stress as defined by a control-demands model focusing on factors such as psychological demands, decision latitude, social support, physical demands, and job insecurity, and physical exposures to ergonomic risk factors, and the relationships between these factors for a group of radiologic technologists. The relationship among clinical specialty, use of specific equipment, age, gender and race of individual workers, and prevalence and severity of musculoskeletal symptoms was also

investigated. Table 2.2 lists the independent and dependent variables for the specific aims introduced. A written questionnaire was used to collect data. Data collection took place over a period of approximately four months (February – May, 2001). It was assumed that the work environment and subject characteristics remained relatively stable during the data collection period. The protocol was approved by two committees which review the use of human subjects in research, one at Duke University Medical Center and one at North Carolina State University. See Appendices 7 and 8 for associated review board approval documentation.

Table 2.2 Independent and dependent variables

Independent Variables	Dependent Variables
Personal characteristics	Presence of musculoskeletal symptoms in any of the following areas: the back, neck, shoulders, or hands and wrists in past 12 months Presence of musculoskeletal symptoms in back, neck, shoulders, or hands and wrists in past 12 months Prevalence of musculoskeletal symptoms in the back, neck, shoulders, or hands and wrists in past seven days Interference of symptoms with work activities in past 12 months
Work history and characteristics: e.g. Years worked in the profession, Hours worked per week, Clinical specialty †	
Work task exposures	
Type of equipment used	

† General diagnostics, ultrasound, vascular and interventional, mammography, computed tomography, magnetic resonance, and contract workers

2.2.1 Subjects

The study population consisted of approximately 160 radiologic technologists employed by Duke University Health System. Subjects were recruited on a voluntary basis from the following specialty areas of practice in inpatient and outpatient settings within one radiology department: vascular and interventional, pediatrics, computed tomography, magnetic resonance, gastrointestinal, genitourinary, orthopedics, mammography, general ultrasound, fetal diagnostics and general diagnostic. Radiation therapy and nuclear medicine technology areas were excluded from the study due to administrative structure of the

participating facility. The facility offered managerial support and interest in outcome of the project, and this assisted with recruitment measures and participation rates.

2.2.2 Questionnaire Distribution

Questionnaires were distributed by the principal investigator at staff meetings over a period of approximately ten weeks. Area supervisors determined meeting times and locations. Alternative questionnaire distribution arrangements were made for those employees who could not or did not attend the staff meetings. Of the potential 189 participants, 30 were removed from the distribution list for various reasons. Seven performed primarily administrative duties. Fifteen technologists worked only on an "as needed" basis and were not at work regularly or frequently. Ten left the facility before or shortly after the questionnaires were administered. Investigators were not able to distribute a questionnaire packet to one of the technologists due to scheduling. This left a potential pool of 157 participants to recruit for the study. A total of 157 questionnaires were distributed over the course of four months.

The written instructions included in the questionnaire encouraged participants to complete and return the questionnaire within two weeks of receiving it. Subjects who returned their completed packet were entered into a drawing to win one of two $25.00 gift certificates to a local dining establishment. The drawing was held approximately two months after the last questionnaires were distributed.

The principal investigator provided each employee with a questionnaire packet that included the following items.

- A cover letter
- Instructions to complete the questionnaire
- Two copies of an Informed Consent Form. One copy was printed on green paper: Participants were instructed to retain the green copy for their own records.
- One Opscan form to be used for responses to Part 2 of the questionnaire
- Two envelopes, pre-addressed to the principal investigator.
- One sharpened No. 2 pencil, located in one of the two campus envelopes.

Major components of the final questionnaire packet are available in Appendix 2. The approved Informed Consent form may be found in Appendix 6.

Two envelopes were provided so that questionnaire responses could travel through the mail separately from the signed informed consent forms, primarily to preserve participant confidentiality. The following components of each questionnaire were marked with a unique questionnaire number so they could be matched up after traveling through campus mail: questionnaire Part 1, questionnaire Part 2, white copy of the Informed Consent Form, green copy of Informed Consent Form. The unique identification number was used to identify participants for the purposes of data analysis, rather than subjects' names. Note that, although participants were not expected to return the green copy of the Informed Consent Form, it was labeled with the unique identification number, because it was foreseeable that they may have returned it instead of the white copy.

2.2.3 Follow-Up Procedures

A series of up to three follow-up letters were sent to those individuals who received a questionnaire. The campus mail system was used to distribute the letters. One week after the date of questionnaire distribution, a follow up letter was sent to all individuals whether or not response packets and Informed Consent Forms had been returned. The letter expressed

gratitude to those who had returned the questionnaire, and served as a reminder to those who had not. Three weeks after the date of distribution, a letter was sent to those whose questionnaires had not been received. The purpose of the second letter was to serve as a reminder of the research project and express the importance of their participation. Seven weeks to two months after the questionnaire distribution date, a final letter was sent via campus mail to those who had not returned their responses and Informed Consent Forms. The letter explained that the questionnaire period was coming to a close, that it was not too late to participate and that their participation was important to the outcome of the study. Preservation of confidentiality of their responses was reviewed in the second and third follow-up letters. The three follow-up letters are located in Appendices 3, 4, and 5. This method of follow-up to promote participation with research questionnaires was adapted from Dillman (2000).

2.3 DATA MANAGEMENT AND STATISTICAL ANALYSIS

Questionnaire distribution, responses, and follow-up letter scheduling were tracked in a Microsoft Excel spreadsheet. Questionnaire responses on the Opscan forms were processed by the Computing Center at North Carolina State University and subsequently organized along with the other manually entered responses within a Microsoft Excel spreadsheet. SAS 8.2 Software (SAS, Cary, North Carolina, USA, 2001) was used for most of the statistical analyses. Descriptive statistics were generated. Frequency tables were used to show distributions and percentages of responses for discrete data variables. Frequency tables were generated for categorical variables and the mean, range and standard deviation were generated for age of participants.

Unadjusted odds ratios were calculated (using PROC GENMOD with the LINK function LOGIT) to examine relationships among presence of musculoskeletal symptoms in the past year and age, gender, clinical specialty and work exposures. Age, gender and any other variables determined to have a statistically significant ($p < .05$) or clinically relevant association with the presence of musculoskeletal symptoms in the past year were used in multivariate logistic regression models. Since this was a preliminary study, variables whose crude odds ratios were less than or equal to 0.50 or greater than or equal to 2.0 were considered in the multivariate analysis of adjusted odds ratios, regardless of their confidence intervals. These criteria were selected arbitrarily as an easy way to ensure liberal inclusion of variables in the multivariate analyses. This was not based on any particular statistical method.

Mean scores for the Job Content Questionnaire responses were calculated in SAS from responses of all technologists in this study. The two-tailed independent t-test for samples of different size, assuming unequal variances, was used to determine if the scores for the radiologic technologists in this study were different from those of aggregated occupational group scores for other health technologists and for nurses. Mean scale scores for these groups are provided in the Job Content Questionnaire and User's Guide (Karasek, *et. al*., 1985) which were calculated from aggregated scores of previously studied groups. Microsoft Excel (1997) was used to perform calculations according to the formulas for the approximation of Student's t-statistic (t') with degrees of freedom (v'), shown below (Steel, *et. al*., 1997).

Equation 1. Calculation of *t* prime, the approximation of Student's *t*

$$t' = (\bar{X}_1 - \bar{X}_2) / [(s_1^2 / n_1) + (s_2^2 / n_2)]^{1/2}$$

Equation 2. Calculation of the effective df for *t* prime

$$v' = [(s_1^2 / n_1) + (s_2^2 / n_2)]^2 / [(s_1^2 / n_1)^2 / (n_1 - 1) + (s_2^2 / n_2)^2 / (n_2 - 1)]$$

Chapter 3

RESULTS

3.1 RESPONSE TO THE QUESTIONNAIRE

A total of 90 questionnaires were completed and returned for a participation rate of 57.3%. Two technologists terminated employment at the facility shortly after receiving their questionnaires. During the course of the study, seven individuals contacted the principal investigator and requested to be removed from the list of participants due to lack of time to complete the questionnaire or interest in participating in the study. Note those technologists who requested to be removed from the study are included in the denominator for the calculated participation rate. However, technologists who did not qualify to participate due to the type of work they performed or the frequency of shifts they worked, who terminated their employment shortly after receiving the questionnaire, or who were no longer employed at the facility are not included in this rate. For example, those technologists who performed primarily administrative or non-clinical work, those who were scheduled on only a p.r.n. or "as needed" basis, and those who were on medical or personal leaves of absence were not included. Sixty-nine technologists did not return their questionnaires.

3.1.1 Timing of Responses and Follow-Up Letters

Table 3.1 shows the timing of the receipt of the questionnaires after they were distributed. The completed questionnaires of twenty-two technologists were received within one week of distributing the questionnaire packet to them. Seventy-one technologists

returned their questionnaires within 3 weeks of receiving the packet. After 94 three-week follow-up letters were sent 19 more completed questionnaires were returned. None of the technologists to whom the final follow-up letter was sent, per our protocol, responded to the questionnaire. In fact, three technologists contacted the principal investigator to request they be removed from the distribution list subsequent to receiving the final follow-up letter. Table 3.2 shows overall response rates and those for individual work groups.

Table 3.1 Timing of responses from radiologic technologists

Response time (days) from date of distribution	Number of questionnaires received within each period n (%)	Cumulative number of questionnaires received n (%)
Up to 7 days	22 (24%)	22 (24%)
8-21 days	49 (54%)	71 (78.9%)
22-39 days	19 (21%)	90 (100%)
40-70	0 (0%)	90 (100%)

Table 3.2 Summary of participation rates for each work group

Work Group	Total # Administered[a]	Returned[b] (Work Group per Pay Roll)	Returned (Work Group per Response Provided on Questionnaire)	Non-Response[c]	Response Rates (%)
Computed Tomography (CT)	27	15	16	12	**55.6**
Interventional/Vascular (IV)	6	4	5	2	**66.7**
Mammography (MM)	7	6	8	1	**85.7**
Magnetic Resonance (MR)	16	8	10	8	**50.0**
General Radiologic (RT)	66	36	29	30	**54.5**
Ultrasound (US)	22	14	15	8	**63.6**
Contract (CON)	13	7	7	6	**53.8**
TOTALS	**157**	**90**	**90**	**67**	**57.3**

[a]Does not include two technologists who terminated employment shortly after receiving questionnaire
[b]Work group assignment based on payroll information varies slightly from actual assigned work group
[c]Includes those who did not return questionnaires that were administered and those who actively requested to be removed from the recruitment list

3.2 MANAGEMENT OF VARIABLES

Multiple categorical variables were condensed due to the small sample size and response distributions. Categories used in statistical analysis are summarized in Table 3.4 and in results tables.

3.2.1 Work Exposure Variables

3.2.1.1 Definitions of Work Exposure Variables

Brief descriptors for task exposures are used throughout the text. Table 3.3 lists the descriptors for the work exposure variables and their definitions as they relate back to the wording on the questionnaire. Although most of these descriptors and their definitions are clear, some may be unique to the field of radiologic technology. For example, "perform exams" is intended to represent the physical act of taking an x-ray, performing an ultrasound exam, obtaining a magnetic resonance image or computed tomography, etc. "Analyzing exams" is intended to describe the act of reviewing the images obtained from performing the exams. For example, in ultrasound, after a scan is completed, the technologist often reviews the images in a remote location, often conferring with the patient's physician, to determine if additional scanning is necessary. "Transport objects" refers to moving non-patient loads such as portable x-ray or ultrasound equipment, special boards or positioners for x-rays, etc.

Table 3.3 Definitions of task exposure descriptors

Task Exposure Descriptor	Definition, per Questionnaire
Perform Exams	Perform exams or clinical studies
Analyze Exams	Analysis or critiquing of exams or study results
Grip Equipment	Grip, grasp, or manipulate equipment with hand
Push or Pull Equipment	Push or pull equipment
Lift Equipment	Lift equipment (not including cassettes)
Transport Objects	Transport objects or equipment (not including patients)
Transport Patients	Transport patients to and from their hospital rooms, between facilities, or between departments
Transfer Patients	Transfer patients who offer little or no assistance
Use Equipment for Patient Transfers	Use equipment to assist with patient transfers
Position Patients	Position or re-position patient who offer little or no assistance
Carry Patients	Carry patients over a distance greater than 5 feet
Perform Administrative Tasks	Meetings, training, etc.
Perform Computer Work	Computer work (data entry or processing, e-mail, etc.)
Supervise Others	Supervise other staff members

3.2.1.2 Grouping of Responses for Work Exposures

Due to the relatively small number of participants and distribution of responses, the following modifications were made to maximize statistical power of the data analysis. Responses for work exposures, originally based on a scale of five responses: "Many times per day," "Daily," "Weekly," "Less than once per week," or "Not at all" were condensed into two groups: "Many times per day" or "Other." This method of grouping the variables separated high levels of potential exposures (many times per day) from the lower exposure levels. However, it also resulted in some groups being small. The exceptions to this

modification for the work exposure responses were applied to exposures that were hypothesized to be protective for the development of musculoskeletal disorders: administrative work, and supervising others. In these cases, responses were condensed into two groups: "Less than once per week or not at all" and "Other." Since it was not clear whether use of equipment for patient transfers would be protective for the development of musculoskeletal disorders, the responses for this task exposure were condensed into the same two groups as the majority of the other task exposures, "Many times per day" or "Other." Lead apron use, estimated in hours per week, was characterized by five responses on the questionnaire, but reduced to two groups for analysis purposes: "0-20 hours" and "21 or more hours." Twenty hours was selected as a cut-off point because it would represent approximately half the hours of a full time technologist and because other research related to lead apron use have not established other parameters to use for exposure to lead apron use.

3.2.2 Demographic Variables

"Age" was condensed into two groups: "Less than 40 years" and "40 years or older," Which allowed for relatively even distribution between two groups. "Race" was condensed from four responses to two: "White" and "Non-white." Responses for "Years worked," originally with five response groups, were condensed to two groups: "Less than or equal to 15 years" and "Greater than 15 years," to balance the number of technologists in each group as much as possible. Responses for "Number of hours worked per week" were condensed from five to three groups: "Less than or equal to 30 hours," "31-40 hours," and "41 or more hours." In this way, technologists who worked part time (less than 31 hours) would be

distinguished from technologists who worked full time. And those who tended to work over time or more than 40 hours would also be distinguished from other groups.

"Work group" was the primary variable used to represent the technologists' clinical subspecialties. There were originally a total of six groups: Computed Tomography (CT), Interventional/Vascular (IV), Mammography (MM), Magnetic Resonance (MR), General Radiology (RT), and Ultrasound (US). During the distribution of the questionnaires it became evident that there were a number of technologists who worked on a contract basis, but had worked consistently within the health system where the study was taking place. In order to maximize the total participation in the study, a new group called "Contract" was developed and used to describe the contract workers. However, with a total of 90 participants, the number in each work group was quite small. The decision to group the technologists into two groups (sonographer and non-sonographer) was based, not on the numbers of technologists in each group, but on the substantial body of research previously described, which characterized, in part, the musculoskeletal disorders associated with sonography. Condensing the work groups in this way could allow comparisons between the sonographers and other technologists and between sonographers in this study and those described in previously published research.

Table 3.4 Frequency of responses and percentages of all respondents used for generating crude and adjusted odds ratios

Variable	Group	n	%
Age, yrs	< 40	43	47.8
	≥ 40	47	52.2
Gender	Male	16	17.8
	Female	74	82.2
Race	Non-White	12	13.3
	White	78	86.7
Years Worked	≤ 15	38	42.2
	>15	52	57.8
Hours Worked Per Week	≤ 30	11	12.2
	31-40	43	47.8
	41+	36	40
Work Group	Sonographers	15	16.7
	Non-Sonographers	75	83.3
Perform Exams	Many Times / Day	71	78.9
	Other[a]	19	21.1
Analyze Exams	Many Times / Day	60	66.7
	Other[a]	30	33.3
Grip Equipment	Many Times / Day	82	91.1
	Other[a]	8	8.9
Push or Pull Equipment	Many Times / Day	70	77.8
	Other[a]	20	22.2
Lift Equipment	Many Times / Day	35	38.9
	Other[a]	55	61.1
Transport Objects	Many Times / Day	36	40
	Other[a]	54	60
Transport Patients	Many Times / Day	8	8.9
	Other[a]	82	91.1
Transfer Patients	Many Times / Day	33	36.7
	Other[a]	57	63.3
Use Equipment for Patient Transfers	Many Times / Day	10	11.1
	Other[a]	80	88.9
Position Patients	Many Times / Day	44	48.9
	Other[a]	46	51.1
Carry Patients	Many Times / Day	3	3.3
	Other[a]	87	96.7
Perform Administrative Tasks	Less than 1x/wk or Not at all	69	76.7
	Weekly or More Frequently	21	23.3
Perform Computer Work	Many Times / Day	73	81.1
	Other[a]	17	18.9
Supervise Others	Less than 1x/wk or Not at all	55	61.1
	Weekly or More Frequently	35	38.9
Wearing a Lead Apron	≤ 20 hours per week	85	94.4
	>20 hours per week	5	5.56

[a] Once per day or less frequently

3.3 PERSONAL CHARACTERISTICS OF RESPONDENTS

Of the 90 respondents, 82% were female and 18% were male. Only 79 of them provided their year of birth to indicate age. The mean age of the group who provided their year of birth was 41.4 years (range, 25-58 years). Almost 89% were white and 11.4% non-white. Eighty-nine percent of respondents had attended two to four years of college. Although 58% had over 16 years of work experience, 43% had worked with their current employer for five years or less. Eighty-eight percent reported working 31 or more hours per week.

3.4 MEDICAL HISTORIES AND HISTORIES OF TRAUMA

3.4.1 Medical Histories

Medical histories and diagnoses are summarized in Figure 3.1. Almost 45% of participants reported a history of taking oral contraceptives or a hysterectomy in the past year. Almost 30% of respondents reported having been diagnosed with tendinitis (29%), arthritis (18%), thyroid dysfunction (8%), or carpal tunnel syndrome (8%). Less than 5% of respondents reported having been diagnosed with any one of the other medical conditions that may be associated with symptoms of musculoskeletal disorders.

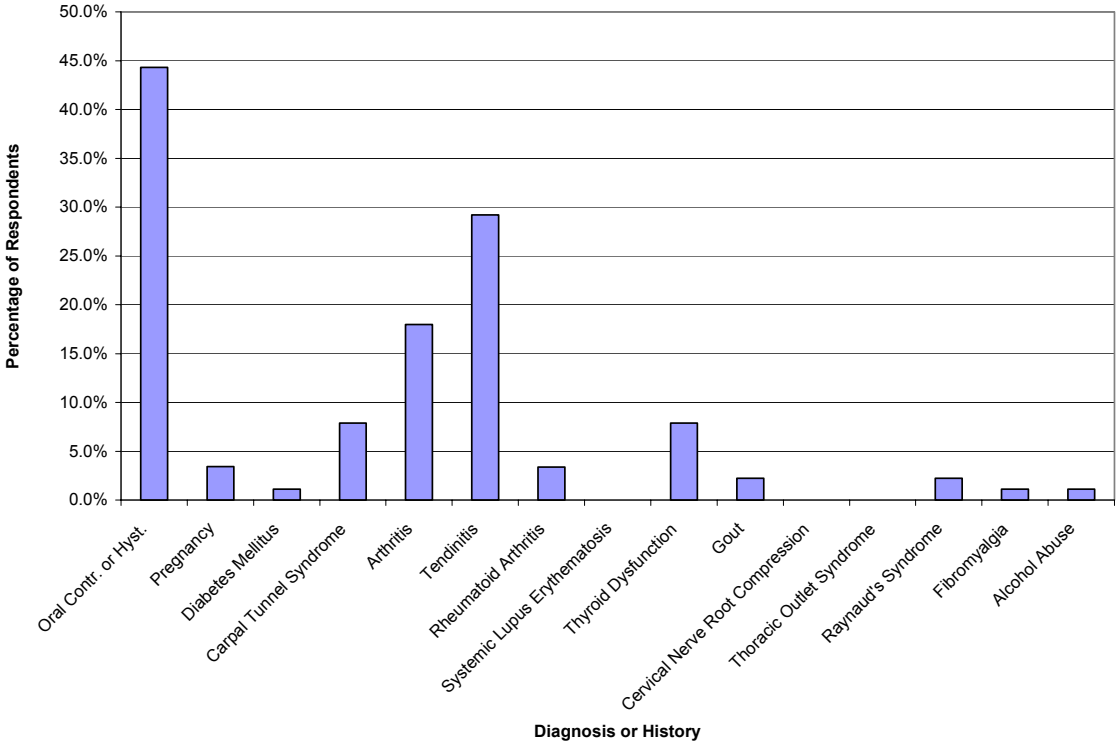

Figure 3.1 History of diagnosis with a medical condition

3.4.2 Histories of Trauma to Body Regions

Reported history of trauma to a major body part is summarized in Figure 3.2. .Between 10% and 15% of respondents reported a positive history of experiencing trauma to the following body regions: eye, neck, right shoulder, right wrist, left wrist or upper back. Thirty percent of respondents reported the same history in the low back region. The questionnaire did not discern between occupational and non-occupational sources of trauma to these body regions, so the details of these experiences are not known.

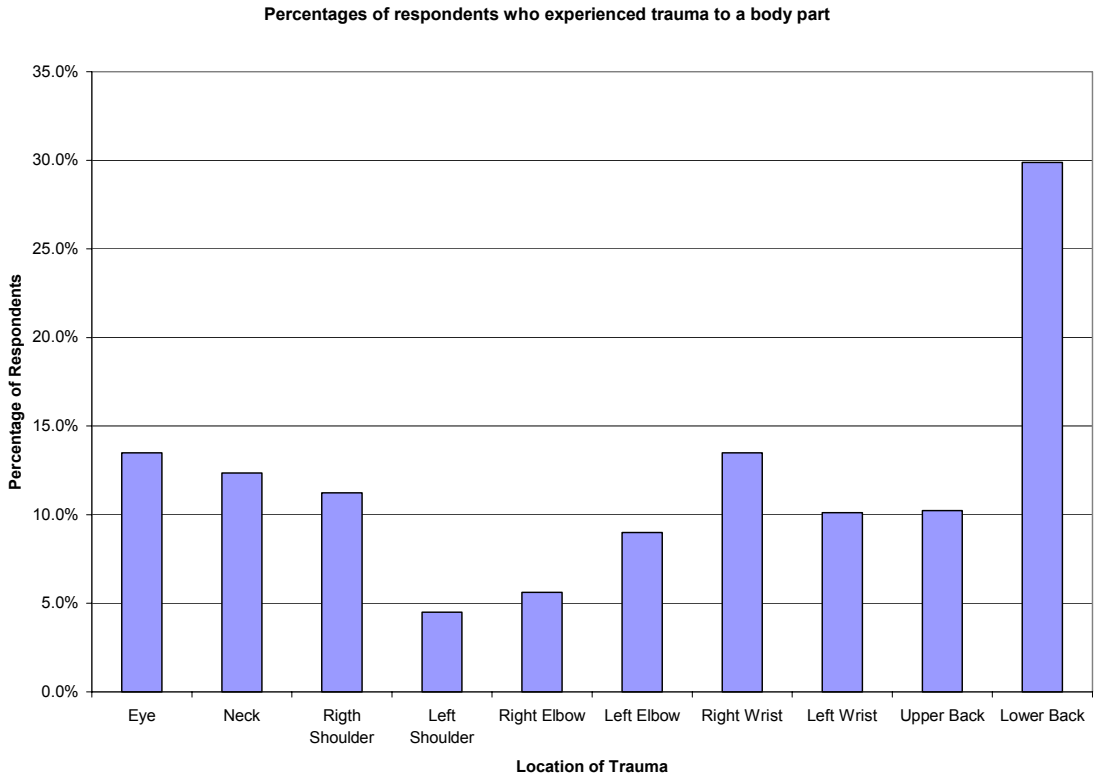

Figure 3.2 History of trauma to a major body part

3.5 OCCUPATIONAL FEATURES OF THE RESPONDENTS

The respondents worked in six clinical subspecialty areas or were contract workers. A breakdown of the groups and the percentage of respondents who worked in each group can be found in Table 3.6. A majority of these respondents worked the first shift (81.1%) or were "on call" zero to two days per week (92.2%). Thirty-two percent reported earning $45,000 or less per year and 64.4% earned over $45,000 annually. Most respondents worked with primarily adult patients (77.8%), versus pediatric patients (10%), or equal numbers of each (12.2%). Approximately 41% reported working primarily with outpatients, versus inpatients (21.1%), or equal numbers of each (37.8%). When asked to estimate the percentage of their

patients who were obese, fifty-nine percent of the technologists estimated that at least 41% of their patients were obese. Seventy-two percent of the technologists reported that their exam procedures were more difficult when performed on obese patients. This response was most prominent among sonographers (100%) and mammography technologists (75%).

