THESIS

PREVALENCE OF CARPAL TUNNEL SYNDROME AMONG DAIRY PARLOR WORKERS

Submitted by

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ABSTRACT

PREVALENCE OF CARPAL TUNNEL SYNDROME AMONG LARGE HERD DAIRY PARLOR WORKERS

BACKGROUND: The purpose of this study was to determine the prevalence of carpal tunnel syndrome (CTS) and median mononeuropathy among dairy workers.

METHODS: Sixty-six dairy parlor workers and 58 non-parlor workers at dairies in Texas, New Mexico and Colorado participated in structured interviews regarding hand symptoms and nerve conduction studies (NCS). A case definition of CTS was based on the presence of characteristic CTS symptoms and an abnormal median mononeuropathy.

RESULTS: The prevalence of CTS among the dairy parlor workers was 16.9% (n=11) and 3.6% (n=2) among non-parlor workers. The difference was found to be statistically significant ($p<0.05$) with an odds ratio of 5.3, CI (1.1-25.5).

CONCLUSIONS: Dairy parlor workers are exposed to highly repetitive and excessive hand and wrist postures combined with high muscle forces increasing the risk of developing CTS. Work tasks in dairy parlor need additional study to identify engineering as well as administrative controls to reduce CTS risk.

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LIST OF NOMENCLATURE

MSDs – Musculoskeletal Disorders

BLS – Bureau of Labor Statistics

CTS – Carpal Tunnel Syndrome

NCS – Nerve Conduction Studies

AAEM – American Association of Electrodiagnostic Medicine

MULD – Median-Ulnar Latency Difference

HAL – Hand Activity Level

SI – Strain Index

TLV – Threshold Limit Value

CHAPTER I

INTRODUCTION

Upper limb musculoskeletal symptoms and upper-limb musculoskeletal disorders (MSDs) have been found to be common in the working population [Roquelaure et al., 2006]. Twenty-eight percent of all workplace injuries requiring time away from work that were reported to the Bureau of Labor Statistics were MSDs [BLS, 2010]. Also, a high incidence rate of 31.2 cases per 10,000 full-time equivalent workers was found for work-related MSDs in the agriculture industry [BLS, 2009]. Previous analyses of workers' compensation data from large-herd milking operations in Colorado indicated that nearly 50% of livestock-handling injury claims involved workers performing work tasks in the milking parlor. Nearly 27% of the injuries were to the wrist, hand, and fingers [Douphrate et al., 2009]. Previous studies by the National Research Council have suggested that up to 95% of upper-extremity injuries may be attributable to workplace factors [N.R.C. 2001]. Despite these findings there has been very little research or public health awareness regarding MSDs among workers in the dairy industry.

Carpal tunnel syndrome (CTS) is a musculoskeletal disorder resulting from a ischemic response to the median nerve in the carpal canal due to repetitive motion and high force [Clark Brian D. et al., 2004]. It is often associated with lengthy disability requiring surgical intervention [Daniell et al., 2009; Manktelow et al., 2004]. Carpal tunnel syndrome is characterized nocturnal and/or activity-related numbness or tingling involving the palmar aspects of atleast 2 of the first 4 fingers in the hand [Atroshi et al., 1999]. Common risk factors often associated with CTS include, pregnancy, obesity, old age, rheumatoid arthritis, diabetes mellitus and hypothyroidism [Tanaka et al., 1997; Werner et al., 1994]. Occupational factors like forceful and repetitive hand/wrist motions, awkward postures, mechanical stress at the base of the palm, and vibration have also been reported to be associated with CTS [Roquelaure et al., 1997; Siverstein et al., 1987 ; Van Rijn et al., 2009].

Carpal tunnel syndrome is usually associated with high direct and indirect costs. A recent study reported CTS to cost between $9,225 to $19,760 per workers compensation claim [Dunning et al., 2010]. Making an accurate diagnosis of CTS and initiating appropriate actions earlier could reduce the disability and costs involved with CTS [Daniell et al., 2005]. Nerve conduction studies (NCS) have been considered the “golden standard” for establishing a case definition of CTS in many studies [Atroshi et al., 2003; Bingham et al., 1996; Rempel et al., 1998]. Some studies have also used a hand symptom questionnaire mapping the clinical symptoms associated with CTS to determine the prevalence of CTS [Harn-Che Chiang et al., 1993; Hou et al., 2007; Katz and Stirrat 1990].