Interviews indicated that some technologists worked in more than one clinical area, so participants were given the opportunity to indicate their secondary location of practice on their questionnaire. However, since several technologists listed more than one secondary work location, it was determined that this question was misunderstood, possibly due to poor wording, and was not considered.

3.6 MUSCULOSKELETAL SYMPTOMS AND TASK EXPOSURES: DESCRIPTIVE STATISTICS

3.6.1 Prevalence and Location of Musculoskeletal Symptoms

Table 3.5 demonstrates the prevalence of symptoms and the body parts affected and the prevalence of interference of symptoms with work and leisure activities. Eighty-nine percent of respondents had experienced musculoskeletal symptoms within the prior twelve months. Shoulder symptoms in the past year were predominantly reported in the right shoulder (28.9%) compared to the left shoulder (7.8%) or both shoulders (12.2%). Similarly, prevalence of symptoms in the right wrist/hand (25.6%) exceeded those for the left wrist/hand (5.6%) or both wrists/hands (10%). Over half (52.2%) of the participants reported neck symptoms. Low back symptoms in the past year were reported by over 73% of respondents. Over half reported their musculoskeletal symptoms interfered with work

(57.8%) or with leisure activities (58.9%). Symptoms in the low back resulted in the highest percentage of technologists who reported interference of symptoms with work or leisure.

Table 3.5 Twelve month prevalence of musculoskeletal symptoms, interference with work, and interference with leisure activities for each body region[a]

	Prevalence Percent (n)		
	Symptoms % (n)	**Interference with Work % (n)**	**Interference with Leisure % (n)**
Overall	88.90% (80)	57.80% (52)	58.90% (53)
Upper Extremity			
Shoulders (Any)	36.7% (33)	17.8% (16)	18.9% (17)
Right Shoulder	28.9% (26)	10% (9)	8.9% (8)
Left Shoulder	7.8% (7)	5.6% (5)	5.6% (5)
Both Shoulders	12.2% (11)	2.2% (2)	4.4% (4)
Wrists/Hands (Any)	31.1% (28)	14.4% (13)	17.8% (16)
Right Wrist/Hand	25.6% (23)	7.8% (7)	10% (9)
Left Wrist/Hand	5.6% (5)	2.2% (2)	2.2% (2)
Both Wrists/Hands	10.0% (9)	4.4% (4)	5.6% (5)
Axial Skeleton			
Neck	52.2% (47)	14.4% (13)	22.2% (20)
Low Back	73.3% (66)	36.7% (33)	40.0% (36)

[a] Percentages based on total number of respondents for each item

Table 3.6 Personal characteristics and 12 month prevalence of musculoskeletal symptoms[a]

	MS Symptoms in Last 12 Months %(n)	No MS Symptoms in Last 12 Months %(n)	Totals %(n)
Overall	88.9% (80)	11.1% (10)	100% (90)
Age (years)	n=71	n=8	n=79
Mean (Range) s.d.	41.3 (25-58), 8.2	42.9 (35-58), 8.2	41.4 (25-58), 8.2
Age (n= , Mean years, s.d)			
< 40	n=28, 32.8, s.d.=3.5	n=4, 36.5, s.d.=1.7	n=32, 33.3, s.d.=3.5
≥ 40	n=43, 46.8, s.d.=5.1	n=4, 49.2, s.d.=6.8	n=47, 47, s.d.=5.2
Gender	n=79	n=10	n=89
Male	75% (12)	25% (4)	18% (16)
Female	91.8% (67)	8.2% (6)	82% (73)
Race	n=78	n=10	n=88
White	88.5% (69)	11.5% (9)	88.6% (78)
Other	90% (9)	10% (1)	11.4% (10)
Education Completed	n=78	n=10	n=88
High School	80% (4)	20% (1)	5.7% (5)
Junior College (2 yrs)	91.7% (44)	8.3% (4)	54.4% (48)
College (4 yrs)	87.5% (28)	12.5% (4)	36.4% (32)
Graduate School	66.7% (2)	33.3% (1)	3.4% (3)
Years Worked	n=80	n=10	n=90
0-15	92.1% (35)	7.9% (3)	42.2% (38)
16+	86.5% (45)	13.5% (7)	57.8% (52)
Hours Worked per Week	n=80	n=10	n=90
0-30	90.9% (10)	9.1% (1)	12.2% (11)
31-40	90.7% (39)	9.3% (4)	47.8% (43)
>40 hours	86.1% (31)	13.9% (5)	40% (36)
Work Group	n=80	n=10	n=90
CT	93.8% (15)	6.25% (1)	17.8% (16)
IV	80% (4)	20% (1)	5.6% (5)
MM	100% (8)	0% (0)	8.9% (8)
MR	90% (9)	10% (1)	11.1% (10)
RT	93.1% (27)	6.9% (2)	32.2% (29)
US	86.7% (13)	13.3% (2)	16.7% (15)
CONTRACT	57.1% (4)	42.9% (3)	7.8% (7)

[a] Percentages based on total number of respondents for each item

3.6.2 Work Exposures and Symptoms in the Past Year

Frequencies of work exposures for radiologic technologists who did and did not have musculoskeletal symptoms in the past year are summarized in Table 3.7. Technologists who experienced musculoskeletal symptoms in the past year performed exams, analyzed exams, gripped equipment, pushed or pulled equipment, and performed computer work "many times per day." Tasks they performed less frequently include lifting equipment, transporting objects, transporting patients, transferring patients and carrying patients. Most of them used equipment to assist with patient transfers daily or less frequently. In general, they performed administrative work infrequently. Almost one third of them were responsible for supervising others weekly or more frequently. Very few technologists wore a lead apron for greater than 20 hours per week.

Table 3.7 Work exposure frequencies and 12 month prevalence of musculoskeletal symptoms[a]

	MS Symptoms in Last 12 Months %(n)	No MS symptoms in Last 12 Months %(n)	Totals %(n)
Overall	88.9% (80)	11.1% (10)	100% (90)
Perform Exams	n=79	n=10	n=89
Many times/day	88.7% (63)	11.3% (8)	79.8% (71)
Other[b]	20.3% (16)	11.1% (2)	20.2% (18)
Analyze Exams	n=78	n=9	n=87
Many times/day	91.7% (55)	8.3% (5)	69% (60)
Other[b]	85.2% (23)	14.8% (4)	30.3% (27)
Grip Equipment	n=80	n=10	n=90
Many times/day	89% (73)	11% (9)	91.1% (82)
Other[b]	87.5% (7)	12.5% (1)	8.9% (8)
Push or Pull Equipment	n=80	n=10	n=90
Many times/day	87.1% (61)	12.9% (9)	77.8% (70)
Other[b]	95% (19)	5% (1)	22.2% (20)
Lift Equipment	n=78	n=10	n=88
Many times/day	88.6% (31)	11.4% (4)	39.8% (35)
Other[b]	88.7% (47)	11.3% (6)	60.2% (53)
Transport Objects	n=79	n=10	n=89
Many times/day	88.9% (32)	11.1% (4)	40.4% (36)
Other[b]	88.7% (47)	11.3% (6)	59.6% (53)
Transport Patients	n=80	n=10	n=90
Many times/day	62.5% (5)	37.5% (3)	8.9% (8)
Other[b]	91.5% (75)	8.5% (7)	91.1% (82)
Transfer Patients	n=80	n=10	n=90
Many times/day	84.8% (28)	15.2% (5)	36.7% (33)
Other[b]	91.2% (52)	8.8% (5)	63.3% (57)
Use Equipment for Patient Transfers	n=80	n=10	n=90
Many times/day	80% (8)	20% (2)	11.1% (10)
Other[b]	90% (72)	10% (8)	88.9% (80)
Position Patients	n=80	n=10	n=90
Many times/day	88.6% (39)	11.4% (5)	48.9% (44)
Other[b]	89.1% (41)	10.9% (5)	51.1% (46)

Table 3.7 (continued)

Carry Patients	n=79	n=10	n=89
Many times/day	66.7% (2)	33.3% (1)	3.4% (3)
Other[b]	89.5% (77)	10.5% (9)	96.6% (86)
Administrative Work	n=78	n=10	n=88
Weekly or more frequently	89.5% (17)	10.5% (2)	21.6% (19)
Less than 1x/wk or not at all	88.4% (61)	11.6% (8)	78.4% (69)
Supervise Others	n=80	n=10	n=90
Weekly or more frequently	85.7% (30)	14.3% (5)	38.9% (35)
Less than 1x/wk or not at all	90.9% (50)	9.1% (5)	61.1% (55)
Computer Work	n=80	n=10	n=90
Many times/day	90.4% (66)	9.6% (7)	81.1% (73)
Other[b]	82.4% (14)	17.6% (3)	18.9% (17)
Wearing a Lead Apron	n=80	n=10	n=90
≤ 20 hours per week	89.4% (76)	10.6% (9)	94.4% (85)
>20 hours per week	80% (4)	20% (1)	5.6% (5)

[a] Percentages based on total number of respondents for each item
[b] Once per day or less frequently

3.6.3 Interference of Symptoms with Work Activities

The distribution of respondents for demographic and task exposure information by positive or negative interference of symptoms with work is summarized in Tables 3.8 and 3.9. Over half (57.8%) of the respondents experienced musculoskeletal symptoms in the past year and reported they interfered with work activities. Less than one third (31%) reported no interference of symptoms with work activities. Magnetic resonance technologists had the lowest rate of interference of symptoms with work activities (only 10%). All of the interventional technologists and contract workers who experienced symptoms also reported interference with work activities. This represented 80% of interventional technologists, the highest rate of interference with work for any of the work groups. Sixty-three percent (63%) of females reported that symptoms interfered with work activities, compared to only 31% of males.

Table 3.8 Personal characteristics frequencies and prevalence of symptoms interference with work in past 12 months[a]

	Work Interference in Last 12 Months % (n)	No Work Interference in Last 12 Months % (n)	No Symptoms Reported % (n)
Overall	57.8 (52)	31.1% (28)	11.1% (10)
Age (years)	n=45	n=26	n=8
Mean (Range), s.d.	41.7(27-58), 7.8	40.42(25-58), 9.1	42.9(35-58), 8.2
Age (n= , Mean years, s.d.)			
< 40	n=16, 33.1, s.d.=2.9	n=12, 32.3, s.d.=4.2	n=4, 36.5, s.d.=1.7
≥ 40	n=29, 46.5, s.d.=4.9	n=14, 47.4, s.d.=5.6	n=4, 49.3, s.d.=6.8
Gender	n=51	n=28	n=10
Male	31.3% (5)	43.8% (7)	25.0% (4)
Female	63.0% (46)	28.8% (21)	8.2% (6)
Race	n=50	n=28	n=10
White	59% (46)	29.5% (23)	11.5% (9)
Other	40% (4)	50% (5)	10% (1)
Education Completed	n=50	n=28	n=10
High School	20% (1)	60% (3)	20% (1)
Junior College (2 yrs)	64.6% (31)	27.1% (13)	8.3% (4)
College (4 yrs)	50% (16)	37.5% (12)	12.5% (4)
Graduate School	66.7% (2)	0% (0)	33.3% (1)
Years Worked	n=52	n=28	n=10
0-15	60.5% (23)	31.6% (12)	7.9% (3)
16+	55.8% (29)	30.8% (16)	14.1% (7)
Hours Worked per Week	n=52	n=28	n=10
0-30	72.7% (8)	18.2% (2)	9% (1)
31-40	55.8% (24)	34.9% (15)	9.3% (4)
>40 hours	55.6% (20)	30.6% (11)	13.9% (5)
Work Group	n=52	n=28	n=10
CT	56.3% (9)	37.5% (6)	6.3% (1)
IV	80% (4)	0% (0)	20% (1)
MM	50% (4)	50% (4)	0% (0)
MR	10% (1)	80% (8)	10% (1)
RT	69.0% (20)	24.1% (7)	6.9% (2)
US	66.7% (10)	20% (3)	13.3% (2)
Contract	57.1% (4)	0% (0)	42.9% (3)

[a] Percentages based on total number of respondents for each item

Table 3.9 Work exposures frequencies and prevalence of symptoms interference with work in past 12 months[a]

	Work Interference in Last 12 Months % (n)	No Work Interference in Last 12 Months % (n)	No Symptoms Reported % (n)
Overall	57.8% (52)	31.1% (28)	11.1% (10)
Perform Exams	n=51	n=28	n=10
Many times/day	56.3% (40)	32.4% (23)	11.3% (8)
Other[b]	61.1% (11)	27.8% (5)	11.1% (2)
Analyze Exams	n=51	n=27	n=10
Many times/day	61.7% (37)	30% (18)	8.3% (5)
Other[b]	51.9% (14)	33.3% (9)	14.8% (4)
Grip Equipment	n=52	n=28	n=10
Many times/day	57.3% (47)	31.7% (26)	11% (9)
Other[b]	62.5% (5)	25% (2)	12.5% (1)
Push or Pull Equipment	n=52	n=28	n=10
Many times/day	52.9% (37)	34.3% (24)	12.9% (9)
Other[b]	75% (15)	20% (4)	5% (1)
Lift Equipment	n=50	n=28	n=10
Many times/day	48.6% (17)	40% (14)	11.4% (4)
Other[b]	62.3% (33)	26.4% (14)	11.3% (6)
Transport Objects	n=51	n=28	n=10
Many times/day	55.6% (20)	33.3% (12)	11.1% (4)
Other[b]	58.5% (31)	30.2% (16)	11.3% (6)
Transport Patients	n=52	n=28	n=10
Many times/day	37.5% (3)	24% (2)	37.5% (3)
Other[b]	59.8% (49)	31.7% (26)	8.5% (7)
Transfer Patients	n=52	n=28	n=10
Many times/day	51.5% (17)	33.3% (11)	15.2% (5)
Other[b]	61.4% (35)	29.8% (17)	8.8% (5)
Use Equipment for Patient Transfers	n=52	n=28	n=10
Many times/day	40% (4)	40% (4)	20% (2)
Other[b]	60% (48)	30% (24)	10% (8)
Position Patients	n=52	n=28	n=10
Many times/day	61.4% (27)	27.3% (12)	11.4% (5)
Other[b]	54.3% (25)	34.8% (16)	10.9% (5)

Table 3.9 (continued)

Carry Patients	n=51	n=28	n=10
Many times/day	66.7% (2)	0% (0)	33.3% (1)
Other[b]	57% (49)	32.6% (28)	10.5% (9)
Administrative Work	n=51	n=27	n=10
Less than 1x/week or not at all	57.9% (11)	31.6% (6)	10.5% (2)
Weekly or more frequently	53.3% (40)	36% (27)	10.7% (8)
Supervise Others	n=52	n=28	n=10
Less than 1x/week or not at all	54.3% (19)	31.4% (11)	14.3% (5)
Weekly or more frequently	60% (33)	30.9% (17)	9.1% (5)
Computer Work	n=52	n=28	n=10
Many times/day	54.8% (40)	35.6% (26)	9.6% (7)
Other[b]	70.6% (12)	11.8% (2)	17.6% (3)
Wearing a Lead Apron	n=52		
≤ 20 hours per week	56.5% (48)	33% (28)	10.6% (9)
>20 hours per week	80% (4)	0% (0)	20% (1)

[a] Percentages based on total number of respondents for each item
[b] Once per day or less frequently

3.6.4 Prevalence of Symptoms in the Past Year, by Work Group and Body Part

Twelve month prevalence of musculoskeletal symptoms for each work group is summarized in Figure 3.3. Between 55% and 80% of all work groups reported musculoskeletal symptoms in the low back in the past year. These rates were highest among interventional technologists (80%) and magnetic resonance technologists (80%). Prevalence of neck symptoms was highest among mammography technologists (87.5%), computed tomography technologists (68.8%), and sonographers (73.3%). Sonographers had the highest prevalence of reported shoulder symptoms (80%) in the past year. Approximately half of the general radiologic technologists (55%), magnetic resonance technologists (50%), and mammography technologists (50%) also reported shoulder symptoms in the past year.

Contract workers had the lowest rate of neck symptoms and shoulder symptoms compared to other work groups. Hand and wrist symptoms were most prevalent among sonographers (60%) and computed tomography technologists (50%), and contract workers (43%).

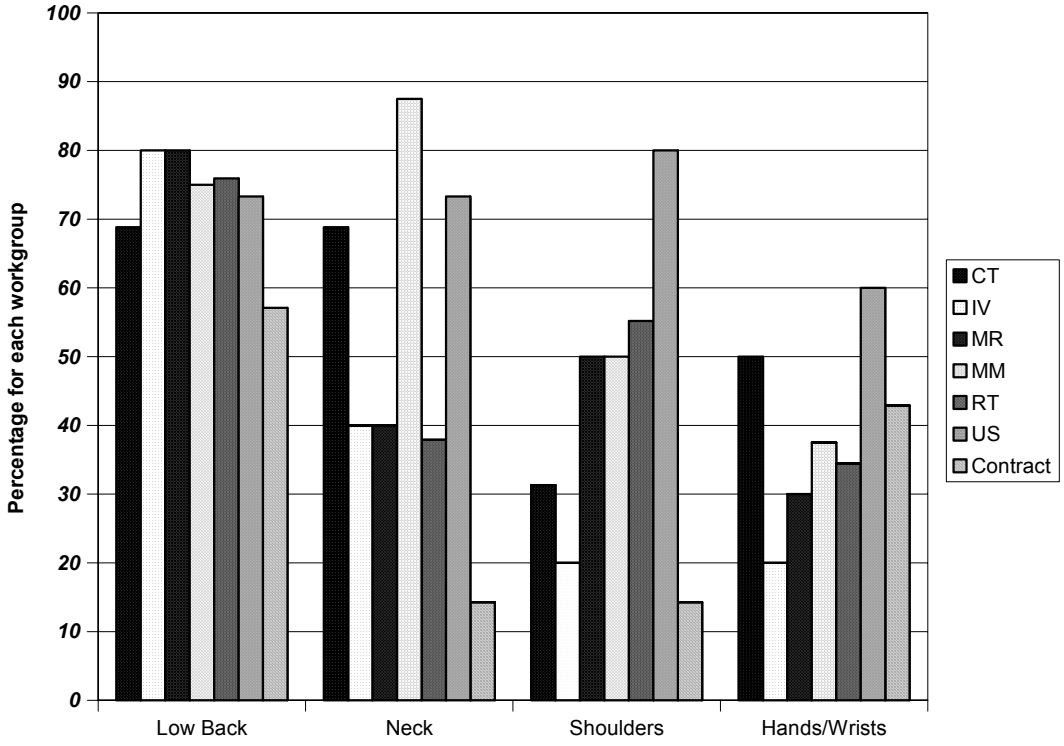

Figure 3.3 Twelve-month prevalence of musculoskeletal symptoms for each body region reported by radiologic technologists in each work group

3.6.5 Prevalence of Symptoms in the Past Week, by Work Group and Body Part

Prevalence of symptoms in the past week by work group and body part are summarized in Figure 3.4. The highest prevalence of recent musculoskeletal symptoms in the low back was seen in the magnetic resonance technologists (40%) and the general radiology technologists (37.9%). Previous research had indicated that there was a high prevalence of back pain among radiolgoic technolgoists. Observations of work performed by

radiologic technologists prior to administering the questionnaire revealed they perform many tasks that required use of awkward back posture or forceful motions. So, this result was expected for the general radiologic technologists based on previous research, but not for the magnetic resonance technologists. Sonographers had the highest prevalence of reported recent neck and shoulder symptoms (40% for both regions). Computed tomography technologists had the highest prevalence of hand and wrist symptoms (37.5%) compared to other work groups. Interventional technologists did not experience any symptoms in the neck or shoulders in the past week. Mammography techs did not experience any shoulder symptoms in the past week. Magnetic resonance technologists did not experience any shoulder symptoms in the past week.

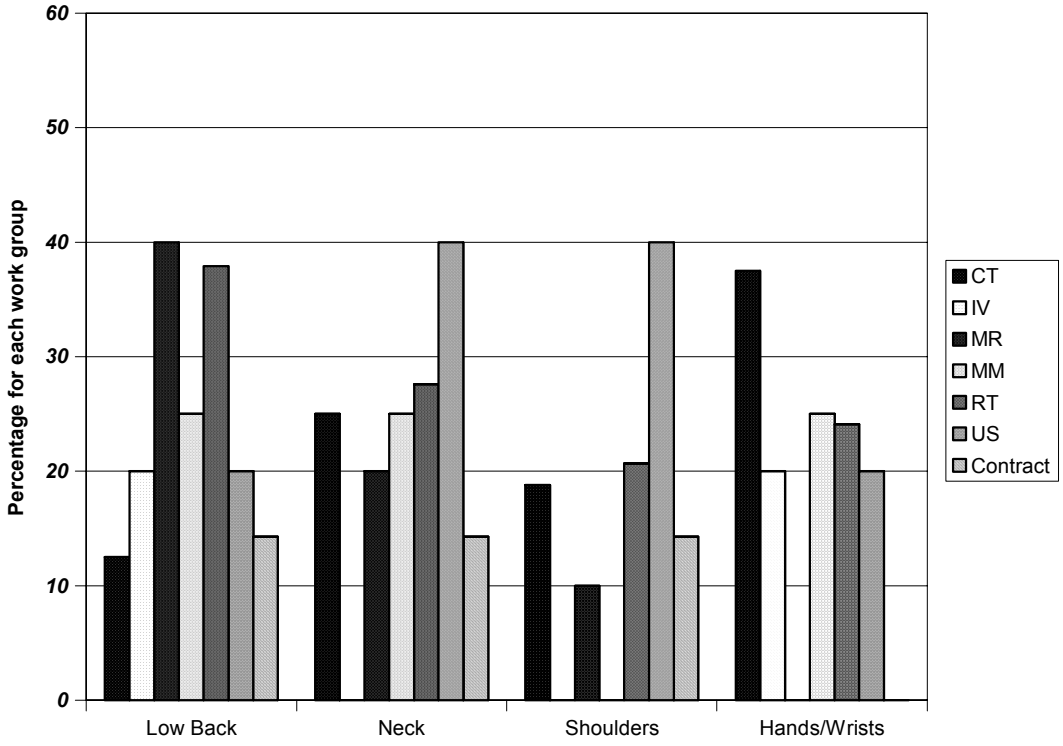

Figure 3.4 Seven-day prevalence of musculoskeletal symptoms for each body region reported by radiologic technologists in each work group

3.6.6 Number of Days with Low Back Symptoms in Past Year

Distribution of responses for the number of days with low back symptoms in the past year are summarized in Figure 3.5. Just over 20% of general radiologic technologists and 20% of interventional technologists reported experiencing low back symptoms daily in the past year. A lower prevalence of daily symptoms in the low back was seen in the other groups: Computed tomography technologists (12.5%), mammography technologists (12.5%), magnetic resonance technologists (10%), sonographers (0%), and contract workers (0%). Sonographers (33.3%) and magnetic resonance technologists (30%) had the highest prevalence of reporting greater than 30 days with symptoms in the past year. Twenty percent

of interventional technologists, 18.8% of computed tomography technologists, 12.5% of mammography technologists, 17.2% of general radiologic technologists and 0% of contract workers also reported greater than 30 days with low back symptoms in the past year.

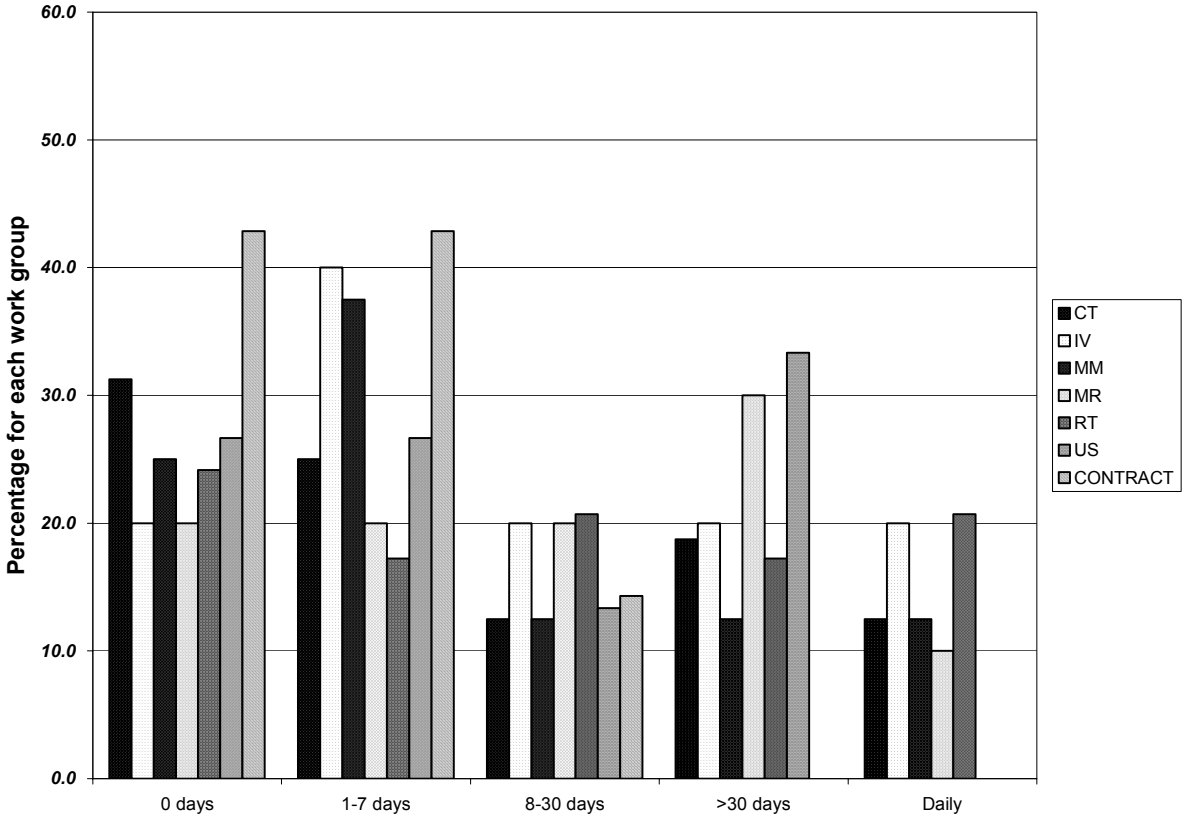

Figure 3.5 Reported number of days with low back symptoms in past 12 months for each work group

3.6.7 Number of Days with Neck Symptoms in the Past Year

Distribution of responses for number of days with neck symptoms in the past year are summarized in Figure 3.6. Members of only two groups reported experiencing musculoskeletal symptoms in the neck on a daily basis. These accounted for 6.3% of

computed tomography technologists and 3.4% of general radiologic technologists. Those who reported experiencing symptoms for greater than 30 days in the past year were 37.5 % of the computed tomography technologists, 10% of the magnetic resonance technologists, 10.3% of the general radiologic technologists, and 46.7% of the sonographers. All of the contract workers reported experiencing neck symptoms to zero days in the past year. This information was only collected for the low back and neck regions, not for the upper extremities.

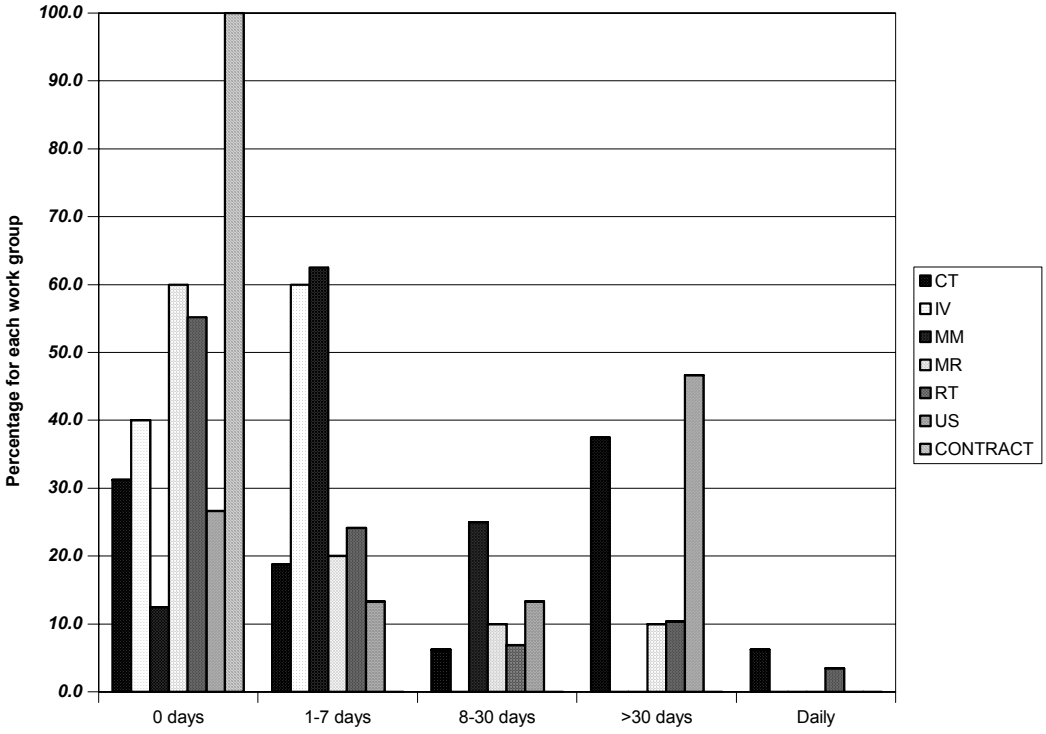

Figure 3.6 Reported number of days with neck symptoms in past 12 months for each work group

3.7 UNADJUSTED (CRUDE) ODDS RATIOS

Unadjusted odds ratios were calculated to explore associations between personal factors and work exposures and the prevalence of musculoskeletal symptoms in the low back, neck, right and left shoulders, right and left hands/wrists, dominant shoulder, dominant hand/wrist, either shoulder, and either hand/wrist. Due to the small sample size, lack of detail regarding the histories of medical conditions or trauma to body parts, and inability to confirm the validity and reliability of the medical diagnoses reported, these factors were not considered in this stage of data exploration of associations between other personal factors and the presence of musculoskeletal symptoms. Factors whose crude odds ratios indicate possible associations with the prevalence of musculoskeletal symptoms are discussed below. Since this is a preliminary study, a liberal approach to inclusion of variables for additional statistical analysis was taken. Variables whose crude odds ratios were .50 or less or 2.0 or greater were considered in further statistical analysis, regardless of whether or not the confidence interval for its crude odds ratios included 1 or not. Details of all associations explored are summarized in tables in Appendix 9.

3.7.1 Unadjusted (Crude) Odds Ratios For Musculoskeletal Symptoms in the Low Back in the Past Year

Unadjusted odds ratios for musculoskeletal symptoms in the low back in the past year are summarized in Table 3.10. None of the factors demonstrated a statistically significant association with the report of low back symptoms in the past year. However, though not statistically significant, subjects who were 40 years old or older (OR=2.26; 95CI 0.87, 5.9) were more likely to report symptoms in the low back. Positioning patients daily or less

frequently was associated with less risk of low back symptoms compared to those who did this many times per day (OR= 0.42; 95CI 0.16, 1.1). Although not expected, pushing or pulling objects once per day or less frequently (OR=2.43; 95CI 0.64, 9.2), and transporting patients once per day or less frequently (OR=3.1; 95CI 0.71, 13.6) were more likely to report symptoms in the low back. Another unexpected finding was that analyzing exams daily or less frequently (OR=0.48; 95CI 0.18, 1.3) appeared to have a protective effect on the report of low back symptoms. Gripping equipment daily or less frequently was associated with and increased risk of low back pain (OR=2.73; 0.32, 23.43) compared to gripping many times per day.

3.7.2 Unadjusted (Crude) Odds Ratios for Musculoskeletal Symptoms in the Neck in the Past Year

Unadjusted odds ratios for musculoskeletal symptoms in the neck in the past year are summarized in Table 3.10. Female gender (OR=4.16; 95CI 1.23, 14.1) and pushing or pulling objects once per day or less frequently (OR=3.56; 95CI 1.17, 10.9) were significantly associated with an increase in prevalence of neck symptoms in the past year. Analyzing exams once per day or less frequently (OR=0.39; 95CI 0.16, 0.95) was associated with a lower prevalence of reported neck symptoms. Non-sonographers were less likely to report neck symptoms (OR= 0.34; 95CI 0.10, 1.2), but this was not statistically significant. Odds ratios increased as number of hours per week increased, but these differences also did not reach a significant level. Though not statistically significant, technologists who used equipment to transfer patients had an increased risk of neck symptoms (OR=2.85; 95CI 0.69, 11.83). Carrying patients once per day or less frequently was associated with greater

likelihood of experiencing neck pain (OR=2.24; 95CI 0.20, 25.67), but this difference was not statistically significant.

Table 3.10 Summary of unadjusted (crude) odds ratios for prevalence of musculoskeletal symptoms in axial skeleton in past 12 months

		Location of Symptoms	
Variable	**Group**	**Low Back n = 66 OR (95%CI)**	**Neck n = 47 OR (95%CI)**
Age (years)	≥ 40	2.26 (0.87, 5.9)	1.55 (0.68, 3.6)
	< 40	1	1
Gender	Female	1.87 (0.60, 5.9)	4.16 (1.23, 14.1)[b]
	Male	1	1
Work Group	Non-Sonographer	1.0 (0.29, 3.5)	0.34 (0.10, 1.2)
	Sonographer	1	1
Analyze Exams	Other[a]	0.48 (0.18, 1.3)	0.39 (0.16, 0.95)[b]
	Many Times/Day	1	1
Push or Pull Equipment	Other[a]	2.43 (0.64, 9.2)	3.56 (1.17, 10.9)[b]
	Many Times/Day	1	1
Transport Patients	Other[a]	3.1 (0.71, 13.6)	–
	Many Times/Day	1	–
Position Patients	Other[a]	0.42 (0.16, 1.1)	2.05 (0.88, 4.74)
	Many Times/Day	1	1
Grip Equipment	Other[a]	2.73 (0.32, 23.43)	–
	Many Times/Day	1	–
Number of Hours Per Week	≤ 30	–	1
	31-40	–	1.04 (0.28, 3.9)
	41+	–	1.89 (0.48, 7.4)
Use Equipment for Patient Transfers	Other[a]	–	2.85 (0.69, 11.83)
	Many Times/Day	–	1
Carry Patients	Other[a]	–	2.24 (0.20, 25.67)
	Many Times/Day	–	1

[a] Once per day or less frequently
[b] Statistically Significant $p < 0.05$
– Not statistically significant or not ≤ .50 or not ≥ 2.0

3.7.3 Unadjusted (Crude) Odds Ratios for Musculoskeletal Symptoms in the Upper Extremities in the Past Year

Refer to Table 3.11 for details of unadjusted odds ratios for symptoms in the extremities in the past year. Whites (OR=0.23; 95CI 0.07, 0.81) and non-sonographers (OR=0.20; 95CI 0.06, 0.63) were significantly less likely to report right shoulder symptoms in the past year. Transferring patients daily or less frequently was associated with significantly increased risk for developing right shoulder symptoms (OR=3.27; 95CI 1.1, 9.8)

compared to doing this many times per day. This result is counterintuitive to what one would normally expect since research has demonstrated increased prevalence of musculoskeletal injuries among workers who perform patient transfers. Although not statistically significant, gripping or manipulating objects or tools only once per day or less frequently seemed to have a protective effect for the development of right shoulder symptoms (OR=0.33; 95CI 0.04, 2.8).

Symptoms in the dominant shoulder were similarly associated with race and work group (white OR=0.24; 95CI 0.07, 0.84, non-sonographer OR=0.26; 95CI 0.08, 0.98). Although transferring patients less frequently also resulted in an increase odds ratio (3.08; 95CI 0.94, 10.1), it was not significant for the dominant shoulder symptoms. Performing exams (OR=2.37; 95CI 0.79, 7.14) and lifting equipment daily or less frequently (OR=2.46; 95CI 0.81, 7.48) were associated with increased risk of symptoms in the dominant shoulder, but these associations were not statistically significant.

Whites (OR=0.28; 95CI 0.08, 0.98) and non-sonographers (OR=0.31; 95CI 0.10, 0.98) were also significantly less likely to experience symptoms in the right hand/wrist in the past year. Presence of right hand/wrist symptoms in the past year was negatively associated with analyzing exams daily or less frequently (OR=0.33; 95CI .010, 1.1), performing exams daily or less frequently (OR=0.28; 95CI 0.06, 1.3), transporting objects daily or less frequently (OR=0.31; 95CI 0.12, 0.84), performing computer work daily or less frequently (OR=0.33; 95CI 0.07, 1.6), and wearing a lead apron less than or equal to 20 hours per week (OR=0.49; 95CI 0.08, 3.15). However, this association was only statistically significant for transporting objects.

Transporting objects daily or less frequently (OR=0.34; 95CI 0.12, 0.98) showed a statistically significant protective effect for experiencing symptoms in the dominant hand/wrist in the past year. Although not statistically significant, female gender (OR=1.93; 95CI 0.40, 9.4), whites (OR=0.28; 95CI 0.08, 1.0), transporting patients daily or less frequently (OR=0.37; 95CI 0.08, 1.7), and wearing a lead apron less than or equal to 20 hours per week (OR=0.35; 95CI 0.05, 2.5) were associated with reduced risk for experiencing dominant hand/wrist symptoms in the past year.

Table 3.11 Summary of unadjusted (crude) odds ratios for prevalence of musculoskeletal symptoms in upper extremities in past 12 months

		Location of Symptoms			
Variable	**Group**	**Right Shoulder n = 26 OR (95%CI)**	**Dominant Shoulder n = 21 OR (95%CI)**	**Right Hand/Wrist n = 23 OR (95%CI)**	**Dominant Hand/Wrist n = 18 OR (95%CI)**
Age (years)	≥ 40	0.71 (0.28, 1.8)	0.89 (0.32, 2.5)	1.0 (0.39, 2.6)	0.89 (0.32, 2.5)
	< 40	1	1	1	1
Gender	Female	0.87 (0.27, 2.8)	0.89 (0.26, 3.1)	1.6 (0.41, 6.2)	1.93 (0.40, 9.4)
	Male	1	1	1	1
Race	White	0.23 (0.07, 0.81)[b]	0.24 (0.07, 0.84)[b]	0.28 (0.08, 0.98)[b]	0.28 (0.08, 1.0)
	Non-White	1	1	1	1
Work Group	Non-Sonographer	0.20 (0.06, 0.63)[b]	0.26 (0.08, 0.84)[b]	0.31 (0.10, 0.98)[b]	–
	Sonographer	1	1	1	–
Analyze Exams	Other[a]	–	–	0.33 (0.10, 1.1)	–
	Many Times/Day	–	–	1	–
Grip Equipment	Other[a]	0.33 (0.04, 2.8)	–	–	–
	Many Times/Day	1	–	–	–
Perform Exams	Other[a]	–	2.37 (0.79, 7.14)	0.28 (0.06, 1.3)	–
	Many Times/Day	–	1	1	–
Number of Hours Per Week	41+	0.40 (0.10, 1.63)	0.24 (0.05, 1.1)	–	0.35 (.08, 1.58)
	31-40	0.46 (0.12, 1.81)	0.36 (0.09, 1.5)	–	0.40 (.09, 1.7)
	≤ 30	1	1	–	1
Transport Patients	Other[a]	–	–	–	0.37 (.08, 1.7)
	Many Times/Day	–	–	–	1
Transfer Patients	Other[a]	3.27 (1.1, 9.8)[b]	3.08 (0.94, 10.1)	–	–
	Many Times/Day	1	1	–	–
Transport Objects	Other[a]	–	–	0.31 (0.12, 0.84)[b]	0.34 (0.12, 0.98)[b]
	Many Times/Day	–	–	1	1
Perform Computer Work	Other[a]	–	–	0.33 (0.07, 1.6)	0.48 (0.10, 2.3)
	Many Times/Day	–	–	1	1

Table 3.11 (continued)

Wearing a Lead Apron	≤ 20 hours per week	–	–	0.49 (0.08, 3.15)	0.35 (0.05, 2.5)
	> 20 hours per week	–	–	1	1
Grip Equipment	Other[a]	–	0.44 (0.05, 3.82)	–	–
	Many Times/Day	–	1	–	–
Lift Equipment	Other[a]	–	2.46 (0.81, 7.48)	–	–
	Many Times/Day	–	1	–	–

[a] Once per day or less frequently
[b] Statistically Significant $p < 0.05$
– Not statistically significant or not ≤. 50 or not ≥ 2.0

3.8 MULTIVARIATE ANALYSIS

Variables whose crude odds ratios were statistically significant, less than or equal to .50 or greater than or equal to 2.0 were considered in the multivariate analysis of adjusted odds ratios, regardless of their confidence intervals. Unadjusted odds ratios for the three levels of hours worked per week demonstrated a trend with exposure level, so this variable was also included. It was decided a priori to include age and gender in all models. Work group was also included in all models as the primary exposure of interest. Other significant variables were identified from the crude analyses and those thought to be clinically relevant, though not statistically significant, were also added. For simplicity, only the final models are presented in Tables 3.12 and 3.13. Details of all models explored are located in Appendix 8.

3.8.1 Adjusted Odds Ratios for Musculoskeletal Symptoms in the Low Back in the Past Year

Refer to Table 3.12 for a summary of adjusted odds ratios for musculoskeletal symptoms in the low back in the past year. Analyzing exams many times per day (OR=0.03; 95CI 0.09, 0.99), pushing or pulling equipment daily or less frequently (OR=5.78; 95CI 1.1, 30.0), transporting patients daily or less frequently (OR=8.34; 95CI 1.4, 48.2), and positioning patients many times per day (OR for positioning patients daily or less frequently = 0.21; 95CI 0.06, 0.72) were associated with significantly greater prevalence of symptoms in the low back. Although not statistically significant, technologists who were 40 years old or greater were almost 2.5 times more likely to experience low back symptoms (OR=2.47; 95CI 0.8, 7.6). There was no significant difference between males and females for symptoms in the low back (OR=1.74; 95CI .043, 7.1).

3.8.2 Adjusted Odds Ratios for Musculoskeletal Symptoms in the Neck in the Past Year

Refer to Table 3.12 for a summary of adjusted odds ratios for musculoskeletal symptoms in the neck in the past year. Female gender (OR=5.11; 95CI 1.28, 20.4), analyzing exams many times per day (OR for analyzing exams daily or less frequently =0.20; 95CI 0.06, 0.69), and pushing or pulling equipment once per day or less frequently (OR=8.77; 95CI 1.9, 41.2) were associated with a significantly greater prevalence of neck symptoms. Non-sonographers were 70% less likely to experience neck symptoms (OR=0.30; 95CI 0.06, 1.5), although this difference did not reach statistical significance. Age did not have a significant effect on symptoms of neck pain (OR=1.63; 95CI 0.61, 4.4). Although a trend in increasing risk was observed in the crude odds ratios for hours worked per week, this variable did not ultimately demonstrate significant contribution to the full model for symptoms of neck pain.

Table 3.12 Adjusted odds ratios for prevalence of musculoskeletal symptoms in axial skeleton in past 12 months – final models

		Location of Symptoms	
		Low Back n = 66 OR (95%CI)	**Neck n = 47 OR (95%CI)**
Age (years)	≥ 40	2.47 (0.8, 7.6)	1.63 (0.61, 4.4)
	< 40	1	1
Gender	Female	1.74 (0.43, 7.1)	5.11 (1.28, 20.4) [b]
	Male	1	1
Work Group	Non-Sonographer	0.94 (0.21, 4.2)	0.30 (0.06, 1.5)
	Sonographer	1	1
Analyze Exams	Other[a]	0.30 (0.09, 0.99) [b]	0.20 (0.06, 0.67) [b]
	Many Times/Day	1	1
Push or Pull Equipment	Other[a]	5.78 (1.1, 30.0) [b]	8.77 (1.9, 41.2) [b]
	Many Times/Day	1	1
Transport Patients	Other[a]	8.34 (1.4, 48.2) [b]	–
	Many Times/Day	1	–
Position Patients	Other[a]	0.21 (0.06, 0.72) [b]	–
	Many Times/Day	1	–

[a] Once per day or less frequently
[b] Statistically significant $p < .05$
– Variable not included in final model

3.8.3 Adjusted Odds Ratios for Musculoskeletal Symptoms in the Upper Extremities in the Past Year

Refer to Table 3.13 for a summary of adjusted odds ratios for musculoskeletal symptoms in the upper extremities in the past year. Non-sonographers had a significantly lower prevalence of symptoms in the right shoulder (OR=0.24; 95CI 0.06, 0.92), dominant shoulder (OR=0.25; 95CI 0.07, 0.89), right hand/wrist (OR=0.08; 95CI 0.02, 0.39) and dominant hand/wrist (OR=0.13; 95CI 0.03, 0.69) than sonographers. Technologists who transport objects daily or less frequently were significantly less likely to experience symptoms in their right hand/wrist (OR=0.11; 95CI 0.03, 0.45) as well as their dominant hand/wrist (OR=0.15; 95CI 0.04, 0.62). Female technologists were more likely to experience symptoms in the right hand/wrist (OR=2.47; 95CI 0.51, 11.9) and the dominant hand/wrist

(OR=3.04; 95CI 0.52, 17.9), though these differences were not statistically significant. Age was not significantly associated with presence of symptoms in any of the extremities. Gender did not show any association with right shoulder or dominant shoulder symptoms. Transferring patients did not show a statistically significant relationship with right shoulder symptoms in the multivariate analysis, and was, therefore, not included in the final model. Although the crude odds ratio for increasing number of hours worked per week had been suggestive of a trend with prevalence of dominant shoulder symptoms, this factor was not significant in the multivariate analysis and was not included in the final model. Although the crude odds ratios for race and transporting objects were statistically significant for right hand/wrist symptoms, these were not significant in the final analysis and were not included in the final model.