An abnormal median nerve conduction finding in the absence of clinical symptoms has been referred to as median mononeuropathy in previous studies [Atroshi et al., 1999; Hamann et al., 2001]. The current study utilizes a median-ulnar sensory latency difference of 0.5 ms or greater to establish a case definition for median mononeuropathy. Previous studies have reported that the 0.5 ms cut-off represents a very conservative criterion for determining median mononeuropathy within carpal tunnel [Redmond and Rivner 1988; Werner and Andary 2002]. However in the current study the case definition of CTS is based on the presence of both the characteristic hand symptoms and median mononeuropathy. The NCS test protocol used is set forth by the American Association of Electrodiagnostic Medicine (AAEM) and has been used in previous epidemiologic studies investigating CTS [Anton et al., 2002; Bingham et al., 1996; Rosecrance et al., 2002].

The prevalence of CTS among the general population has been reported to range from 0.6% to 4.9% in previous studies depending on the case definition used [Armstrong et al., 2008; Atroshi et al., 1999; De Krom et al., 1992]. The prevalence of CTS has been found to be higher in workers exposed to the occupational risk factors of CTS. High prevalence of CTS has been found in occupations like fish and meat processing, pork-processing and Swedish dairy parlor workers [Harn-Che Chiang et al., 1993; Moore and Garg 1994; Stål et al., 1998]. A previous study also found that the French farmers had a higher prevalence of CTS as compared to the French white-collar workers [Roquelaure et al., 2008].

In the United States dairy production is steadily moving toward large-herd operations (>500 head) [Douphrate et al., 2009]. Dairy work involves a variety of tasks. The tasks can be classified as feeder, nursery worker, driver, pusher and parlor worker. Feeders are workers responsible for feeding the cows and the calves, whereas the nursery workers care for the young calves and help with new births. Drivers are mostly responsible for transporting the feed and cleaning the farms using heavy equipment including tractors, dairy-livestock feeding equipment and utility equipment. The pusher directs the cows in the milking parlor and the parlor worker performs the milking tasks. An overlap of these duties can be seen on many dairy farms.

One previous study investigated median nerve entrapment among stanchion small herd dairy parlor workers in Sweden. In a stanchion milking facility, a stanchion which is upright beam or bar is used to restrain cows by the necks and confine them to their stalls. The milker sits next to cow and performs the milking procedure by attaching the milking cluster to each cow. All the subjects included in this study were female, and 23 of the 30 subjects were clinically diagnosed as having the pronator syndrome [Stål et al., 1998]. A survey by Nonnenmann et al., [2008] assessed the prevalence of neck and upper extremity musculoskeletal symptoms and examined associations between symptoms and dairy operations activities in a group of dairy farmers. Forty percent of the respondents reported wrist/hand related musculoskeletal symptoms whereas 54% of the respondents reported shoulder related musculoskeletal symptoms [Nonnenmann, et al. 2008]. Even though a high percentage of wrist/hand related pain has been reported in this population, prevalence of CTS has not been adequately determined.

Dairy parlor workers primarily perform the milking tasks. Work tasks requiring high repetition, forceful and awkward movements have been shown to be high risk for developing CTS [Palmer et al., 2007; Silver et al., 1985; Van Rijn et al., 2009]. Performing milking tasks has been shown to require forceful and repetitive exertions in addition to awkward movements at the wrist in previous studies [Pinzke et al., 2001; Stål et al., 1999; Stål et al., 2003]. This suggests that dairy parlor workers are at a high risk of developing CTS. As to our knowledge no previous study has investigated the prevalence of CTS among dairy parlor workers in the United States, it is imperative to investigate the prevalence of CTS among dairy workers. Identifying CTS prevalence will help us make a better case towards introducing ergonomic interventions and improving the work process.

PURPOSE OF THE STUDY

Few studies have assessed the prevalence of musculoskeletal disorders in dairy parlor workers [Nonnenmann et al., 2008; Stål et al., 1998]. Even though some studies found that dairy parlor work involves tasks that are considered high risk for CTS, no previous study has specifically assessed the prevalence of CTS among large herd dairy parlor workers in the United States [Pinzke et al., 2001; Stål et al., 2003].