Table 3.13 Adjusted odds ratios for musculoskeletal symptoms in upper extremities in past 12 months – final models

		Location of Symptoms			
		Right Shoulder n = 26 OR (95%CI)	**Dominant Shoulder n = 21 OR (95%CI)**	**Right Hand/Wrist n = 23 OR (95%CI)**	**Dominant Hand/Wrist n = 18 OR (95%CI)**
Age (years)	≥ 40	0.90 (0.31, 2.7)	0.76 (0.25, 2.3)	1.33 (0.44, 4.0)	1.03 (0.32, 3.3)
	< 40	1	1	1	1
Gender	Female	1.18 (0.31, 4.6)	1.10 (0.28, 4.4)	2.47 (0.51, 11.9)	3.04 (0.52, 17.9)
	Male	1	1	1	1
Work Group	Non-Sonographer	0.24 (0.06, 0.92) [b]	0.25 (0.07, 0.89) [b]	0.08 (0.02, 0.39) [b]	0.13 (0.03, 0.69) [b]
	Sonographer	1	1	1	1
Race	White	0.19 (0.05, 0.75) [b]	0.21 (0.06, 0.80) [b]	–	–
	Non-White	1	1	–	–
Transport Objects	Other[a]	–	–	0.11 (0.03, 0.45) [b]	0.15 (0.04, 0.62) [b]
	Many Times/Day	–	–	1	1

[a] Once per day or less frequently
[b] Statistically Significant $p < 0.05$
– Variable not included in final model

3.9 EQUIPMENT USE

The only type of equipment used daily by a majority of all technologists was computer related equipment such as keyboards, computer mice and trackballs. However, some equipment was used by most individuals within a work group. For example, most of the sonographers (80%) reported using the ATL ultrasound machine daily. All computed tomography technologists used the GE CT scanner daily. The Phillips Vascular Lab and the Phillips Angio Table were used daily by all of the interventional technologists on a daily basis. Most of the magnetic resonance technologists (90%) used the MRI coils and MRI scanner on a daily basis. The responses also indicate that not only do sonographers use ultrasound machines on a regular basis, but so do technologists in mammography and interventional radiology. Information on daily use of equipment for technologists with and without symptoms in any body region in the past year is located in Table 3.14. Due to the large proportion of technologists who had symptoms in the past 12 months and the small number of individuals in each group who used specific pieces of equipment on a frequent basis, no further exploration of this data was conducted.

Table 3.14 Equipment used daily for radiology technologists with and without symptoms in the past year

Equipment and Location	Technologists Who Use Equipment Daily % (n)	MS Symptoms in last 12 months % (n)	No MS Symptoms in last 12 months %(n)
ALL AREAS			
Computer keyboard	98% (88)	87% (78)	13% (10)
Computer mouse	94% (85)	88% (75)	12% (10)
Computer trackball	56% (50)	90% (45)	10% (5)
Other computer pointing device	30% (27)	85% (23)	15% (4)
ULTRASOUND			
Acuson Ultrasound	3% (3)	100% (3)	0% (0)
ATL Ultrasounds	16% (14)	86% (12)	14% (2)
Hitachi Ultrasound	2% (2)	100% (2)	0% (0)
Siemens Elegra Ultrasound	4% (4)	100% (4)	0% (0)
MRI			
Coils for MRI Exam	10% (9)	89% (8)	11% (1)
Clinical MRI Scanner	10% (9)	89% (8)	11% (1)
Mobile MRI Scanner	2% (2)	100% (2)	0% (0)
CT			
GE CT Scanners	19% (17)	94% (16)	6% (1)
VASCULAR			
Phillips Vascular Lab	4% (4)	75% (3)	25% (1)
Phillips Digital Thoravision	1% (1)	100% (1)	0% (0)
Phillips Angio table	4% (4)	75% (3)	25% (1)
OTHER			
GE Portable X-ray unit	10% (9)	100% (9)	0% (0)
Continental Gen. Rad Room	2% (2)	100% (2)	0% (0)
GE Gen. Rad Room	6% (5)	80% (4)	20% (1)
Phillips Gen. Rad Room	17% (15)	87% (13)	13% (2)
Picker Analog Chest	8% (7)	100% (7)	0% (0)
Phillips Amber Unit	1% (1)	100% (1)	0% (0)
Panorex (for mandibular views)	1% (1)	0% (0)	100% (1)
Wall Bucky	21% (19)	84% (16)	16% (3)
GE R&F Room	12% (11)	91% (10)	9% (1)
Phillips Angio with C-Arm	1% (1)	100% (1)	0% (0)
GE Fluoro	9% (8)	86% (7)	14% (1)
OEC C-Arm	2% (2)	100% (2)	0% (0)
Breast Biopsy Unit	1% (1)	100% (1)	0% (0)
Siemens Mammomat/Breast Imager	1% (1)	100% (1)	0% (0)
Scoliosis Board	2% (2)	50% (1)	50%(1)
Pigg-o-Stat	4% (4)	100% (4)	0% (0)
GE Legacy Fluoro	1% (1)	100% (1)	0% (0)
Phillips B25 C-Arm	1% (1)	100% (1)	0% (0)
Phillips GU Fluoro Unit	2% (2)	100% (2)	0% (0)
Philips Tomography Unit	2% (2)	100% (2)	0% (0)

3.10 JOB CONTENT QUESTIONNAIRE

Job Content Questionnaire scores were calculated according to the scales defined in the Job Content Questionnaire User's Guide (Karasek, *et. al.*, 1985). Because of the way the scales are constructed, a higher score for most scales indicates positive perception of work, higher level of satisfaction or support, or a more positive outcome. However, lower scores for Job Insecurity, Psychological Demands, Physical Exertion, and Job Dissatisfaction indicate a more positive outcome for these scales. Mean scores for the radiologic technologists in this study were compared to scores for similar occupational groups previously collected and summarized by Karasek, *et. al.* (1985). Specifically, aggregated occupation codes for other health technologists and technicians TECN-MED(009) and for registered and practical nurses NURSES (008) were used. A comparison of the mean scores between the radiologic technologists in this study and the TECN-MED and NURSES groups is summarized in Table 3.15. The mean age for the technologists in this study was significantly higher than the TECN-MED and NURSES comparison groups, and are as follows. The distribution of men versus women was similar to both comparison groups. Statistically significant differences between the groups were observed for some of the scores. The radiology technologists in this study had significantly more years of education than the comparison group of health technologists. They had significantly higher scores for decision authority than both the TECN-MED and NURSES groups. The radiologic technologists in this study had significantly higher scores for decision latitude than the TECN-MED group. However, they had higher scores for psychological demands than both of the comparison groups. They also had higher scores for physical exertion than the TECN-MED group and higher scores for job dissatisfaction than both comparison groups.

Table 3.15 Mean job content questionnaire scores – comparison of radiologic technologists in this study to aggregated occupational groups[1]

Constructed Scale (range possible[2])	RADIOLOGIC TECHNOLOGISTS (This study) n, mean (s.d.)		Aggregated Occupational Groups: TECN-MED n=26 mean (s.d.)	Aggregated Occupational Groups: NURSES n=80 mean (s.d.)
Age (years)	79,	41.4 (8.19)	29.5 (11.5) †c	37.9 (11.9) †a
Sex (M=1, F=2)	89,	1.8 (0.39)	1.7 (0.49)	1.9 (0.32)
Education (8-18 years)	88,	14.8 (1.30)	13.6 (2.44) †a	14.5 (3.05)
Created Skills (3-12)	89,	9.6 (1.76)	9.03 (2.39)	9.6 (2.15)
Skill Discretion (3-48)	89,	35.3 (4.26)	34.4 (7.17)	36.5 (6.36)
Decision Authority (12-48)	89,	33.1 (7.13)	27.5 (7.76) †b	30.5 (6.14) †a
Decision Latitude (15-96)	88,	68.5 (9.82)	61.2 (11.32) †b	66.6 (9.81)
*Job Insecurity (3-17)	90,	4.2 (1.95)	4.4 (1.39)	4.3 (1.07)
Total Social Support (11-45)	89,	24.8 (3.71)	23.1 (4.80)	24.8 (3.92)
Supervisor Support (4-32)	89,	12.5 (2.57)	10.3 (6.15)	13.2 (3.18)
Coworker Support (7-13)	89,	12.3 (1.76)	11.7 (2.28)	12.8 (2.55)
*Psychological Demands (15-48)	90,	35.1 (5.64)	30.7 (6.44) †b	31.3 (8.42) †c
*Physical Exertion (1-4)	90,	3.3 (0.73)	2.9 (0.10) †c	3.1 (0.89)
*Job Dissatisfaction (0-1)	86,	0.3 (0.23)	0.2 (0.16) †a	0.2 (0.17) †b

[1] Karasek, *et. al.* (1985).
[2] Minimum and maximum scores possible for each scale calculated per Job Content Questionnaire User's Guide (Karasek, *et. al.* 1985)
[*] Higher scores for these scales indicate a less desirable outcome
[†] Statistically significant difference from mean score for radiologic technologists in this study
[a] $p < 0.05$
[b] $p < 0.01$
[c] $p < 0.001$

Chapter 4

DISCUSSION

The specific aims of this study were to determine the prevalence and severity of musculoskeletal complaints among radiologic technologists who work within a large health system; to characterize work exposures and their variability among those technologists; to identify specific areas of practice for radiologic technologists; to describe levels of occupational stress and related work organization issues among the technologists and compare them to similar occupational groups; and to explore associations among the following factors: type of clinical specialty and prevalence, severity and location of reported musculoskeletal symptoms; occupational task exposures and prevalence, severity and location of reported musculoskeletal symptoms; frequency of use and type of equipment and prevalence, severity and location of reported musculoskeletal symptoms; and personal factors (age, sex, race) and their effect on the associations listed just above. A musculoskeletal and work content questionnaire was developed based on direct observations of the work radiologic technologists perform, interviews with technologists, and established questionnaire tools such as the Nordic Questionnaire and the Job Content Questionnaire. The questionnaire was distributed to radiologic technologists within a large health system. The results of this study as they relate to the specific aims and to results of previous research are discussed in this chapter.

4.1 PREVALENCE AND SEVERITY OF MUSCULOSKELETAL COMPLAINTS

This group of radiologic technologists had a very high prevalence of musculoskeletal symptoms with approximately 90% of them reporting musculoskeletal symptoms in at least one body region with tin the past year. Although we expected to see a higher prevalence of low back symptoms in this group, the overall prevalence was quite high (73.3%), and was consistently high for each work group. Additionally, the prevalence of interference of symptoms with work activities was quite high (57.8%). This impact was markedly more severe for those who experienced low back pain (36.7%) compared to those with other symptoms. Sonographers were expected to have a high prevalence of symptoms in the neck, shoulders and hands/wrists based on previously published research, and this turned out to be the case. Computed tomography technologists also had a relatively high prevalence of symptoms in the neck (68%) and hands/wrists (50%) in the past year which could be attributed to the high amount of computer interaction required to perform CT exams. Severity of musculoskeletal symptoms as measured by report of daily low back pain was highest among the interventional technologists and the general radiologic technologists with approximately 20% of both groups reporting daily symptoms in the low back in the past year.

Though not statistically significant, there was an increase in prevalence of low back symptoms with increased age (OR= 2.47; 95CI 0.8, 7.6). These findings are consistent with the generally accepted concept that prevalence of musculoskeletal disorders increases with age. We expected to see effects of certain exposures on the presence of musculoskeletal symptoms for many of the factors that did not result in significant odds ratios in the statistical analysis for this group. For example, the effects of exposure to frequently performing tasks such as patient transfers, lifting, and gripping objects or tools were not associated with

significantly greater prevalence of symptoms in any of the body regions. Similarly, we expected that the use of equipment to perform patient transfers would have a protective effect on the prevalence of low back symptoms, but no effect was seen in this group. One possible explanation for lack of findings related to use of equipment to assist with patient transfers is that technologists in this study use patient transfer equipment infrequently and the size of the group who participated in the study was too small to detect any effect the equipment may have had on those who do use it.

A higher percentage of sonographers in this study had experienced symptoms in the neck, shoulders and hands/wrists in the past twelve months than technologists in other clinical specialties. This difference was statistically significant for right shoulder (OR=0.24; 95CI 0.06, 0.92), dominant shoulder, right hand/wrist (OR=0.08; 95CI 0.02, 0.39) and dominant hand/wrist (OR=0.13; 95CI 0.03, 0.69). This was expected based on observed awkward upper extremity and neck postures and sustained gripping of an ultrasound transducer while performing exams, as well as information learned in previous research of symptoms among sonographers. For shoulder and hand/wrist symptoms, the number of technologists with symptoms on the right side was greater than the number with symptoms on the dominant side. This suggests that even the technologists who are left hand dominant probably use their right upper extremity to perform exams. This may be due to the likelihood that they learn techniques from right-handed technologists and that equipment is most often arranged to facilitate use with the right hand.

Whites in this study were significantly less likely to have symptoms in the right shoulder (OR=0.19; 95CI 0.05, 0.75) and dominant shoulder (OR=0.21; 95CI 0.06, 0.80). We did not expect to see any significant associations based on race. The differences

observed in this study are probably the result of other confounding factors the questionnaire was not sensitive to, rather than to any real effect that race has on the prevalence of symptoms.

These data suggest a reduced risk of experiencing low back symptoms for those technologists who position patients only daily or less frequently (OR=0.21; 95CI 0.06, 0.72). This was expected, because previous research looking at nurses and patient positioning suggests that positioning patients and patient handling, in general, increase the risk of having a low back injury. In addition, it was evident from the observation sessions that the technologists are often expected to assist patients who have minimal ability to position themselves due to their medical condition, their age, their size, or a combination of these.

Some of the associations between work exposures and the prevalence of musculoskeletal symptoms were different from what was originally expected. For example, transporting objects many times per day was associated with a higher prevalence of symptoms in the right hand/wrist and symptoms in the dominant hand/wrist. Transporting equipment may involve gripping handles on equipment, which could explain this group's increased likelihood of experiencing hand/wrist symptoms. It is possible that the task of transporting objects is correlated with a different high risk activity that was not detected with the questionnaire. One example of this type of task could be performing ultrasound examinations in the inpatient units (portable ultrasound examinations). This would require transporting equipment, as well as gripping the ultrasound transducer for each exam.

It was unexpected that less frequently performing the tasks of pushing and pulling objects and transporting patients would be associated with a greater likelihood of developing musculoskeletal symptoms, but this was the case for low back symptoms and neck symptoms

(push/ pull equipment only). This result may be due to a number of scenarios. For example, technologists who are symptomatic had dropped out of the work force, or they may have found ways to avoid pushing and pulling objects and transporting patients by taking advantage of the availability of radiology aides or transporters. Alternatively, it is possible that the technologists who push or pull equipment more frequently or transport patient more frequently use safer methods due to practice. They may have improved physical conditioning from performing such tasks more frequently than their less conditioned, symptomatic counterparts who perform the tasks less frequently.

Analyzing exams daily or less frequently had a protective effect for low back symptoms (OR=0.30; 95CI 0.09, 0.99) and neck symptoms (OR=0.20; 95CI 0.06, 0.67). This implies that analyzing exams more frequently would be associated with higher levels of low back and neck symptoms. This result was not expected. The process of analyzing exams was not associated with observable ergonomic risk factors during the direct observations conducted in this study. Nor has this type of activity been identified as a high-risk activity in previously reported studies. One explanation for this result is the possibility that technologists who take on the responsibility of analyzing results of exams do so to avoid more physically strenuous tasks because they have pre-existing symptoms in some body regions. In other words, the "healthy" workers tend to perform the exams while workers with symptoms tend to analyze them.

4.2 CLINICAL FACTORS

Almost 60% of the technologists reported that at least 41% of their patients are obese. Most of the technologists (73%) reported that the exams were more difficult to perform on

obese patients. This seemed to be particularly important to sonographers and mammography technologists. Obesity is a patient-based exposure variable that may influence the presence of ergonomic stressors for the technologists. This raises the interesting questions of how this variable may be controlled for in future research, and how to control for it when assigning patients to technologists.

4.3 EQUIPMENT USE AND PREVALENCE OF MUSCULOSKELETAL SYMPTOMS

With the exception of computer equipment, which was used by most technologists, the equipment used by individuals in this study was primarily determined by their clinical subspecialty. Those practicing in general radiology had many types of equipment available to them, while others such as mammography technologists, magnetic resonance technologists, computed tomography technologists and sonographers had one, three or four different types of equipment available. The small number of technologists in each group and the small number within each group who used some of the equipment limited any extensive statistical analyses of the effect of using specific pieces equipment may have had on the prevalence of musculoskeletal symptoms. However, the data that were collected indicate that technologists other than sonographers are exposed to ultrasound equipment, although perhaps to a lesser extent. In addition, some equipment stands out as being used by most individuals in a group, or more frequently than other equipment. This information could be useful in the design of future studies.

4.4 OCCUPATIONAL STRESS AND WORK ORGANIZATION

The study group showed many similarities in scores of the comparison group, they were significantly older and demonstrated more troublesome scores for several of the categories of occupational stress related to demands and control than the health technologists or nurses in the comparison groups. This was a surprise, because it was hypothesized that they would have similar scores for these factors. This is possibly due to the dramatic changes that have taken place in the health care industry since 1985 when the scores for the comparison groups were published. Specifically, there is a greater emphasis on productivity of health care workers in the face of limited or captivated reimbursement for health care services. In addition, it is possible that technology has increased the pace of work for radiologic technologists by enabling them to perform more exams per day than could be done in the early to mid 1980s. This increase in work pace could impact a change for the worse in perceived job demands and stress levels. The technologists in this study scored in the higher ranges for created skills and co-worker support. They had low levels of job insecurity and job dissatisfaction, (though job dissatisfaction was higher than the comparison groups), two factors that have the potential to increase prevalence of musculoskeletal disorders when levels are high. More extensive analysis of the scores might shed light on the sources of the differences observed in the scores between the radiology technologists in this study and the health technologists and nurses from previous studies in which the Job Content Questionnaire was used.

4.5 COMPARISON TO RELEVANT LITERATURE

4.5.1 Response Rate

Despite use of gift certificates as incentives and multiple follow-up letters to facilitate participation, the response rate for this study was similar to those achieved in other studies. Although Fowler (1993) suggests that group-administered questionnaires, such as those given to groups of workers, typically yield acceptable response rates, depending on rate of absenteeism among a group of workers, the overall number of participants was smaller than that of many of the other studies of radiologic technologists. The distribution of responses from the various clinical subspecialties indicates that some groups had greater participation than others. This could be a reflection of the variability in support technologists received from their supervisors to participate in the study, or the free time they may have had available to complete the questionnaire. Since the technologists in this study worked in many different clinical subspecialties, the total number of technologists representing any one specialty is small.

4.5.1.1 Follow-Up Procedures

Implementation of an aggressive follow-up process in the form of three follow-up letters subsequent to questionnaire distribution was intended to assist with maximizing total response rates for the study. The response rate is comparable to other reports. Based on the dates the questionnaires were received relative to distribution and sending follow-up letters, the use of multiple follow-up letters assisted with recruitment. However, the third follow up letter, sent eight weeks after distribution, had little impact on recruitment. This group of workers may respond better to additional recruitment methods. Investigators could request

more direct support from management in the form of dedicating a specific amount technologists' clinical time to complete the questionnaire. The investigator could consider remaining onsite after the questionnaires are distributed to answer questions and encourage completion of the questionnaire during the day it was distributed. Instead of distributing the questionnaire at a staff meeting, smaller group sessions, to include the investigator could be arranged at which the questionnaire would be distributed and completed. Simply checking in with the technologists on a frequent, but informal, basis after the questionnaires had been distributed might also serve as a reminder and an indication of interest on the part of the investigator.

4.5.2 Personal Characteristics and Prevalence of Musculoskeletal Symptoms

The participants in this study were mostly white females, which is consistent with the populations of radiology technologists from other studies. Other studies have demonstrated a high prevalence of back problems among radiologic technologists, which was also the case for this study. Solanki, *et. al.* (1997) noted an association between back pain and interference with work and limitation of lifestyle among the sonographers he studied. This tendency for symptoms in the low back to interfere with work and leisure activities was also seen in this study. Factors such as the number of studies performed per day or week or month, number of hours worked per week, and number of years worked in ultrasound has been associated with higher prevalence of musculoskeletal symptoms among sonographers in other studies, but these factors were not significant in this study. Because gripping an ultrasound transducer has been associated with symptoms of hand and wrist pain in other studies, we expected to see this same association in this study. Rather, there was a lack of a

significant association observed in this study between activities that required gripping or manipulation of objects and the presence of hand/wrist symptoms.

4.5.3 Prevalence of Musculoskeletal Symptoms Compared to Other Workers

In a study of family care workers that used the Nordic Questionnaire to obtain information about musculoskeletal symptoms, (Moens, *et. al.*, 1993), 63% of participants suffered from back pain in the past 12 months. In a study of the prevalence of back pain among nurses, Coggan, *et. al.* (1994) reported a 62.3% prevalence of nursing-related back pain and a 36.8% prevalence of back pain experienced by nurses in the past year. In a comparison of the prevalence of back pain among nurses in two different hospitals (Larese and Fiorito, 1994) identified the prevalence of back pain reported in the past year at each of those facilities to be 48% and 33%. These results were much lower than observed in the radiologic technologists in this study. Lagerstrom, *et. al.* (1995) studied the factors related to musculoskeletal symptoms in five body regions among Swedish nursing personnel. The prevalence of ongoing musculoskeletal symptoms in the neck, low back, and hands were 44%, 52%, and 17%, respectively. The prevalence of symptoms in thee body regions are similar to the radiologic technologists in this study for the neck, but much lower for the back and hands. In general, the prevalence rates for symptoms in the neck, low back, and hands for this study group are comparable to or exceed the rates for other health care workers.

It is particularly noteworthy to point out that the group of technologists were very homogenous in regards to their experiencing any musculoskeletal symptoms in the past year. Almost 90% of them reported having symptoms in at least one body region in the past year. This homogeneity made it difficult to explore associations between the independent variable

and the outcome measures identified for this study. This could perhaps have been addressed by including questions about the specific nature of symptoms in each of the body regions to differentiate those technologists who experienced minor aches from those who had more severe, distinct symptoms. For example, "Did you experience low back pain with or without radicular symptoms?" "How many of the following symptoms did you experience in your hands/wrists: pain, numbness, burning?" Similarly, homogeneity could be reduced if the focus of the study was on recent symptoms in conjunction with a physical exam by a medical professional trained in developing a diagnosis of musculoskeletal disorders based on pre-determined, strictly followed guidelines for consistency. At the same time, it would be important to limit the number of potential outcomes to retain power in the statistical analysis.

4.6 LIMITATIONS OF THIS STUDY

Some limitations of this study were known from the outset and some were discovered as the study progressed. These are discussed in the following sections.

4.6.1 Experimental Design

This was a cross-sectional study, which, by nature, has some limitations. Analyses of the associations among variables are prone to influences of the healthy worker effect in cross-sectional studies. For example, analyzing exams was associated with a higher risk for experiencing symptoms in the low back. This outcome was not expected. However, it could be explained by the possibility that technologists who have a history of symptoms in the low back self-select to work in areas where they are less likely to do heavier physical work and spend more time analyzing exams (which was not observed to be a high-risk activity). It is

impossible to make conclusions about temporal relationships of factors, such as cause and effect, with this study design. There is no way to know from this study when symptoms of low back pain began relative to performing exam analysis. In addition, the questionnaire results of this study are more likely to be influenced by events that may have occurred during the questionnaire distribution and response period, such as turnover or reduction in staffing, changes in management, and institutional climate. However, we were not informed of the occurrence of any of these events during the study period. Those who agreed to participate may have introduced some bias to the results depending on why they agreed to participate and why others did not. For example, technologists who are symptomatic may have a greater interest in sharing information about their symptoms and work activities than technologists who have not experienced any symptoms and, therefore, have little interest in sharing information about themselves. Similarly, it is possible that only the technologists who were not very busy at work took the time to complete and return the questionnaire, whereas those who did not participate may have had symptoms, or they were too busy at work to complete the questionnaire. This would possibly influence the responses by reducing the number of respondents who perform certain physical tasks many times per day, inaccurately representing exposure levels.

4.6.2 Sample Size

This study was hampered by the relatively small number of participants, despite drawing the sample from a large health care system. Therefore, many of the statistical models lacked power, making the study preliminary. A large multi-center study is likely

needed to obtain enough participants and diversity for more effective statistical analysis, particularly to explore differences between the work groups.

4.6.3 Variation in Work Exposures

Overall variation in work task frequency and type is assumed to be significant in this group of workers. Inter-subject and intra-subject variation of work methods cannot be entirely captured with this type of design. For example, individuals may do different tasks on different days. They may use different strategies to perform similar tasks. Additionally, their work assignment (patient type, volume, location) may change from day to day. Additionally, many radiologic technologists are cross-trained in several areas and may be in computed tomography one day, and helping out in general radiology the next day. Use of direct observations of work tasks in the various clinical areas and interviews with the technologists assisted in developing a questionnaire that addressed the variety of work these individuals perform. Pre-testing the questionnaire also assisted in ensuring that the questionnaire items were appropriate and comprehensive for this group of workers. In order to account for this variability with a cross-sectional study using a questionnaire, a greater number of more detailed questions related to the specific methods used to perform each task would be necessary.

4.7 STRENGTHS OF THIS STUDY

Despite the limitations discussed above, this study has many strengths. The study drew from a large health system which included a tertiary hospital, providing access to a relatively large number of technologists. Because of the large number of technologists and

the levels of care provided within the health system, the variety of tasks performed by the technologists in this study were likely to be representative of those performed by most workers in radiologic technology. This made it possible to perform preliminary analyses of exposures by the clinical specialty.

The access the investigator had to the technologists and their work environments was particularly important. It allowed for direct observations of work exposures in the preliminary phases of the study. This process was essential to developing an understanding of the differences and similarities among the various clinical subspecialties. This information improved the quality of the questionnaire used in the study. Several technologists agreed to complete the questionnaire, with the support of their managers, which assisted in the quality of the questionnaire. In addition, the access the investigator had to the technologists allowed for prompt delivery and receipt of reminder letters once the questionnaires had been distributed.

Previous research of radiologic technologists limited investigations to only one clinical subspecialty. This study is unique in that it investigated and compared many of the clinical subspecialties within radiologic technology. This is the first time that this type of investigation had been done for magnetic resonance technologists and computed tomography technologists. It was also the first time interventional technologists were reported on as a unique group, separate from others who perform sonography. Descriptive analysis of symptoms and exposures were possible for each work group. This allowed some differences between the groups to be highlighted. It is unusual to find circumstances in which different groups with such similarities as their educational backgrounds, level of responsibility and within the same work organization can be investigated.

This study used a questionnaire based on direct observations of work performed in conjunction with previously established, well-known research tools such as the Job Content Questionnaire and the Nordic Questionnaire, making it possible to compare and contrast results with previous and future research.

4.8 FUTURE RESEARCH

Most of the published research on the work of radiologic technologists has used cross-sectional study design and it has been questionnaire-based. Future research should focus on prospective studies of technologists who enter the field as new graduates to better define the temporal relationship between personal characteristics, work exposures, and musculoskeletal disorders. In addition, studies are needed to quantify the work exposures in radiologic technology in biomechanical terms, in addition to subjective reports of symptoms. Since this study suggests that sonographers are at greater risk of developing symptoms in their right upper extremities, it seems a likely approach to investigate the biomechanical loads and related physical effects of using the various types of ultrasound transducers. Finally, the issue of performing exams on obese patients should be investigated further. A large number of the technologists in this study reported the negative impact that obesity of patients has on the ease of their exam procedures. Future studies should explore what aspects of the exams are more difficult and what could improve the ease with which technologists may care for obese patients. Since the number of obese people in the United States continues to increase, this is likely to impact a greater number of technologists as time passes.

Chapter 5

CONCLUSIONS

In this study, we used a combination of new and previously established research tools and techniques. The multi-component questionnaire used in this study was developed with information learned from performing direct observations of work tasks and conducting interviews with individuals in the work areas of interest. Newly developed questions specific to the work requirements were combined with established tools, the Job Content Questionnaire and the Nordic questionnaire, and used to collect information about work content and exposures, musculoskeletal symptoms and work organization factors for a group of radiologic technologists. The entire questionnaire was pre-tested and modified according to feedback received. A raffle to win a gift certificate was used as an incentive for technologists to participate. Finally, a series of follow-up contacts subsequent to the distribution of the questionnaires was used as a recruitment tool to promote participation in the study.

Radiologic technologists represent a group of workers, primarily females, who are trained in similar educational programs, yet work in a number of clinical specialties and environments. The environments and tasks encountered by individuals vary depending on the clinical specialty. Work in some clinical specialties may be associated with increased risk of developing musculoskeletal symptoms. In particular, working as a sonographer appears to introduce increased risk for developing symptoms in the upper extremities. In some cases, specific tasks performed by all technologists regardless of clinical specialty, such

as positioning patients or transporting objects, may be associated with greater risk of injury. The following specific conclusions can be made based on the results of this research.

- Radiologic technologists have a high prevalence of low back symptoms that may interfere with work and leisure activities. Patient positioning was associated with an increased prevalence of low back symptoms (relates to Hypothesis #2).
- Transporting equipment many times per day was associated with an increased risk of experiencing right hand/wrist symptoms and dominant hand/wrist symptoms (Relates to Hypothesis #2).
- Working as a sonographer was associated with increased risk of experiencing symptoms in the right shoulder, dominant shoulder, right hand/wrist and dominant hand/wrist (relates to Hypothesis #1 and #4).
- Positioning patients many times per day was associated with greater risk of experiencing musculoskeletal symptoms in the low back (Relates to Hypothesis #2).
- A large percentage of technologists estimate that a high percentage of their patients are obese. Most of them indicate that obesity makes their exam procedures more difficult.
- Technologists in this study were older and had more education than other health care technologists from previous research using the Job Content Questionnaire. They had better scores for decision authority and decision latitude than the other technologists. However, they also had higher levels of physical exertion, psychological demands, and job dissatisfaction than the other technologists. They had a similar distribution of males versus females, and scores for created skills, job insecurity, total social support, co-

worker support, supervisor support, and job dissatisfaction as the other health technologists.

- Technologists in this study were older than nurses in previous research. They had higher scores for decision authority and reported higher levels for psychological demands and job satisfaction than the nurses in previous research. No other significant differences were observed for the other Job Content questionnaire scores. They had significantly different scores from the comparison groups of nurses, compared to five significantly different scores from the health technologist group, suggesting they are more similar to nurses than to other health technologists from a psychosocial and work organization aspect.

Adjusted odds ratios for low back symptoms appear to be limited by either the cross-sectional study design or confounded by other factors the questionnaire was not sensitive to. However, the high prevalence of low back pain among these workers is a concern and should be investigated further. Patient handling and positioning activities have been associated with back pain and back injury in other studies, as have pushing and pulling activities. These are all tasks that are very prevalent among radiologic technologists and may be the explanation for their back symptoms.

Reducing the size or weight of equipment that is transported, or the frequency with which it is transported may reduce the risk of technologists developing hand and wrist symptoms. This specifically applies to portable x-ray and ultrasound units. Small, hand-held portable ultrasound machines are currently available. However, image quality available in these

machines does not compare to that of full-sized machines. Therefore, use of the hand-held units is often discouraged.

Although some previous studies have recognized the variability in the type of work performed by radiologic technologists, overall, it has not been addressed and remains difficult to manage in the context of clinic-based research or questionnaires. Many recommendations have been made to improve the ergonomics of work environments for sonographers, such as the availability of height adjustable chairs and stretchers, use of remote monitors, adjustable keyboards and monitors on the ultrasound machines, increased leg room on machines, light weight transducers and flexible cords, implementation of stretching programs and observance of regular break schedules, use of supports for the upper extremity during exams which require extended reach, alternate between sitting and standing, and improved design of transducers to promote better grip posture. Despite the fact that many of these recommendations were already in place during the time of this study, the sonographers still had significantly greater risk of developing symptoms in the right or dominant upper extremity than other work groups.

Although there were many similarities between the technologists in this study and the health technologists and nurses of the aggregated occupation groups reported on by Karasek (1985), there were important differences, as well. The concept of the aging work force is evident in this group, which may have an impact in the prevalence of musculoskeletal symptoms. The combination of the increased age with higher levels of physical and psychological demands than previously studied groups punctuates the importance of identifying occupational factors that may be associated with their symptoms.

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APPENDICES

Appendix 1

Instructions and Feedback Questions for Pre-Test of Questionnaire

Wednesday, September 19, 2001

As you may know, I have a special interest in ergonomics for radiologic technologists and related clinical subspecialties. I am getting very close to initiating a research project here at Duke, within your department. One of the last steps I am taking to ensure the usability of the questionnaire I have developed is to have just a few of you take the questionnaire and provide feedback. This will help me "fine tune" the questionnaire so that it is easy for participants to use ad also provides the information I need. There are a few things I'd like you to know before starting:

- At this point, your responses will **not** be analyzed as data points. I am merely testing the usability of this questionnaire. Please note that all documents provided are DRAFTS, including Informed Consent documents.
- You do not have to sign the documents provided, or send the documents back through Campus Mail (as you will be instructed to do when the formal study is initiated).
- This questionnaire is the actual tool I will be using for part of my research project. As such, I ask that you please not share detailed information about the survey with your co-workers. Sharing information or discussing the content of the questionnaire may result in certain biases among co-workers when the actual study is initiated.
- When you are done with the survey, you may call me at 286-1722 ext 240. If I am not there, leave a message to let me know you have completed the questionnaire. I will pick it up (directly from you) to ensure that your responses and feedback are handled confidentially.

The following items are questions or issues I'd like you to think about as you complete the survey. You may write responses and feedback on these pages. Feel free to use the back of the pages if you need more space. You may also make notes about particular questions on the questionnaire itself.

1. How long did it take you to complete the questionnaire. I estimate that it will take approximately 45-50 minutes. I'd like to know if this is an accurate estimate. Please keep track of the time you spend to complete the questionnaire.

2. Did you feel like the instructions were clear?

3. Did the instructions prepare you for the questionnaire?

4. Were the questions easy to understand?

5. Were you able to answer all of the questions with responses you felt were accurate?

6. Were you uncomfortable answering some of the questions?

7. Did you feel like your responses would be kept confidential? Like confidentiality was sufficiently addressed up front?

8. Did you have enough choices in your responses?

9. Did the questionnaire take you longer than you thought it would?

10. Did the questionnaire take more time than you think is "worth it?"

11. What could be stated up front to better prepare you for the content and length of the questionnaire?

12. How did you feel about using the Opscan form for your responses?

Thank you very much. Please provide your first name and a number where I may reach you with any questions I may have.

Appendix 2

Cover Letter, Instructions, and Work Content and Musculoskeletal Questionnaire

Dear Radiology Professional,

I am writing to ask for your help in a study of musculoskeletal and work organization factors for radiologic technologists being conducted as part of my work toward a Master of Science degree in Industrial Engineering at North Carolina State University. This study is part of an effort to learn more about the ergonomic stressors involved in the type of work you do.

It is my understanding that you are a radiologic technologist, a sonographer, a magnetic resonance imaging technologist, or a computed tomography technologist. With the support of the Department of Radiology, I am requesting the participation of all Duke hospital and clinic employees who work in this capacity. By understanding the type of work you do and the environments in which you work, I may be able to make recommendations for improvements that will reduce the ergonomic stressors in work areas such as yours.

Your answers are completely confidential and will be released only as summaries in which no individual's answers can be identified. When you return your completed questionnaire, your name will be deleted from the mailing list and never connected to your answers in any way. This survey is voluntary. However, you can help me very much by taking some time to answer these questions about yourself and your work. Although the survey appears to be lengthy, it should only take you less than 60 minutes to complete, if you choose to do so. If you are interested in participating, you will find detailed instructions on how to proceed on the next page of this packet.

As a way to demonstrate my appreciation for your participation, at the close of the survey period (approximately eight weeks after all surveys have been distributed) I will hold a drawing in which two individuals who have returned their surveys to me will win $25.00 gift certificates to Café Parizade restaurant in Durham.

I would like to have all of the surveys returned within two weeks of the date you receive it. This should give you ample time to complete the survey at your convenience.

If you have any questions or comments about this study, I would be happy to talk with you. I can be reached at (919)286-1722 extension 240. You may also contact my research advisor, Dr. Carolyn Sommerich, at (919)515-8614, or my Faculty Sponsor, Dr. Hester Lipscomb, at (919)286-1722 extension 256.

Thank you very much for considering this opportunity to participate in this study.

Sincerely,

Sabrina Lamar, PT
North Carolina State University, Department of Industrial Engineering
Duke Occupational and Environmental Safety Office, Ergonomics Division

INSTRUCTIONS: This survey packet should contain the following items.

- ✓ Cover Sheet (which you just read)
- ✓ Two copies of an Informed Consent form (a white copy and a pink copy)
- ✓ One questionnaire
- ✓ One Opscan form (white response sheet with red print)
- ✓ Two gold Campus envelopes pre-addressed to Sabrina Lamar, Box 3834

Please contact me at 286-1722 extension 240 if your packet does not contain each of these items, otherwise, please continue.

The **Informed Consent Form** is provided for your protection. Please review it carefully. If you agree to participate in the study, sign the white copy and place it in one of the gold Campus envelopes provided. *Keep the green copy* for your own records.

The **questionnaire** consists of two parts and has several sections within each part. Part 1 of the questionnaire has white pages. For Part 1, write your responses directly on the questionnaire pages. Part 2 of the questionnaire has off-white pages. You will use the Opscan form to respond to questions in Part 2. Instructions will clearly indicate when you should begin using the Opscan form for your responses.

Using the Opscan form: Once you have reached Part 2 of the questionnaire, you will be ready to use the Opscan form for your responses. Please use the following guidelines when using the Opscan form.

- Turn to Side 2 of the Opscan form. Review the examples of correct and incorrect methods for filling out the form.
- Use a pencil, preferably with #2 lead.
- Fill in the circles that correspond to your answer neatly and completely.
- Do not use check marks or "Xs" in the circles.

Once you have completed the questionnaire, place it and the Opscan form in the other gold Campus envelope (the one that does **not** have the signed Informed Consent form in it). Place both Campus envelopes in Campus mail. They are pre-addressed to "Sabrina Lamar, Box 3834" for your convenience. Note that you are being asked to use separate envelopes for your Informed Consent Form and your questionnaire response forms so that your responses will remain confidential as they travel through Campus mail.

We appreciate having your completed survey within two weeks.

If you have any questions about the survey content or procedures do not hesitate to contact Sabrina Lamar at 286-1722 extension 240, Dr. Carolyn Sommerich at 515-8614, or my Faculty Sponsor, Dr. Hester Lipscomb, at (919) 286-1722 extension 256 at anytime.

DO NOT SIGN YOUR NAME TO THIS FORM.

Part 1. Job Content Section

INSTRUCTIONS: This section of the survey pertains to information about the locations in which you work and the type of work you perform. For this section of the survey, please enter your responses directly in the blanks on this survey.
For written responses, please PRINT.

1. What is your job title? Be Specific. _____

2. Primary and secondary work locations for this job:
   Indicate your *primary* with a "1" and your *secondary* with a "2." If you do not have a secondary work location, do not use a "2."

Duke North Hospital
____General Diagnostics
____MRI
____CT
____Vascular
____OR
____Ultrasound

Duke South/ Duke Clinic Building
____General Diagnostics
____Urology
____Orthopedics
____Mammography
____Ultrasound
____Breast Biopsy

Other
____CHC General Diagnostics
____CHC Pediatric Ultrasound
____Herndon Rd./ Southpoint Clinic, General
____Herndon Rd./ Southpoint Clinic, MRI
____Duke Clinic, Fetal Diagnostic Center
____North Pavilion
____Lenox-Baker
____4020 Roxboro Road
____Pickens Clinic (Family Medicine)
____Pickett Road Clinic
____ Other, please list here_____

3. What is your professional/clinical specialty? _____

4. How long are the shifts you typically cover at your job?
   ____ 4 hours ____ 8 hours ____ 12 hours ____ Other (List)_____

5. How many patients do you see or treat in an average workday? _____

6. In a given week, what type of patient best represents the type of patients you see or treat most often? (check one response)
   ____Outpatient
   ____Inpatient
   ____I see equal numbers of each

7. In a given week, what type of patient best represents the type of patients you see most often? (Check one response.)
   ____Pediatric
   ____Adult
   ____I see equal numbers of each

8. Please describe the frequency of various categories of work you perform. Place a check (✓) in the appropriate box depending on if you perform that task **many times per day**, on a **daily** basis, on a **weekly** basis, **less than weekly** or **not at all.**

8.1. Examination/Clinical Studies

Many Times Per Day	Daily	Weekly	Less Than Once Per Week	Not at All
☐	☐	☐	☐	☐

8.2. Analysis or critiquing of exam or study results

Many Times Per Day	Daily	Weekly	Less Than Once Per Week	Not at All
☐	☐	☐	☐	☐

8.3. Grip, grasp, manipulate equipment with hand

Many Times Per Day	Daily	Weekly	Less Than Once Per Week	Not at All
☐	☐	☐	☐	☐

8.4. Push or pull equipment

Many Times Per Day	Daily	Weekly	Less Than Once Per Week	Not at All
☐	☐	☐	☐	☐

8.5. Lift equipment (not including cassettes)

Many Times Per Day	Daily	Weekly	Less Than Once Per Week	Not at All
☐	☐	☐	☐	☐

8.6. Transporting objects or equipment (not including patients)

Many Times Per Day	Daily	Weekly	Less Than Once Per Week	Not at All
☐	☐	☐	☐	☐

8.7. Transport patients to and from their hospital rooms, between facilities or between departments

Many Times Per Day	Daily	Weekly	Less Than Once Per Week	Not at All
☐	☐	☐	☐	☐

8.8. Transfer patients who offer little or no assistance

Many Times Per Day	Daily	Weekly	Less Than Once Per Week	Not at All
☐	☐	☐	☐	☐

8.9. Use equipment to assist with transfers (such as On3, sliding board, mechanical lift device)

Many Times Per Day	Daily	Weekly	Less Than Once Per Week	Not at All
☐	☐	☐	☐	☐

8.10. Position or re-position patients who offer little or no assistance

Many Times Per Day	Daily	Weekly	Less Than Once Per Week	Not at All
☐	☐	☐	☐	☐

8.11. **Carry** patients over a distance greater than 5 feet (e.g. pediatric patients)

Many Times Per Day	Daily	Weekly	Less Than Once Per Week	Not at All
☐	☐	☐	☐	☐

8.12. Administrative (meetings, training, etc.)

Many Times Per Day	Daily	Weekly	Less Than Once Per Week	Not at All
☐	☐	☐	☐	☐

8.13. Supervise other staff members

Many Times Per Day	Daily	Weekly	Less Than Once Per Week	Not at All
☐	☐	☐	☐	☐

8.14. Computer work (data entry or processing, e-mail, etc.)

Many Times Per Day	Daily	Weekly	Less Than Once Per Week	Not at All
☐	☐	☐	☐	☐

8.15. Other _____

Many Times Per Day	Daily	Weekly	Less Than Once Per Week	Not at All
☐	☐	☐	☐	☐

8.16. Other _____

Many Times Per Day	Daily	Weekly	Less Than Once Per Week	Not at All
☐	☐	☐	☐	☐

9. Please refer to the following table to describe the frequency you use specific pieces of equipment while at work by placing a check in the appropriate column. Examples of locations where the equipment can be found are listed in some cases. However, all possible equipment locations are not necessarily listed. Note that the table is continued on the next page.

To respond, place a check
In the first column for equipment used on a **daily** basis;
In the second column for equipment used on a **weekly** basis;
In the third column for equipment used **less than weekly**;
In the fourth column if you **do not use the equipment** at all.

Equipment	Daily	Weekly	Less Than Weekly	Not At All
ALL AREAS				
Computer keyboard				
Computer mouse				
Computer trackball				
Other computer pointing device _____				
ULTRASOUND				
Acuson Ultrasound (North, South)				
ATL Ultrasounds (North)				
Corometrics/Aloka Ultrasound (L&D North)				
GE Ultrasound (North)				
Hitachi Ultrasound (North, Urology-South)				
Siemens Elegra Ultrasound (South)				
MRI				
Coils for MRI Exam				
Clinical MRI Scanner				
Research MRI Scanner				
Mobile MRI Scanner				
CT				
GE CT Scanners (North, SW Clinic)				
Siemens Tomo Room (North)				
VASCULAR				
Phillips Vascular Lab (North Vasc. Rad.)				
Toshiba Vascular Lab (North Vasc. Rad.)				
Phillips Digital Thoravision (North)				
Angiojet thrombectomy unit				
Phillips Angio table				
OTHER				
GE Portable X-ray unit				
Continental Gen. Rad Room (Pickens, Roxboro Rd., SW Clinic)				
GE Gen. Rad Room (North-*H2*)				

Phillips Gen. Rad Room (Pickett Rd., CFL, South, Sports Med., North-*H1*)				
Picker Analog Chest (North-*A2,* South)				
Phillips Amber Unit (South)				
Equipment	**Daily**	**Weekly**	**Less Than Weekly**	**Not At All**
Franklin Head Unit				
Panorex (for mandibular views)				
Wall Bucky				
GE R&F Room (GI-North, North, South)				
Phillips Angio with C-Arm (North-*G5*)				
GE Fluoro (GI-North, North-*E1*, North-*E2*)				
OEC C-Arm (OR North, RM D-1, Research Park II)				
Breast Biopsy Unit				
Siemens Mammomat/Breast Imager				
Scoliosis Board				
HSG Tray				
Pigg-o-Stat				
GE Legacy Fluoro				
Phillips B25 C-Arm (OR North, OR South, 8200, 2200)				
EUB-515 ultrasound scanner				
Phillips GU Fluoro Unit				
Philips Tomography Unit				
Other, List _____				
Other, List _____				
Other, List _____				

Continue on to the Next Page of this Survey.