The purpose of this cross-sectional study was to determine the prevalence of CTS among large herd dairy parlor and non-parlor workers. Additionally, the study also reports the prevalence of median mononeuropathy in the absence of characteristic CTS symptoms among the dairy parlor and non-parlor workers.

HYPOTHESES

Based on the review of literature, the following hypotheses were proposed:

1. A higher prevalence of CTS and median mononeuropathy will be found among dairy parlor workers compared to non-parlor workers as parlor workers perform milking tasks which are repetitive, forceful and involve awkward movements.
2. Median nerve conduction latencies will be longer for dairy parlor workers.

AIMS OF THE STUDY

The specific aims of this cross-sectional epidemiologic study are:

1. To assess the prevalence of CTS among dairy parlor workers and non-parlor workers. All subjects underwent NCS and completed a hand symptom questionnaire. The case definition of CTS was based on positive responses on both the NCS and the hand symptom questionnaire. The prevalence of CTS in each group of workers was determined by dividing the number of workers with CTS by total number of participants

within the group. The prevalence of median mononeuropathy and only characteristic CTS symptoms among parlor and non-parlor workers was similarly determined.

2. To compare the prevalence of CTS among dairy parlor workers and non-parlor workers The prevalence of CTS, median mononeuropathy and CTS characteristic of symptoms only were compared using a χ^2 test for proportions and odds ratios (OR) with their 95% confidence interval (CI) determined among the parlor and non-parlor workers.

CHAPTER II

REVIEW OF LITERATURE

The following review of literature provides an overview of CTS and its association with personal and workplace risk factors. Additional sections include a discussion on NCS, the hand symptom survey, injuries in agriculture and dairy industry, risk factors of MSDs in dairy industry, and previous epidemiologic studies on CTS prevalence in different working populations.

CTS AND ASSOCIATED RISK FACTORS

Work-related CTS is one of the leading causes of pain and disability in the working population [Daniell et al., 2009]. The prevalence rate of CTS in the general working population has been estimated to be between 0.6% to 4.9% depending on the definition of CTS used and whether or not it was confirmed by NCS [Armstrong et al., 2008; Atroshi et al., 1999; De Krom et al., 1992]. Significantly higher prevalence ranging from 5 to 15% has been found in the industrial setting [Franzblau et al., 1993; Rosecrance et al., 2002; Rosecrance and Douphrate 2010].

A retrospective study of CTS claimants in the Washington State, documented earning loses of $46,000-70,000 per patient over a period of six years [Foley et al., 2007]. More complex cases of CTS and late diagnosis of CTS have been shown to require higher days away from work [Daniell et al., 2005]. Manktelow et al., [2004] reported that individuals who underwent CTS surgery had significantly better clinical outcomes and greater likelihood of successful return to work. The findings suggest CTS is a common musculoskeletal disorder and disability and costs associated with CTS can be minimized by establishing the CTS diagnosis as early as possible.

Carpal tunnel syndrome is characterized by numbness and paresthesias along the distribution of median nerve, pain and weakness of thenar muscles [D'Arcy and McGee 2000]. Typically slowed conduction of sensory and motor components of the median nerve is also seen [Werner and Andary 2002]. The symptoms have been suggested to arise from pressure exerted by the flexor tendons or the interstitial fluid on the median nerve in the carpal canal [Werner and Andary 2002]. A review of literature published by NIOSH (National Institute of Occupational Safety and Health) in 1997 suggested occupational risk factors including, forceful exertions, repetition, posture, and vibration have the potential to cause upper extremity MSDs. The review also found that force, repetition, and vibration were the most well-established risk factors for CTS [Bernard 1997]. A relatively recent systematic review of literature by Palmer et al., [2007] supported conclusions made by the NIOSH study. Palmer et al., [2007] found reasonable evidence in the literature that prolonged and highly repetitious flexion or extension of the wrist increases the risk of CTS, especially when allied with a forceful grip.