10. Magnetic Resonance and Computed Tomography Section

NOTE: If you do not work in any of these areas, or with MR or CT equipment, please skip to the *next page* of this survey.

MR1. Review the list of work categories in the table below. For each category, check the appropriate box based on the amount of time you spend on each task during a **typical** workweek.

Task	I spend the majority of my time	I spend some of my time	I spend a little of my time	I don't spend any time
Performing exams				
Critiquing exams				
Invasive procedures				
Paper work				
Computer work				
Down time (waiting for patients, waiting to have films read, breaks, etc.)				
Transporting patients (includes time to go to get a patient)				
Restocking supplies				
Administrative time: meetings, continuing ed., etc.				
Emptying trash				
Cleaning/mopping floors				
Other. List and describe briefly				
Other. List and describe briefly				

MR2. Of the time you perform exams/studies, what percentage do you spend on

____ computer interaction during exam procedures
____ patient preparation or positioning
____ other, describe _____
100%

MR3. Of the time you use the computer, estimate the percentage you use the pointing device versus keyboard.

____ mousing or other pointing device (list) _____
____ keying
100%

Continue to Page 10 if You Have Completed All of the Questions on This Page.

10. Diagnostic Ultrasound Section (Includes General, Vascular, Fetal Diagnostic, etc.)

NOTE: If you do not work in any of these areas, or with ultrasound equipment, please skip to the *next page* of this survey.

US1. Review the list of work categories in the table below. For each category, check the appropriate box based on the amount of time you spend on each task during an average workweek.

Task	I spend the majority of my time	I spend some of my time	I spend a little of my time	I don't spend any time
Performing ultrasound exams				
Critiquing exams				
Paper work				
Computer work				
Down time (waiting for patients, waiting to have films read, breaks, etc.)				
Transporting patients (includes time to go to get a patient)				
Restocking supplies				
Administrative time: meetings, continuing ed., etc.				
Emptying trash				
Cleaning/mopping floors				
Other. List and describe briefly				
Other. List and describe briefly				

US2. Of the time you are performing procedures and exams, what percentage of time do you spend on each type of task?

____ non-portable ultrasound
____ portable ultrasound
100%

____ exams
____ invasive procedures
100%

US3. Of the time you use an ultrasound probe, what percent of time is spent using each type?

____ endovaginal probe
____ vector probe ultrasound head
____ linear probe ultrasound head
____ curved probe ultrasound head
____ other. Describe _____
100%

US4. ____ Of the time you perform portable or non-portable ultrasound exams, what percentage of time do you use your *non-dominant* hand to hold the sound head?

Continue to Page 10 if You Have Completed All of the Questions on This Page.

10. General / Diagnostic Radiology Section (includes General, Vascular, Orthopedics, Urology, Gastrointestinal, Mammography and Others)

NOTE: If you do not work in any of these areas, please skip to page 10 of this survey.

GR1. Review the list of work categories in the table below. For each category, check the appropriate box based on the amount of time you spend on each task during an average workweek.

Task	I spend the majority of my time	I spend some of my time	I spend a little of my time	I don't spend any time
Performing radiographic exams				
Critiquing exams				
Invasive procedures				
Develop films				
Quality check on breast biopsy equipment				
Paper work				
Computer work				
Down time (waiting for patients, waiting to have films read, breaks, etc.)				
Transporting patients (includes time to go to get a patient)				
Restocking supplies				
Administrative time: meetings, continuing ed., etc.				
Emptying trash				
Cleaning/mopping floors				
Other. List and describe briefly				
Other. List and describe briefly				

GR2. Of the time you are performing exams, what percentage of time do you spend on each type of exam?

____ non-portables
____ portable x-ray exam
100%

GR3. Of the time you perform exams, what percentage of time do you spend on each type of exam?

____ fluoro exam
____ mammograms
____ breast biopsy
____ chest x-ray
____ mandibular/head/neck
____ extremity/body
____ prostate biopsies
____ Other. Describe _____
100%

GR4. Of the time you perform **portable exams,** what percentage of time do you spend on each type of exam

____ I do not perform portable exams.
____ Chest x-ray
____ Other. Describe _____
100%

GR5. Of the time you transport x-ray cassettes, what **percentage** of that time do you

____ Carry less than 3 cassettes at a time?
____ Carry 3, 4 or 5 cassettes at a time?
____ Carry 6 or more cassettes at a time?
100%

GR6. What percentage of exams that you perform are

____ Digital?
____ Performed with "lightweight" cassettes?
____ Performed with standard cassettes?
____ Other? Describe _____
100%

GR7. How often do you (note number of times, not the percentage of time)

____ use cassettes that are *larger than* 17x7 or 11x17? (average **number of times** per week)
____ use an upright Bucky? (average **number of times** per week)

Continue to Page 10 if You Have Completed All of the Questions on This Page.

<u>Part 2. NOTE</u>: For the remainder of the survey, please respond on the Opscan form provided (white page with red print).

<u>INSTRUCTIONS</u>: Turn to Side 1 of the form. Do NOT write your name on the Opscan form. Please complete the circles that correspond to your SEX and to your BIRTH DATE (month and year), then begin answering the following questions.

1. How many years have you been working altogether?
   A. 0-5 years
   B. 5-10 years
   C. 11-15 years
   D. 16-20 years
   E. Greater than 20 years

2. How many years have you been working with your current employer?
   A. 0-5 years
   B. 5-10 years
   C. 11-15 years
   D. 16-20 years
   E. Greater than 20 years

3. How many hours per week do you work at this job on the average?
   A. 0-10 hours
   B. 11-20 hours
   C. 21-30 hours
   D. 31-40 hours
   E. More than 40 hours

4. What is your total annual wage or salary from this job?
   A. Less than $15,000
   B. $15,000 - $30,000
   C. $30,001 - $45,000
   D. $45,001 - $60,000
   E. Greater than $60,000

5. What shift do you work?
   A. First
   B. Second
   C. Third
   D. Rotating

6. How many days per week do you take "call?"
   A. 0
   B. 1 or 2
   C. 3 or 4
   D. 5 or 6
   E. 7

7. Job Content Questionnaire item here.

8. How many hours per week do you wear a lead apron?
   A. 0-10 hours
   B. 11-20 hours
   C. 21-30 hours
   D. 31-40 hours
   E. More than 40 hours

9. In your best estimation, what percentage of your patients are obese?
   A. 0-20%
   B. 21-40%
   C. 41-60%
   D. 61-80%
   E. 81-100%

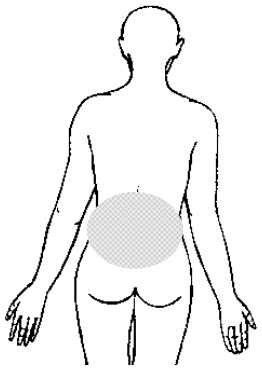
10. How much does working with an obese patient make *your exam procedure* more difficult*?*
    A. Not at all B. Somewhat C. Very much D. I do not perform exam procedures

Please continue to the Musculoskeletal Section on the next page of the survey. You should be ready to respond to Number 11 on your OPSCAN form.

MUSCULOSKELETAL SECTION

This section pertains to musculoskeletal problems. Please continue using the Opscan form

LOW BACK: How to answer the following questions: In this picture, you can see the approximate position of the part of the body referred to in the questions. "Low back trouble" means ache, pain or discomfort in the shaded area whether or not it extends from there to one or both legs. You may be in doubt as to how to answer, but please do your best anyway.



11. Have you ever had **low back** trouble (ache, pain or discomfort)?
    A. Yes B. No

If you answered No to question #11, skip to question # 21.

12. Have you ever been hospitalized because of **low back** trouble?
    A. Yes B. No

13. Have you ever had to change jobs or duties because of **low back** trouble?
    A. Yes B. No

14. Have you had **low back** trouble during the last 12 months?
A. Yes B. No

If you answered No to question #14, then skip to question #21.

15. What is the total length of time that you have had **low back** trouble during the last 12 months?
A. 0 days
B. 1-7 days
C. 8-30 days
D. More than 30 days but not every day
E. Every day

16. Has your **low back** trouble caused you to reduce your WORK activity (at home or away from home) during the last 12 months?
    A. Yes B. No

17. Has your **low back** trouble caused you to reduce your LEISURE activity during the last 12 months?
    A. Yes B. No

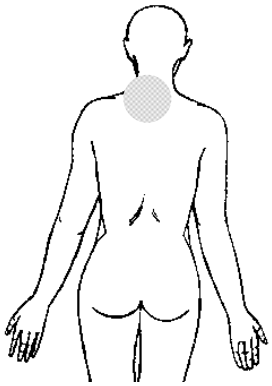
18. What is the total length of time your **low back** trouble has prevented you from doing your normal activities (at home or away from home) during the last 12 months?
A. 0 days
B. 1-7 days
C. 8-30 days
D. More than 30 days

19. Have you been seen by a doctor, physical therapist, chiropractor, or other such person because of **low back** trouble during the last 12 months?
    A. Yes B. No

20. Have you had **low back** trouble at any time during the last 7 days?
    A. Yes B. No

NECK: How to answer the following questions: In this picture, you can see the approximate position of the part of the body referred to in the questions. "Neck trouble" means ache, pain or discomfort in the shaded area. Please concentrate on this area, ignoring any trouble you may have in adjacent parts of the body. There is a separate section for shoulder trouble. Please answer by filling in the circle **on the Opscan form** that corresponds to your response. You may be in doubt as to how to answer, but please do your best anyway.

21. Have you ever had **neck** trouble (ache, pain or discomfort)?
    A. Yes B. No



If you answered No to question #21, skip to question #31.

22. Have you ever been hospitalized because of **neck** trouble?
    A. Yes B. No

23. Have you ever had to change jobs or duties because of **neck** trouble?
    A. Yes B. No

24. Have you had **neck** trouble during the last 12 months?
    A. Yes B. No

If you answered No to question #24, then skip to question #31.

25. What is the total length of time that you have had **neck** trouble during the last 12 months?
A. 0 days
B. 1-7 days
C. 8-30 days
D. More than 30 days but not every day
E. Every day

26. Has your **neck** trouble caused you to reduce your WORK activity (at home or away from home) during the last 12 months?
    A. Yes B. No

27. Has your **neck** trouble caused you to reduce your LEISURE activity during the last 12 months?
    A. Yes B. No

28. What is the total length of time your **neck** trouble has prevented you from doing your normal activities (at home or away from home) during the last 12 months?
A. 0 days
B. 1-7 days
C. 8-30 days
D. More than 30 days

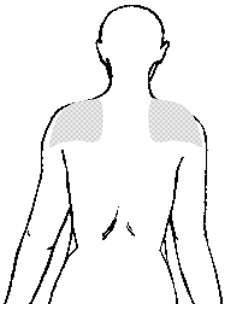
29. Have you been seen by a doctor, physical therapist, chiropractor, or other such person because of **neck** trouble during the last 12 months?
    A. Yes B. No

30. Have you had **neck** trouble at any time during the last 7 days?
    A. Yes B. No

SHOULDER: How to answer the following questions: In this picture, you can see the approximate position of the part of the body referred to in the questions. "Shoulder trouble" means ache, pain or discomfort in the shaded area. Please concentrate on this area ignoring any trouble you may have in adjacent parts of the body. Please answer by filling in the circle **on the OPSCAN form** that corresponds to your response. You may be in doubt as to how to answer, but please do your best anyway.

31. Have you ever had **shoulder** trouble (ache, pain or discomfort)?
    A. Yes B. No

If you answered No to question #31, skip to question #39.



32. Have you ever had to change jobs or duties because of **shoulder** trouble?
    A. Yes B. No

33. Have you had **shoulder** trouble during the last 12 months?
    A. No
    B. Yes, my right shoulder
    C. Yes, my left shoulder
    D. Yes, both shoulders

If you answered No to question #33, skip to question #39.

34. Has your **shoulder** trouble caused you to reduce your WORK activity (at home or away from home) during the last 12 months?
    A. Yes B. No

35. Has your **shoulder** trouble caused you to reduce your LEISURE activity during the last 12 months?
    A. Yes B. No

36. What is the total length of time your **shoulder** trouble has prevented you from doing your normal activities (at home or away from home) during the last 12 months?
    A. 0 days
    B. 1-7 days
    C. 8-30 days
    D. More than 30 days

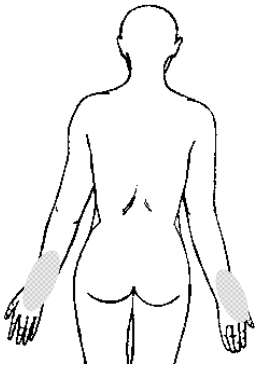
37. Have you been seen by a doctor, physical therapist, chiropractor, or other such person because of **shoulder** trouble during the last 12 months?
    A. Yes B. No

38. Have you had **shoulder** trouble at any time during the last 7 days?
    A. Yes B. No

HANDS/WRISTS: How to answer the following questions: In this picture, you can see the approximate position of the part of the body referred to in the questions. "Hand/wrist" trouble means ache, pain or discomfort in the shaded area. Please concentrate on this area ignoring any trouble you may have in adjacent parts of the body. Please answer by filling in the circle **on the OPSCAN form** that corresponds to your response. You may be in doubt as to how to answer, but please do your best anyway.

39. Have you ever had **hand/wrist** trouble (ache, pain or discomfort)?
    A. Yes B. No

If you answered No to question #39, skip to the next page.



40. Have you ever had to change jobs or duties because of **hand/wrist** trouble?
    A. Yes B. No

41. Have you had **hand/wrist** trouble during the last 12 months?
    A. No
    B. Yes, my right hand/wrist
    C. Yes, my left hand/wrist
    D. Yes, both hands/wrists

If you answered No to question #41, skip to the next page.

42. Has your **hand/wrist** trouble caused you to reduce your WORK activity (at home or away from home) during the last 12 months?
    A. Yes B. No

43. Has your **hand/wrist** trouble caused you to reduce your LEISURE activity during the last 12 months?
    A. Yes B. No

44. What is the total length of time your **hand/wrist** trouble has prevented you from doing your normal activities (at home or away from home) during the last 12 months?
    A. 0 days
    B. 1-7 days
    C. 8-30 days
    D. More than 30 days

45. Have you been seen by a doctor, physical therapist, chiropractor, or other such person because of **hand/wrist** trouble during the last 12 months?
    A. Yes B. No

46. Have you had **hand/wrist** trouble at any time during the last 7 days?
    A. Yes B. No

Please continue to the Work Content and Organization Section on the next page of the survey.
You should be ready to respond to Number 47 on your OPSCAN form.

WORK CONTENT AND ORGANIZATION SECTION

INSTRUCTIONS: This section of the survey pertains to the content and organization of your work. Please answer each question by filling in the circle **on the OPSCAN form** that corresponds to your response. You may be in doubt as to how to answer, but please do your best anyway.

47. – 157. Job Content Questionnaire item(s) here.

Questions 158-191 pertain to demographic and health information about you.

158. What is your ethnic background? (Please mark only one response.)
A. Black B. Hispanic C. White D. Other

159. What is your marital status?
A. Single B. Married C. Divorced/Separated D. Widowed

160. What is your education (Highest grade completed?)
A. Junior High School (8th & 9th grade)
B. High School
C. Junior College (1-2 yrs. College)
D. College Graduate
E. Graduate School

161. What level of skill is required on your job in terms of formal training? (Not necessarily the same as your education.)
A. High School Graduate
B. Some College Education
C. College Graduate
D. Graduate School

162. What is your weight in pounds?
A. Less than 130 lbs.
B. 130-160 lbs.
C. 161-200 lbs.
D. 201-240 lbs.
E. Greater than 240 lbs.

163. What is your height? (1 foot = 12 inches)
A. Less than 5 feet
B. Equal to 5 ft - 5 ft 4 in
C. Greater than 5 ft 4 in. - 5 ft 9 in
D. Greater than 5 ft 9 in - 6 ft 2 in
E. Greater than 6ft 2 in

164. Select only one. Are you
A. Right hand dominant?
B. Left hand dominant?
C. Ambidextrous? i.e. able to use either hand in a coordinated manner

165. Which statement best describes your history of smoking?
A. Never smoked
B. Smoked previously, but quit more than 12 months ago
C. Smoked previously, but quit within the last 12 months
D. Current smoker

166. If you smoke cigarettes, how many **cigarettes** do you smoke per day?
   A. Non-smoker
   B. Less than 10
   C. 10-20
   D. More than 20

167. Do you or have you used oral contraceptives in the last 12 months or have you had a hysterectomy?
   A. Yes
   B. No

168. Have you had a pregnancy during the last 12 months?
   A. Yes
   B. No

For questions numbered 169-181 on the Opscan form, please answer "A" for Yes and "B" for No to the following question.

Have you ever been diagnosed (by a physician) with any of the following conditions?

169. Diabetes Mellitus
170. Carpal tunnel syndrome
171. Arthritis
172. Tendinitis
173. Rheumatoid Arthritis
174. Systemic lupus erythematosus
175. Thyroid problems
176. Gout
177. Cervical nerve root compression
178. Thoracic outlet syndrome
179. Raynaud's phenomenon
180. Fibromyalgia
181. Alcoholism

For questions numbered 182-191 on the Opscan form, please answer "A" for Yes and "B" for No to the following question.

Have you ever had a traumatic (sudden) injury to any of the parts of your body listed below? Eye(s)

182. Neck
183. Right shoulder
184. Left shoulder
185. Right elbow/forearm
186. Left elbow/forearm
187. Right wrist/hand
188. Left wrist/hand
189. Upper back
190. Lower back

You have reached the end of the questionnaire. Thank you for completing it. Please return your completed questionnaire and Informed Consent form to:

Sabrina Lamar
Duke Ergonomics Division
Box 3834

Appendix 3

Follow-up Letter – One Week Post Distribution

Dear Radiology Professional,

Last week, a questionnaire requesting information about you, your work and some health-related issues was provided to you as part of a research study concerning musculoskeletal problems and ergonomic stressors for radiologic technologists.

If you have already completed and returned the questionnaire to me, please accept my sincere thanks. If not, please do so today or at your earliest convenience. I am especially grateful for your help because it is only by asking people like you to share this information that I can better understand the demands of your work and the effects they may have on you.

If you did not receive a questionnaire, or if it was misplaced, please call me and I will provide a replacement copy. I can be reached at (919)286-1722 extension 240. You may also contact my research advisor, Dr. Carolyn Sommerich, at (919)515-8614 or my Faculty Sponsor, Dr. Hester Lipscomb, at (919)286-1722 extension 256.

Sincerely,

Sabrina Lamar, PT
North Carolina State University, Department of Industrial Engineering
Duke Occupational and Environmental Safety Office, Ergonomics Division

Appendix 4

Follow-up Letter – Three Weeks Post Distribution

May 2, 2002

Dear Mr./Ms. Radiology Professional,

About three weeks ago, I sent a questionnaire to you that asked about you, your work, and some health-related issues. To the best of my knowledge, it has not been returned.

The comments of radiologic technologists who have already responded include a wide variety of responses about their musculoskeletal symptoms, work demands and work organization. I think the results of this research will be very useful to ergonomists and radiologic technologists interested in improving work conditions for professionals in your field.

I am writing again because of the importance that your responses to the questionnaire have for helping to get accurate results. Although I sent the questionnaire to most of the technologists working within the Duke Department of Radiology, it is only by hearing from nearly everyone that I can be sure that the results are truly representative.

A comment about our survey procedures. A questionnaire identification number is printed on the back cover of the questionnaire so that I can check your name off the mailing list when it is returned. The names are then discarded so that individual names can never be connected to the results in any way. Protecting the confidentiality of people's answers is very important to me, as well as to the universities I represent.

I hope that you will fill out and return the questionnaire soon, but if for any reason you prefer not to answer it, please let me know by returning a note or blank questionnaire in a campus envelope to me at Box 3834.

Sincerely,

Sabrina Lamar, PT
North Carolina State University, Department of Industrial Engineering
Duke Occupational and Environmental Safety Office, Ergonomics Division

P.S. If you have any questions, please feel free to contact me. I can be reached at (919)286-1722 extension 240. You may also contact my research advisor, Dr. Carolyn Sommerich, at (919)515-8614 or my Faculty Sponsor, Dr. Hester Lipscomb, at (919)286-1722 extension 256.

Appendix 5

Final Follow-up Letter – Eight Weeks Post Distribution

June 14, 2002

Dear Mr./Ms. Radiology Professional,

During the last two months, I have sent you several mailings about an important research study concerning the work of radiologic technologists which I am conducting through North Carolina State University. Its purpose is to help me better understand the type of work you do and how it affects you.

The study is drawing to a close, and this is the last contact that I will make with you by mail regarding the completion of this questionnaire.

I am sending this final contact because of my concern that people, such as you, who have not responded, may have had different experiences than those who have responded. Hearing from everyone in this small sample at Duke helps assure that the survey results are as accurate as possible. I also want to assure you that your participation in the study is voluntary. You may choose to not respond, but let me know if that is your choice.

Finally, I appreciate your willingness to consider my request as I conclude this effort to better understand the type of work you do and how it affects you and others in your field. Thank you very much.

If you have any questions, please feel free to contact me. I can be reached at (919)286-1722 extension 240. You may also contact my research advisor, Dr. Carolyn Sommerich, at (919)515-8614 or my Duke faculty sponsor, Dr. Hester Lipscomb, at (919)286-1722 extension 256.

Sincerely,

Sabrina Lamar, PT
North Carolina State University, Department of Industrial Engineering
Duke Occupational and Environmental Safety Office, Ergonomics Division

Appendix 6

Informed Consent Form

Form
M0345

DUKE UNIVERSITY HEALTH SYSTEM

Consent Form for Participation in a Research Study
Sponsored by North Carolina State University and Duke University
Investigation of the Factors That Influence the Prevalence and Severity of Musculoskeletal Symptoms Among Radiologic Technologists
(Cross-Sectional Study)
IRB#3303-01-11ER

Introduction

You are being asked to participate in a research study of radiologic technologists at Duke Hospital and the associated satellite clinics. In order to decide whether or not you wish to be in the study, you will need to know about any good or bad things that could happen to you if you decide to participate. This sheet tells you about the study. Sabrina Lamar, PT in the Ergonomics Division of the Duke Occupational and Environmental Safety Office, is conducting this study as part of her thesis research toward a Master of Science degree in Industrial Engineering from North Carolina State University in Raleigh, North Carolina under the direction of Dr. Carolyn Sommerich. Hester Lipscomb, PhD, of the Duke Department of Community and Family Medicine, is the Duke Faculty Sponsor for this research. You can contact Sabrina Lamar at (919)286-1722 extension 240, Dr. Carolyn Sommerich at (919)515-8614, or Dr. Hester Lipscomb at (919)286-1722 extension 256 to ask any questions you might have at any time.

Purpose of the Study

The goal of this study is to learn more about the type of work you perform, how it is structured, any occupational or health issues that may be associated with higher frequency and severity of musculoskeletal symptoms. Examples of musculoskeletal symptoms are pain, tingling or numbness that occurs in various locations of the body.

How the Study Works

You are being asked to complete the attached questionnaire and return it promptly with the envelope provided. You will need approximately sixty minutes to complete the questionnaire. Some of the questions are personal. You may choose to not answer any of the questions for any reason by simply leaving them blank. You may receive a series of 2-4 follow up letters over a 1-2 month period after receiving this research packet, depending on when you return your completed questionnaire. The letters will be reminders for those who have not yet completed and returned their questionnaires, or they will be letters to thank you for completing the questionnaire.

Confidentiality

What you tell us will be kept private to the extent allowed by law. This means that only study staff can see this information. Your name will only be used to keep track of the status of your response, i.e. whether you have or have not responded. This will help us determine what type of follow-up letters to send you after your initial receipt of the research packet. Your name will never appear on papers with

the responses that you give us, nor will it be associated with the responses in any way. We will use a randomly assigned number on the back of the questionnaire to identify you as a participant. The number-name key will be maintained and accessed only by study staff and will be destroyed at the end of the study period. In addition, you will never be identified by name in any report about this study.

Risks to You

There are minimal risks to you if you decide to participate in the study. Survey responses will be kept confidential. Your employer will not be informed which employees do or do not choose to participate, nor will they be involved in any way with monitoring or managing the survey responses. The key linking your name to your survey ID# will be destroyed after the surveys have been returned making it impossible to link your name to your responses. The section below called "Your Rights" also explains what happens if you decide not to be in the study.

Benefits to You

There are minimal direct benefits to you for being in the study. However, your being in the study will help us determine which areas of radiologic technology may benefit from further investigation or interventions such as task re-design, equipment re-design, or process reorganization.

Compensation

At the close of this part of the study, a drawing will be held from the pool of participants who have completed and returned the questionnaire. Two entries will be selected to win $25.00 gift certificates to Café Parizade restaurant at 2200 W. Main Street in Durham.

Funding of this Study

This is essentially a non-funded study. The principal investigator, North Carolina State University, Department of Industrial Engineering, and Duke Occupational and Environmental Safety Office, Ergonomics Division are primarily responsible for administrative expenses that occur as a result of this study.

Form
M0345

DUKE UNIVERSITY HEALTH SYSTEM

Consent form for Participation in a Research Study
Sponsored by North Carolina State University and Duke University
Investigation of the Factors That Influence the Prevalence and Severity of Musculoskeletal Symptoms Among Radiologic Technologists
(Cross-Sectional Study)
IRB#3303-01-11ER

Your Rights

It is necessary that you read and understand several general points that apply to everyone who takes part in this study:

1. Joining this study is voluntary. You have the right to stop being in this study at any time.
2. Your name will not be used in medical journal articles or at meetings when the results of this study are reported.
3. You will be given a copy of this form and a copy will be placed in the study files.

Questions

If you have any questions, you may contact the principal investigator, Sabrina Lamar, PT at (919) 286-1722 extension 240, Dr. Carolyn Sommerich at (919) 515-8614, or Dr. Hester Lipscomb at (919) 286-1722 extension 256. Staff in the Duke Hospital Office of Risk Management can provide more information about your rights as a research subject. They can be reached by calling (919) 684-3277. You may also contact Dr. Matthew Zingraff, Chair of the NCSU IRB for the Use of Human Subjects in Research Committee, Box 7514, NCSU Campus (919/513-1834) or Mr. Matthew Ronning, Assistant Vice Chancellor, Research Administration, Box 7514, NCSU Campus (919/513-2148) with any questions you may have about participating in this research.

Authorization

"The purposes of this study, procedures to be followed, risks and benefits have been fully explained to me. I have been allowed to ask any questions I have, and all of my questions have been answered to my satisfaction. I have been told who to contact if I have additional questions. I understand that I may refuse to participate or withdraw from this study at any time, for any reason. I have read this consent form and consent to be a study participant. I have been given a copy of this consent form."

_____
Signature of Subject Date

_____
Signature of Person Obtaining Consent Date

Appendix 7

Unadjusted Odds Ratios Tables

Table A.7.1 Unadjusted odds ratios and 95% confidence intervals for history of any musculoskeletal symptoms in the past 12 months

Variable	Group	Any MS Symptoms in Past 12 Months n=80 (88.9%) OR (95%CI)	Interference with Work in Past 12 Months n=52 (57.8%) OR (95%CI)	Interference with Leisure in Past 12 Months n=53 (58.9%) OR (95%CI)
Age	< 40	1	1	1
	≥ 40	1.74 (0.46, 6.65)	0.93 (0.29, 3.01)	1.33 (0.41, 4.32)
Gender	Male	1	1	
	Female	3.78 (0.93, 15.41)	2.41 (0.64, 9.09)	2.41 (0.64, 9.09)
Race	Non-White	1	1	
	White	0.7 (0.08, 6.05)	1.22 (0.23, 6.32)	1.22 (0.23, 6.32)
Years Worked	≤ 15	1	1	
	>15	0.55 (0.13, 2.29)	0.36 (0.09, 1.41)	0.56 (0.16, 1.98)
Number Of Hours Per Week	≤ 30	1	1	1
	31-40	0.98 (0.1, 9.7)	0.76 (0.08, 7.26)	1.69 (0.28, 10.15)
	41+	0.62 (0.06, 5.96)	0.41 (0.05, 3.8)	1.11 (0.19, 6.49)
Work Group	Sonographers	1	1	1
	Non-Sonographers	1.29 (0.25, 6.77)	0.90 (0.18, 4.52)	1.62 (0.39, 6.79)
Perform Exams	Many Times / Day	1	1	1
	Other [a]	1.08 (0.21, 5.56)	1.56 (0.31, 7.72)	1.56 (0.31, 7.72)
Analyze Exams	Many Times / Day	1	1	1
	Other [a]	0.45 (0.12, 1.71)	0.77 (0.23, 2.59)	0.77 (0.23, 2.59)
Grip Equipment	Many Times / Day	1	1	1
	Other [a]	0.86 (.09, 7.84)	1.2 (0.14, 10.65)	1.2 (0.14, 10.65)
Push or Pull Equipment	Many Times / Day	1	1	1
	Other [a]	2.8 (0.33, 23.57)	3.93 (0.48, 32.26)	1.68 (0.34, 8.28)
Lift Equipment	Many Times / Day	1	1	1
	Other [a]	1.05 (0.28, 4.04)	2.04 (0.62, 6.68)	1.42 (0.43, 4.63)
Transport Objects	Many Times / Day	1	1	1
	Other [a]	1.0 (0.26, 3.83)	1.34 (0.41, 4.38)	0.93 (0.28, 3.10)
Transport Patients	Many Times / Day	1	1	1
	Other [a]	6.43 (1.26, 32.73) [b]	8.11 (1.72, 38.19) [b]	4.32 (0.89, 20.91)
Transfer Patients	Many Times / Day	1		1
	Other [a]	1.86 (0.50, 6.97)	1.59 (0.48, 5.2)	1.09 (0.33, 3.67)
Use Equipment for Patient Transfers	Many Times / Day	1	1	1
	Other [a]	2.25 (0.41, 12.48)	3.0 (0.67, 13.53)	1.57 (0.29, 8.37)
Position Patients	Many Times / Day	1	1	1
	Other [a]	1.05 (0.28, 3.92)	0.88 (0.27, 2.86)	0.61 (0.18, 2.03)
Carry Patients	Many Times / Day	1	1	1
	Other [a]	4.33 (0.36, 52.67)	3.12 (0.26, 37.19)	3.12 (0.26, 37.19)
Perform Administrative Tasks	Less than 1x/wk or Not at all	1	1	1
	Weekly or More Frequently	1.25 (0.24, 6.38)	1.02 (0.25, 4.10)	1.8 (0.37, 8.86)
Perform Computer Work	Many Times / Day	1	1	1
	Other [a]	0.49 (0.11, 2.15)	0.74 (0.18, 3.05)	0.46 (0.12, 1.71)

Table A.7.1 (continued)

Supervise Others	Less than 1x/wk or Not at all	1	1	1
	Weekly or More Frequently	0.60 (0.16, 2.25)	0.70 (0.22, 2.3)	1.02 (0.31, 3.42)
Wearing a Lead Apron	≤ 20 hours per week	1	1	1
	> 20 hours per week	2.11 (0.21, 21.01)	1.52 (0.16, 14.79)	1.52 (0.16, 14.79)

a Once per day or less frequently

[b] Statistically Significant $p < 0.05$

Table A.7.2 Unadjusted odds ratios and 95% confidence intervals for musculoskeletal symptoms in low back or neck in the past 12 months

Variable	Group	MS symptoms in LOW BACK n=66 (73%) OR (95%CI)	MS symptoms in NECK n=47 (52.2%) OR (95%CI)
Age	< 40	1	1
	≥ 40	2.26 (0.87, 5.91)	1.55 (0.68, 3.57)
Gender	Male	1	1
	Female	1.87 (0.60, 5.85)	4.16 (1.23, 14.13) [b]
Race	Non-White	1	1
	White	2.22 (0.63, 7.81)	1.63 (0.48, 5.59)
Years Worked	≤ 15	1	1
	>15	1.2 (0.48, 3.13)	1.77 (0.5, 2.7)
Number Of Hours Per Week	≤ 30	1	1
	31-40	1.09 (0.25, 4.86)	1.04 (0.28, 3.94)
	41+	.97 (0.21, 4.43)	1.89 (0.48, 7.37)
Work Group	Sonographers	1	1
	Non-Sonographers	1.0 (0.29, 3.5)	0.34 (0.10, 1.15)
Perform Exams	Many Times / Day	1	1
	Other[a]	1.02 (0.32, 3.23)	0.78 (0.28, 2.15)
Analyze Exams	Many Times / Day	1	1
	Other[a]	0.48 (0.18, 1.25)	0.39 (0.16, 0.95) [b]
Grip Equipment	Many Times / Day	1	1
	Other[a]	2.73 (0.32, 23.43)	1.59 (0.36, 7.08)
Push Or Pull Equipment	Many Times / Day	1	1
	Other[a]	2.43 (0.64, 9.18)	3.56 (1.17, 10.88) [b]
Lift Equipment	Many Times / Day	1	1
	Other[a]	0.92 (0.35, 2.42)	1.53 (0.65, 3.6)
Transport Objects	Many Times / Day	1	1
	Other[a]	0.87 (0.33, 2.27)	2.04 (0.86, 4.8)
Transport Patients	Many Times / Day	1	1
	Other[a]	3.1 (0.71, 13.55)	1.1 (0.26, 4.71)
Transfer Patients	Many Times / Day	1	1
	Other[a]	1.05 (0.40, 2.76)	1.27 (0.54, 2.99)
Use Equipment for Patient Transfers	Many Times / Day	1	1
	Other[a]	0.66 (0.13, 3.35)	2.85 (0.69, 11.83)
Position Patients	Many Times / Day	1	1
	Other[a]	0.42 (0.16, 1.11)	2.05 (0.88, 4.74)
Carry Patients	Many Times / Day	1	1
	Other[a]	1.39 (0.12, 16.08)	2.24 (0.20, 25.67)
Perform Administrative Tasks	Less than 1x/wk or Not at all	1	1
	Weekly or more frequently	1.22 (0.39, 3.78)	1.67 (0.62, 4.54)
Perform Computer Work	Many Times / Day	1	1
	Other[a]	1.23 (0.41, 2.84)	0.77 (0.27, 2.23)

Table A.7.2 (continued)

Supervise Others	Less than 1x/wk or Not at all	1	1
	Weekly or more frequently	1.08 (0.36, 4.21)	1.15 (0.49, 2.68)
Wearing a Lead Apron	> 20 hours per week	1	1
	≤ 20 hours per week	0.67 (0.07, 6.35)	1.69 (0.27, 10.62)

[a] Once per day or less frequently
[b] Statistically Significant $p < 0.05$

Table A.7.3 Unadjusted odds ratios and 95% confidence intervals for musculoskeletal symptoms in either shoulder, both shoulders, right shoulder, or left shoulder in the past 12 months

Variable	Group	MS Symptoms in EITHER SHOULDER n=44 (48.9%) OR (95%CI)	MS Symptoms in BOTH SHOULDERS n=11 (12.2%) OR (95%CI)	MS Symptoms in RIGHT SHOULDER n=26 (28.9%) OR (95%CI)	MS Symptoms in LEFT SHOULDER n=7 (7.8%) OR (95%CI)
Age	< 40	1	1	1	1
	≥ 40	0.78 (0.34, 1.82)	0.71 (0.18, 2.83)	0.71 (0.28, 1.77)	0.34 (0.06, 1.84)
Gender	Male	1	Cannot calculate**	1	1
	Female	1.76 (0.58, 5.34)		0.87 (0.27, 2.81)	1.32 (0.15, 11.82)
Race	Non-White	1	Cannot calculate**	1	Cannot calculate**
	White	0.64 (0.19, 2.21)		0.23 (0.07, 0.81) [b]	
Years Worked	≤ 15	1	1	1	1
	>15	0.93 (0.40, 2.14)	3.77 (0.76, 18.57)	0.51 (.20, 1.29)	0.97 (.20, 4.62)
Number Of Hours Per Week	≤ 30	1	Cannot calculate**	1	Cannot calculate**
	31-40	1.26 (0.33, 4.75)		0.46 (0.12, 1.81)	
	41+	1.07 (0.28, 4.16)		0.40 (0.10, 1.63)	
Work Group	Sonographers	1	1	1	1
	Non-Sonographers	0.19 (0.05, 0.71) [b]	0.89 (0.17, 4.59)	0.20 (0.06, 0.63) [b]	1.22 (0.14, 10.92)
Perform Exams	Many Times / Day	1	1	1	1
	Other[a]	1.21 (0.44, 3.33)	0.81 (0.16, 4.11)	1.6 (.55, 4.65)	0.60 (.07, 5.33)
Analyze Exams	Many Times / Day	1	1	1	1
	Other[a]	0.88 (0.36, 2.10)	1.16 (0.31, 4.34)	0.66 (0.24, 1.8)	1.56 (0.32, 7.45)
Grip Equipment	Many Times / Day	1	1	1	Cannot calculate**
	Other[a]	0.60 (0.13, 2.68)	2.7 (0.47, 15.46)	0.33 (0.04, 2.79)	
Push or Pull Equipment	Many Times / Day	1	1	1	1
	Other[a]	1.37 (0.51, 3.72)	2.25 (0.59, 8.64)	1.07 (0.36, 3.18)	0.56 (.06, 4.96)
Lift Equipment	Many Times / Day	1	1	1	1
	Other[a]	1.8 (0.76, 4.25)	1.13 (0.31, 4.18)	1.64 (0.62, 4.33)	1.65 (.30, 9.01)
Transport Objects	Many Times / Day	1	1	1	1
	Other[a]	1.96 (0.83, 4.64)	3.4 (0.69, 16.77)	1.09 (0.43, 2.79)	1.73 (0.32, 9.47)
Transport Patients	Many Times / Day	1	1	Cannot calculate**	1
	Other[a]	3.15 (0.60, 16.53)	0.97 (0.11, 8.75)		0.55 (0.06, 5.27)

Table A.7.3 (continued)

Transfer Patients	Many Times / Day	1	1	1	1
	Other[a]	1.83 (0.77, 4.38)	0.66 (0.18, 2.35)	3.27 (1.09, 9.75) [b]	0.75 (0.16, 3.6)
Use Equipment to Transfer Patients	Many Times / Day		1	1	Cannot calculate**
	Other[a]	1.5 (.39, 5.72)	0.51 (0.09, 2.77)	1.71 (0.34, 8.68)	
Position Patients	Many Times / Day		1	1	1
	Other[a]	1.10 (0.48, 2.5)	0.77 (0.22, 2.74)	1.81 (.72, 4.6)	0.35 (0.07, 1.93)
Carry Patients	Many Times / Day	Cannot calculate**	Cannot calculate**	Cannot calculate**	Cannot calculate**
	Other[a]				
Perform Administrative Tasks	Less than 1x/wk or Not at all	1	1	1	1
	Weekly or more frequently	1.2 (0.45, 3.19)	2.08 (0.55, 7.96)	0.71 (0.23, 2.21)	1.35 (0.24, 7.51)
Perform Computer Work	Many Times / Day	1	1	1	1
	Other[a]	1.22 (0.42, 3.52)	0.95 (0.19, 4.85)	1.45 (0.47, 4.43)	0.7 (0.08, 6.21)
Supervise Others	Less than 1x/wk or Not at all	1	1	1	1
	Weekly or more frequently	0.67 (0.29, 1.58)	2.07 (0.58, 7.38)	0.61 (0.23, 1.61)	0.24 (0.03, 2.09)
Wearing a Lead Apron	> 20 hours per week	1	1	Cannot calculate**	Cannot calculate**
	≤ 20 hours per week	1.47 (0.23, 9.22)	0.18 (0.03, 1.21)		

[a] Once per day or less frequently
[b] Statistically Significant $p < 0.05$
** Some cell(s) have zero frequencies and/or 20 percent of cell frequencies are <5

Table A.7.4 Unadjusted odds ratios and 95% confidence intervals for musculoskeletal symptoms in either hand/wrist, both hands/wrists, right hand/wrist, or left hand/wrist in the past 12 months

Variable	Group	MS symptoms in EITHER HAND/WRIST n=37 (41%) OR (95%CI)	MS symptoms in BOTH HANDS/WRISTS n=9 (10%) OR (95%CI)	MS symptoms in RIGHT HAND/WRIST n=23 (25.6%) OR (95%CI)	MS symptoms in LEFT HAND/WRIST n=5 (5.6%) OR (95%CI)
Age	< 40	1	1	1	1
	≥ 40	0.78 (0.34, 1.82)	0.71 (0.18, 2.83)	1.0 (0.39, 2.57)	0.59 (0.09, 3.73)
Gender	Male	1	Cannot calculate**	1	1
	Female	1.68 (0.53, 5.31)		1.6 (0.41, 6.23)	0.30 (0.05, 1.94)
Race	Non-White	1	Cannot calculate**	1	1
	White	0.45 (0.13, 1.53)		0.28 (0.08, 0.98) [b]	0.59 (0.06, 5.82)
Years Worked	≤ 15	1	1	1	1
	>15	0.93 (0.40, 2.18)	2.8 (0.55, 14.31)	0.58 (0.22, 1.51)	1.10 (0.17, 6.94)
Number Of Hours Per Week	≤ 30	1	Cannot calculate**	1	Cannot calculate**
	31-40	1.14 (0.29, 4.51)		0.53 (0.13, 2.19)	
	41+	1.40 (0.35, 5.64)		0.58 (0.14, 2.47)	
Work Group	Sonographers	1	1	1	Cannot calculate**
	Non-Sonographers	0.40 (0.13, 1.23)	0.67 (0.12, 3.59)	0.31 (0.10, 0.98) [b]	
Perform Exams	Many Times / Day	1	1	1	1
	Other[a]	0.31 (0.09, 1.02)	0.44 (0.05, 3.73)	0.28 (0.06, 1.32)	0.93 (0.10, 8.85)
Analyze Exams	Many Times / Day	1	1	1	1
	Other[a]	0.30 (0.11, 0.82) [b]	0.54 (0.11, 2.78)	0.33 (0.10, 1.09)	0.48 (0.05, 4.52)
Grip Equipment	Many Times / Day	1	1	Cannot calculate**	1
	Other[a]	0.45 (0.09, 2.35)	3.57 (0.60, 21.13)		0
Push or Pull Equipment	Many Times / Day	1	1	1	1
	Other[a]	0.72 (0.26, 2.02)	1.0 (0.19, 5.24)	0.96 (0.31, 3.03)	0
Lift Equipment	Many Times / Day	1	1	1	1
	Other[a]	0.73 (0.31, 1.73)	2.41 (0.47, 12.32)	0.61 (0.23, 1.59)	0.40 (0.06, 2.54)
Transport Objects	Many Times / Day	1	1	1	1
	Other[a]	0.54 (0.23, 1.28)	2.53 (0.49, 12.95)	0.31 (0.12, 0.84) [b]	1.0 (0.16, 6.30)
Transport Patients	Many Times / Day	1	Cannot calculate**	1	1
	Other[a]	0.67 (0.16, 2.88)		0.54 (0.12, 2.45)	0.36 (0.04, 3.67)

Table A.7.4 (continued)

Transfer Patients	Many Times / Day	1	1	1	Cannot calculate**
	Other[a]	1.37 (0.57, 3.3)	2.17 (0.42, 11.12)	0.68 (0.26, 1.79)	
Use Equipment for Patient Transfers	Many Times / Day	1	Cannot calculate**	1	Cannot calculate**
	Other[a]	1.72 (0.42, 7.16)		0.78 (0.18, 3.3)	
Position Patients	Many Times / Day	1	1	1	1
	Other[a]	1.02 (0.44, 2.35)	2.05 (0.48, 8.76)	0.84 (0.32, 2.16)	0.62 (0.10, 3.91)
Carry Patients	Many Times / Day	1	Cannot calculate**	1	Cannot calculate**
	Other[a]	1.41 (0.12, 16.17)		0.68 (0.06, 7.83)	
Perform Administrative Tasks	Less than 1x/wk or Not at all	1	1	1	1
	Weekly or more frequently	1.41 (0.53, 3.78)	0.93 (0.18, 4.87)	1.22 (0.41, 3.65)	2.32 (0.36, 14.88)
Perform Computer Work	Many Times / Day	1	Cannot calculate**	1	1
	Other[a]	0.25 (0.07, 0.93)[b]		0.33 (0.07, 1.57)	1.08 (0.11, 10.31)
Supervise Others	Less than 1x/wk or Not at all	1	1	1	1
	Weekly or more frequently	0.93 (0.39, 2.2)	1.29 (0.32, 5.18)	1.01 (0.38, 2.68)	0.38 (0.04, 3.5)
Wearing a Lead Apron	> 20 hours per week	1	Cannot calculate**	1	Cannot calculate**
	≤ 20 hours per week	1.05 (0.17, 6.62)		0.49 (0.08, 3.15)	

[a] Once per day or less frequently
[b] Statistically Significant $p < 0.05$
** Some cell(s) have zero frequencies and/or 20 percent of cell frequencies are <5

Table A.7.5 Unadjusted odds ratios and 95% confidence intervals for musculoskeletal symptoms in hand/wrist or in shoulder on dominant side in the past 12 months

Variable	Group	MS Symptoms in DOMINANT HAND/WRIST n=18 (20%) OR (95%CI)	MS Symptoms in DOMINANT SHOULDER n= 21(23.3%) OR (95% CI)
Age	< 40	1	1
	≥ 40	0.89 (0.32, 2.51)	0.89 (0.32, 2.51)
Gender	Male	1	1
	Female	1.93 (0.40, 9.39)	0.89 (0.26, 3.14)
Race	Non-White	1	1
	White	0.28 (0.08, 1.02)	0.24 (0.07, 0.84) [b]
Years Worked	≤ 15	1	1
	>15	0.67 (0.24, 1.9)	0.45 (0.17, 1.22)
Number of Hours Per Week	≤ 30	1	1
	31-40	0.40 (0.09, 1.7)	0.36 (0.09, 1.45)
	41+	0.35 (0.08, 1.58)	0.24 (0.05, 1.05)
Work Group	Sonographers	1	1
	Non-Sonographers	0.42 (0.12, 1.43)	0.26 (0.08, .84) [b]
Perform Exams	Many Times / Day	1	1
	Other[a]	0.40 (0.08, 1.94)	2.37 (0.79, 7.14)
Analyze Exams	Many Times / Day	1	1
	Other[a]	0.51 (0.15, 1.7)	1.00 (0.35, 2.82)
Grip Equipment	Many Times / Day	1	1
	Other[a]	0	0.44 (0.05, 3.82)
Push or Pull Equipment	Many Times / Day	1	1
	Other[a]	1.46 (0.45, 4.75)	1.57 (0.52, 4.79)
Lift Equipment	Many Times / Day	1	1
	Other[a]	1.0 (0.35, 2.88)	2.46 (0.81, 7.48)
Transport Objects	Many Times / Day	1	1
	Other[a]	0.34 (0.12, .98) [b]	1.11 (0.41, 3.03)
Transport Patients	Many Times / Day	1	Cannot calculate**
	Other[a]	0.37 (0.08, 1.74)	
Transfer Patients	Many Times / Day	1	1
	Other[a]	0.66 (0.23, 1.90)	3.08 (0.94, 10.12)
Use Equipment for Patient Transfers	Many Times / Day	1	1
	Other[a]	0.54 (0.12, 2.33)	1.25 (0.24, 6.38)
Position Patients	Many Times / Day	1	1
	Other[a]	0.72 (.25, 2.02)	1.77 (0.65, 4.82)
Carry Patients	Many Times / Day	Cannot calculate**	Cannot calculate**
	Other[a]		
Perform Administrative Tasks	Less than 1x/wk or Not at all	1	1
	Weekly or more frequently	1.35 (0.42, 4.34)	0.72 (0.21, 2.44)
Perform Computer Work	Many Times / Day	1	1
	Other[a]	0.48 (0.10, 2.30)	1.48 (0.46, 4.84)

Table A.7.5 (continued)

Supervise Others	Less than 1x/wk or Not at all	1	1
	Weekly or more frequently	1.33 (0.47, 3.79)	0.55 (0.19, 1.59)
Wearing a Lead Apron	> 20 hours per week	1	Cannot calculate**
	≤ 20 hours per week	0.35 (0.05, 2.26)	

[a] Once per day or less frequently
[b] Statistically Significant p< 0.05
** Some cell(s) have zero frequencies and/or 20 percent of cell frequencies are <5

Appendix 8

Adjusted Odds Ratios Table, All Models

Table A.8.1 Adjusted odds ratios and 95% confidence intervals for musculoskeletal symptoms in low back in past 12 months (n= 66)

		Model 1	Model 2	Model 3	Model 4	Model 5
Age	≥ 40	2.12 (.8, 5.63)	2.22 (0.82, 6.05)	2.15 (0.78, 5.93)	2.14 (0.76, 6.02)	2.22 (0.77, 6.43)
	< 40	1	1	1	1	1
Gender	Female	1.57 (0.48, 5.09)	1.61 (0.49, 5.23)	1.49 (0.44, 4.98)	1.52 (0.44, 5.28)	1.80 (0.50, 6.44)
	Male	1	1	1	1	1
Work Group	Non-Sonographers	–	0.74 (0.20, 2.76)	0.78 (.20, 3.0)	1.15 (0.27, 4.85)	1.32 (0.30, 5.83)
	Sonographers	–	1	1	1	1
Analyze Exams	Other[a]	–	–	0.52 (0.19, 1.40)	0.36 (0.12, 1.05)	0.31 (0.10, 0.94)[b]
	Many Times/Day	–	–	1	1	1
Push or Pull Equipment	Other[a]	–	–	–	4.23 (0.94, 19.06)	3.96 (0.85, 18.52)
	Many Times/Day	–	–	–	1	1
Transport Patients	Other[a]	–	–	–	–	4.44 (0.89, 22.19)
	Many Times/Day	–	–	–	–	1
Position Patients	Other[a]	–	–	–	–	–
	Many Times/Day	–	–	–	–	–
Grip Equipment	Other[a]	–	–	–	–	–
	Many Times/Day	–	–	–	–	–

[a] Once per day or less frequently
[b] Statistically significant $p < 0.05$
– Variable not included in model

Table A.8.1 (continued)

		Model 6[c]	Model 7	Model 8	Model 9
Age	≥40	2.47 (0.8, 7.61)	2.61 (0.83, 8.19)	2.18 (0.79, 6.02)	2.45 (0.80, 7.44)
	<40	1	1	1	1
Gender	Female	1.74 (.43, 7.06)	1.86 (0.45, 7.75)	1.54 (0.45, 5.3)	1.73 (0.43, 7.02)
	Male	1	1	1	1
Work Group	Non-Sonographers	0.94 (0.21, 4.24)	0.77 (0.16, 3.76)	–	–
	Sonographers	1		–	–
Analyze Exams	Other[a]	0.30 (0.09, .99) [b]	0.27 (0.08, 0.88) [b]	0.36 (0.12, 1.05)	0.30 (0.09, 0.97) [b]
	Many Times/Day	1	1	1	1
Push or Pull Equipment	Other[a]	5.78 (1.11, 30.03) [b]	3.06 (0.47, 20.08)	4.09 (0.94, 17.74)	5.87 (1.17, 29.33) [b]
	Many Times/Day	1	1	1	1
Transport Patients	Other[a]	8.34 (1.44, 48.16) [b]	8.89 (1.51, 52.45) [b]	–	8.39 (1.46, 48.19) [b]
	Many Times/Day	1	1	–	1
Position Patients	Other[a]	0.21 (0.06, .72) [b]	0.19 (0.06, 0.67) [b]	–	0.21 (0.06, 0.71) [b]
	Many Times/Day	1	1	–	1
Grip Equipment	Other[a]	–	4.48 (0.25, 80.19)	–	–
	Many Times/Day	–	1	–	–

[a] Once per day or less frequently
[b] Statistically Significant $p < 0.05$
[c] Most descriptive model
– Variable not included in model

Table A.8.2 Adjusted odds ratios and 95% confidence intervals for musculoskeletal symptoms in neck in past 12 months (n=47)

		Model 1 OR(95%CI)	Model 2 OR(95%CI)	Model 3 OR(95%CI)	Model 4 [c] OR(95%CI)	Model 5 OR(95%CI)
Age	≥40	1.3 (0.55, 3.10)	1.69 (0.67, 4.26)	1.63 (0.63, 4.2)	1.63 (0.61, 4.37)	1.69 (0.61, 4.65)
	<40	1	1	1	1	1
Gender	Female	3.91 (1.13, 13.49) [b]	4.92 (1.29, 18.71) [b]	4.56 (1.21, 17.22) [b]	5.11 (1.28, 20.43) [b]	5.66 (1.37, 23.36) [b]
	Male	1	1	1	1	1
Work Group	Non-Sonographers	–	0.20 (0.05, 0.84) [b]	0.20 (0.05, 0.91) [b]	0.30 (0.06, 1.46)	0.29 (0.05, 1.57)
	Sonographers	–	1	1	1	1
Analyze Exams	Other[a]	–	–	0.43 (0.17, 1.12)	0.20 (0.06, 0.67) [b]	0.19 (0.05, 0.65) [b]
	Many Times/Day	–	–	1	1	1
Push or Pull Equipment	Other[a]	–	–	–	8.77 (1.86, 41.22) [b]	8.41 (1.82, 38.84) [b]
	Many Times/Day	–	–	–	1	1
Hours Worked Per Week	>40 hours	–	–	–	–	3.49 (0.66, 18.53)
	31-40 hours	–	–	–	–	2.52 (0.49, 12.94)
	0-30 hours	–	–	–	–	1
Use Equipment for Patient Transfers	Other[a]	–	–	–	–	–
	Many Times/Day	–	–	–	–	–
Position Patients	Other[a]	–	–	–	–	–
	Many Times/Day	–	–	–	–	–
Carry Patients	Other[a]	–	–	–	–	–
	Many Times/Day	–	–	–	–	–

Table A.8.2 (continued)

		Model 6	Model 7	Model 8	Model 9
Age	≥40	1.71 (0.62, 4.78)	1.71 (0.61, 4.77)	1.73 (0.62, 4.84)	1.44 (0.54, 3.83)
	<40	1	1	1	1
Gender	Female	5.55 (1.33, 23.20) [b]	5.46 (1.31, 22.7) [b]	5.29 (1.26, 33.13) [b]	4.7 (1.24, 17.9) [b]
	Male	1	1	1	1
Work Group	Non-Sonographers	0.32 (0.06, 1.74)	0.35 (0.06, 2.03)	0.35 (0.06, 2.05)	–
	Sonographers	1	1	1	–
Analyze Exams	Other[a]	0.19 (0.06, 0.67) [b]	0.19 (0.05, 0.65) [b]	.18 (0.05, 0.64) [b]	0.18 (0.05, .61) [b]
	Many Times/Day	1	1	1	1
Push or Pull Equipment	Other[a]	7.97 (1.73, 36.7)	7.62 (1.64, 35.3)	7.61 (1.64, 35.25)	10.05 (2.21, 45.4) [b]
	Many Times/Day	1	1		1
Hours Worked Per Week	> 40 hours	0.39 (0.73, 20.7)	3.73 (0.69, 20.02)	3.78 (0.70, 20.38)	3.47 (0.67, 18.0)
	31-40 hours	2.76 (0.54, 14.2)	2.79 (0.54, 14.42)	2.86 (0.55, 14.84)	2.16 (0.43, 10.8)
	0-30 hours	1	1	1	1
Use Equipment for Patient Transfers	Other[a]	2.34 (0.47, 11.67)	2.07 (0.39, 10.87)	2.01 (0.38, 10.67)	–
	Many Times/Day	1	1	1	–
Position Patients	Other[a]	–	1.44 (0.50, 4.13)	1.4 (0.40, 4.08)	–
	Many Times/Day	–	1	1	–
Carry Patients	Other[a]	–	–	1.6 (0.11, 22.91)	–
	Many Times/Day	–	–	1	–

[a] Once per day or less frequently
[b] Statistically significant $p < 0.05$
[c] Most descriptive model
– Variable not included in model

Table A.8.3 Adjusted odds ratios and 95% confidence intervals for musculoskeletal symptoms in right shoulder in past 12 months (n=26)

		Model 1	Model 2	Model 3 [c]	Model 4	Model 5
Age	≥ 40	0.72 (0.28, 1.8)	0.95 (0.35, 2.7)	0.98 (0.34, 2.8)	0.90 (0.31, 2.7)	0.87 (0.29, 2.6)
	< 40	1	1	1	1	1
Gender	Female	0.95 (0.29, 3.1)	1.06 (0.30, 3.8)	1.05 (0.28, 3.9)	1.18 (0.31, 4.6)	1.11 (0.28, 4.4)
	Male	1	1	1	1	1
Work Group	Non-Sonographer	–	0.20 (0.06, .66) [b]	0.17 (0.05, .61) [b]	0.24 (0.06, 0.92) [b]	0.26 (0.07, 0.99) [b]
	Sonographer	–	1	1	1	1
Race	White	–	–	0.20 (0.05, .74) [b]	0.19 (0.05, 0.75) [b]	0.19 (0.05, 0.74) [b]
	Non-White	–	–	1	1	1
Transfer Patients	Other[a]	–	–	–	2.35 (0.69, 8.0)	2.55 (0.73, 8.9)
	Many Times/Day	–	–	–	1	1
Grip Equipment	Other[a]	–	–	–	–	0.27 (0.03, 2.6)
	Many Times/Day	–	–	–	–	1
Hours worked per Week	> 40 hours	–	–	–	–	–
	31-40 hours	–	–	–	–	–
	0-30 hours	–	–	–	–	–

[a] Daily, Weekly, Less Than Once per Week, or Not at All
[b] Statistically Significant $p < 0.05$
[c] Most descriptive model
– Variable not included in model

Table A.8.3 (continued)

		Model 6	Model 7
Age	≥ 40	0.93 (0.31, 2.81)	0.66 (0.24, 1.8)
	< 40	1	1
Gender	Female	1.02 (0.26, 3.98)	1.08 (0.28, 4.1)
	Male	1	1
Work Group	Non-Sonographer	0.20 (0.05, 0.85) [b]	–
	Sonographer	1	–
Race	White	0.18 (0.04, 0.72) [b]	0.21 (0.05, .79) [b]
	Non-White	1	1
Transfer Patients	Other[a]	2.68 (0.74, 9.68)	3.81 (1.2, 12.3) [b]
	Many Times/Day	1	1
Grip Equipment	Other[a]	0.36 (0.04, 3.54)	–
	Many Times/Day	1	–
Hours worked per Week	> 40 hours	0.47 (0.09, 2.49)	–
	31-40 hours	1.01 (0.20, 5.07)	–
	0-30 hours	1	–

[a] Daily, Weekly, Less Than Once per Week, or Not at All
[b] Statistically Significant $p < 0.05$
[c] Most descriptive model
– Variable not included in model

Table A.8.4 Adjusted odds ratios and 95% confidence intervals for musculoskeletal symptoms in dominant shoulder in past 12 months (n=21)

		Model 1	Model 2	Model 3[c]	Model 4	Model 5
Age	≥ 40	0.61 (0.22, 1.7)	0.76 (0.26, 2.2)	0.76 (0.25, 2.3)	0.81 (0.26, 2.5)	0.74 (0.23, 2.4)
	< 40	1	1	1	1	1
Gender	Female	1.01 (0.28, 3.7)	1.12 (0.29, 4.3)	1.10 (0.28, 4.4)	0.85 (0.21, 3.4)	1.01 (0.24, 4.2)
	Male	1	1	1	1	1
Work Group	Non-Sonographer	–	0.28 (0.08, 0.94)[b]	0.25 (0.07, 0.89)[b]	0.19 (0.05, 0.79)[b]	0.26 (0.06, 1.1)
	Sonographer	–	1	1	1	1
Race	White	–	–	0.21 (.06, .80)[b]	0.21 (0.05, 0.83)[b]	0.19 (0.04, 0.76)[b]
	Non-White	–	–	1	1	1
Hours Worked Per Week	41+	–	–	–	0.22 (0.04, 1.2)	0.23 (0.04, 1.3)
	31-40	–	–	–	0.60 (0.12, 2.8)	0.71 (0.15, 3.5)
	≤ 30	–	–	–	1	1
Transfer Patients	Other[a]	–	–	–	–	2.76 (0.68, 11.3)
	Many Times/Day	–	–	–	–	1
Perform Exams	Other[a]	–	–	–	–	–
	Many Times/Day	–	–	–	–	–
Grip Equipment	Other[a]	–	–	–	–	–
	Many Times/Day	–	–	–	–	–
Lift Equipment	Other[a]	–	–	–	–	–
	Many Times/Day	–	–	–	–	–

[a] Once per day or less frequently
[b] Statistically Significant $p < 0.05$
[c] Most descriptive model
– Variable not included in model

Table A.8.4 (continued)

		Model 6	Model 7	Model 8
Age	≥ 40	0.68 (0.21, 2.21)	0.64 (0.19, 2.12)	0.68 (0.20, 2.27)
	< 40	1	1	1
Gender	Female	1.14 (0.26, 4.97)	1.13 (0.26, 4.95)	1.06 (0.24, 4.73)
	Male	1	1	1
Work Group	Non-Sonographer	0.27 (0.06, 1.18)	0.29 (0.07, 1.3)	0.34 (0.07, 1.56)
	Sonographer	1	1	1
Race	White	0.21 (0.05, 0.87) [b]	0.22 (0.05, 0.92) [b]	0.19 (0.04, 0.86) [b]
	Non-White	1	1	1
Hours Worked Per Week	41+	0.23 (0.04, 1.3)	0.26 (0.05, 1.51)	0.28 (0.05, 1.65)
	31-40	0.75 (0.15, 3.86)	0.74 (0.14, 3.98)	0.76 (0.14, 4.11)
	≤ 30	1	1	1
Transfer Patients	Other[a]	2.46 (0.60, 10.13)	2.39 (0.58, 9.89)	1.96 (0.44, 8.66)
	Many Times/Day	1	1	1
Perform Exams	Other[a]	2.16 (0.58, 8.13)	2.67 (0.65, 10.95)	2.71 (0.65, 11.27)
	Many Times/Day	1	1	1
Grip Equipment	Other[a]	–	0.36 (0.03, 3.96)	0.28 (0.02, 3.34)
	Many Times/Day	–	1	1
Lift Equipment	Other[a]	–	–	1.8 (0.44, 7.47)
	Many Times/Day	–	–	1

[a] Once per day or less frequently
[b] Statistically Significant $p < 0.05$
[c] Most descriptive model
– Variable not included in model

Table A.8.5 Adjusted odds ratios and 95% confidence intervals for musculoskeletal symptoms in right hand/wrist in past 12 months (n=23)

		Model 1	Model 2	Model 3	Model 4	Model 5
Age	≥ 40	0.93 (0.35, 2.5)	1.18 (0.42, 3.3)	1.2 (0.41, 3.5)	1.34 (0.43, 4.2)	1.3 (0.42, 4.0)
	< 40	1	1	1	1	1
Gender	Female	1.63 (0.41, 6.5)	1.85 (0.44, 7.8)	1.81 (0.42, 7.7)	2.27 (0.47, 10.9)	2.13 (0.44, 10.3)
	Male	1	1	1	1	1
Work Group	Non-Sonographer	–	0.27 (0.08, 0.9) [b]	0.25 (0.07, 0.9) [b]	0.08 0.02, 0.4) [b]	0.09 (0.02, .5) [b]
	Sonographer	–	1	1	1	1
Race	White	–	–	0.26 (0.07, 0.95) [b]	0.41 (0.10, 1.6)	0.42 (0.10, 1.7)
	Non-White	–	–	1	1	1
Transport Objects	Other[a]	–	–	–	0.13 (0.03, 0.5) [b]	0.15 (0.04, .6) [b]
	Many Times/Day	–	–	–	1	1
Analyze Exams	Other[a]	–	–	–	–	0.59 (0.16, 2.2)
	Many Times/Day	–	–	–	–	1
Perform Computer Work	Other[a]	–	–	–	–	–
	Many Times/Day	–	–	–	–	–
Perform Exams	Other[a]	–	–	–	–	–
	Many Times/Day	–	–	–	–	–
Wear Lead Apron	< 20 hours per week	–	–	–	–	–
	> 20 hours per week	–	–	–	–	–

[a] Once per day or less frequently
[b] Statistically Significant p< 0.05
[c] Most descriptive model
– Variable not included in model

Table A.8.5 (continued)

		Model 6	Model 7	Model 8	Model 9 [c]
Age	≥ 40	1.31 (0.42, 4.1)	1.49 (0.46, 4.8)	1.43 (0.44, 4.69)	1.33 (0.44, 4.0)
	< 40	1	1	1	1
Gender	Female	2.27 (0.47, 11.0)	1.86 (0.38, 9.2)	1.86 (0.38, 9.14)	2.47 (0.51, 11.9)
	Male	1	1	1	1
Work Group	Non-Sonographer	0.10 (0.02, 0.5) [b]	0.09 (0.02, 0.8) [b]	0.07 (0.01, 0.42) [b]	0.08 (0.02, 0.39) [b]
	Sonographer	1	1	1	1
Race	White	0.44 (0.11, 1.8)	0.31 (0.06, 1.5)	0.27 (0.06, 1.35)	–
	Non-White	1	1	1	–
Transport Objects	Other[a]	0.16 (0.04, 0.8) [b]	0.17 (0.04, 0.7) [b]	0.16 (0.04, 0.70) [b]	0.11 (0.03, 0.45) [b]
	Many Times/Day	1	1	1	1
Analyze Exams	Other[a]	0.62 (0.17, 2.3)	0.82 (0.21, 3.2)	0.76 (0.18, 3.12)	–
	Many Times/Day	1	1	1	–
Perform Computer Work	Other[a]	0.60 (0.11, 3.4)	0.62 (0.11, 3.6)	0.69 (0.12, 4.08)	–
	Many Times/Day	1	1	1	–
Perform Exams	Other[a]	–	0.26 (0.04, 1.7)	0.27 (0.04, 1.73)	–
	Many Times/Day	–	1	1	–
Wear Lead Apron	< 20 hours per week	–	–	0.21 (0.02, 2.06)	–
	> 20 hours per week	–	–	1	–

[a] Once per day or less frequently
[b] Statistically Significant $p < 0.05$
[c] Most descriptive model
– Variable not included in model

Table A.8.6 Adjusted odds ratios and 95% confidence intervals for musculoskeletal symptoms in dominant hand/wrist in past 12 months (n=18)

		Model 1	Model 2	Model 3[c]	Model 4	Model 5
Age	≥ 40	0.82 (0.28, 2.34)	0.96 (0.32, 2.88)	1.03 (0.32, 3.27)	1.02 (0.32, 3.31)	0.97 (.30, 3.2)
	< 40	1	1	1	1	1
Gender	Female	2.04 (0.41, 10.14)	2.23 (0.43, 11.52)	3.04 (0.52, 17.88)	2.77 (0.47, 16.16)	2.55 (.43, 15.21)
	Male	1	1	1	1	1
Work Group	Non-Sonographer	–	0.39 (0.11, 1.41)	0.13 (0.03, 0.69)[b]	0.14 (0.03, .75)[b]	0.13 (.03, 0.70)[b]
	Sonographer	–	1	1	1	1
Transport Objects	Other[a]	–	–	0.15 (0.04, 0.62)[b]	0.18 (0.04, 0.75)[b]	0.19 (0.04, 0.80)[b]
	Many Times/Day	–	–	1	1	1
Race	White	–	–	–	0.41 (0.10, 1.62)	0.43 (0.10, 1.75)
	Non-White	–	–	–	1	1
Transport Patients	Other[a]	–	–	–	–	0.43 (0.07, 2.52)
	Many Times/Day	–	–	–	–	1
Wear Lead Apron	< 20 hours per week	–	–	–	–	–
	> 20 hours per week	–	–	–	–	–
Computer Work	Other[a]	–	–	–	–	–
	Many Times/Day	–	–	–	–	–
Hours Worked Per Week	41+	–	–	–	–	–
	31-40	–	–	–	–	–
	≤ 30	–	–	–	–	–

[a] Once per day or less frequently
[b] Statistically significant $p < 0.05$
[c] Most descriptive model
– Variable not included in model

Table A.8.6 (continued)

		Model 6	Model 7	Model 8
Age	≥ 40	0.94 (0.28, 3.16)	0.96 (0.28, 3.26)	0.94 (0.28, 3.18)
	< 40	1	1	1
Gender	Female	2.57 (0.43, 15.2)	2.36 (0.40, 14.13)	2.61 (0.44, 15.53)
	Male	1	1	1
Work Group	Non-Sonographer	0.11 (0.02, 0.63) [b]	0.12 (0.02, 0.74)	0.12 (0.02, 0.67)
	Sonographer	1	1	1
Transport Objects	Other[a]	0.18 (0.04, .078) [b]	0.18 (0.04, 0.83)	0.18 (0.04, 0.82)
	Many Times/Day	1	1	1
Race	White	0.37 (0.09, 1.54)	0.43 (0.09, 1.99)	0.37 (0.09, 1.6)
	Non-White	1	1	1
Transport Patients	Other[a]	0.51 (0.08, 3.3)	0.49 (0.07, 3.38)	0.51 (0.08, 3.29)
	Many Times/Day	1	1	1
Wear Lead Apron	< 20 hours per week	0.17 (0.02, 1.66)	0.17 (0.02, 1.68)	0.17 (0.02, 1.69)
	> 20 hours per week	1	1	1
Computer Work	Other[a]	–	0.74 (0.12, 4.63)	0.86 (0.15, 4.92)
	Many Times/Day	–	1	1
Hours Worked Per Week	41+	–	–	0.42 (0.07, 2.40)
	31-40	–	–	0.54 (.09, 3.16)
	≤ 30	–	–	1

[a] Once per day or less frequently
[b] Statistically significant $p < 0.05$
[c] Most descriptive model
– Variable not included in model