Carpal tunnel syndrome has been found to be strongly associated with high force-high repetitive jobs and to a lesser extent with low force-high repetitive jobs and high force-low repetitive jobs [Silverstein et al., 1987]. Repetitiveness has been considered a stronger risk factor than force [Silverstein et al., 1987]. Recent work in animal models suggests that performance of repetitive tasks induces median neuropathies, hand movement dysfunctions and inflammatory changes in the median nerve structure [Elliott et al., 2010]. Rat model studies have reported, degraded myelin, increased macrophages and cytokines, decreased nerve conduction velocity in the median nerve of rats performing repetitive reaching and high force grasping activities for 8-12 weeks [Al-Shatti et al., 2005; Barr 2006; Clark et al., 2003; Elliott et al., 2010].

Even though epidemiologic evidence supports a significant relationship between work and CTS many other non-work related risk factors may be involved. Gender, higher Body Mass Index (BMI), increasing age and certain medical conditions have been found to be associated with the development of CTS [Tong et al., 2004; Werner 2006]. Previous population based studies have demonstrated that women are more likely to develop CTS than men [Lam and Thurston 1998 ; Maghsoudipour et al., 2008]. Pregnancy is an independent risk factor for the development of CTS and is often attributed to the physiological changes in the carpal canal [Padua et al., 2001]. A strong association has been reported between obesity (i.e., higher BMI) and the development of CTS [Bland 2005]. A study by Lam and Thurston, (1998) found that patients undergoing carpal tunnel release surgery were twice as likely to be overweight (BMI > 25) than the general population. Additionally slower median sensory nerve conduction across the wrist has been reported in obese subjects [Letz and Gerr 1994]. A study investigating CTS among older adults found electrophysiologic evidence of more severe median nerve entrapment [Blumenthal et al., 2006]. The study showed that the older group (≥65 years) of participants had significantly more prolonged latencies and slowed conduction velocities in both median motor and sensory responses than the young (≤50 years) and middle-aged groups (51-64 years). Tong et al., [2004] also found that changes occurred more rapidly in the median sensory than the ulnar sensory nerve conduction parameters as age increased. Diabetes and Rheumatoid arthritis are well known risk factors of CTS [Perkins et al., 2002; Werner 2006]. A study by Perkins et al., [2002] found that 13 to 40 % prevalence of CTS in a diabetic population as compared to the control group in the study that had a CTS prevalence of 2%.

Sensory and motor NCS of the median nerve segment across the wrist compared to another nerve segment that does not go through the carpal tunnel (i.e. radial, or ulnar) are the most sensitive and accurate techniques to establish a diagnosis of CTS [Werner and Andary 2002]. Other neurophysiologic techniques used to document CTS like vibrometry threshold testing, current perception testing, Semmes–Weinstein monofilament testing and two-point discrimination consist of considerable subjective components and have not been found to be as sensitive as traditional NCS [Werner and Andary 2002].

CTS AND OTHER NERVE ENTRAPMENTS

Median and ulnar nerves pass through the carpal canal and the guyon's canal at the wrist respectively. The two canals are at close proximity. The volar carpal ligament forms the roof of the carpal canal and the floor of the guyon's canal. It has been suggested that the pathologic process causing CTS might have an effect on ulnar nerve at the wrist level [Sedal et al., 1973]. A study by Gozke et al., [2003] investigating ulnar nerve entrapment at the wrist in cases diagnosed with CTS revealed that 18% of the 53 subjects gave abnormal results from the ulnar nerve sensory conduction studies. The authors suggested that when using median-ulnar latency cut-off as criterion for CTS, results from the ulnar sensory nerve studies should also be considered separately to detect ulnar nerve entrapment.

A case-control study by Moghtaderi and Ghafarpoor, [2009] compared the NCS outcomes between 181 cases of CTS and 99 controls with other musculoskeletal pain. The authors measured the ulnar nerve sensory latencies and ulnar nerve motor latencies for both groups. Results from a repeated measures ANOVA analysis showed no significant differences in the latencies among the CTS group and the control group. The authors concluded that there may not be any association between CTS and ulnar nerve compression at the wrist and if present nerve conduction studies alone would not be sufficient to diagnose the same

[Moghtaderi and Ghafarpoor 2009]. Even though the present study uses the median-ulnar latency cut-off of 0.5 ms as a criterion to establish the case definition of CTS an increased ulnar nerve sensory latency (>2.3 ms) would be considered while establishing the case definition.

"Double crush" syndrome has been associated with CTS by previous investigators [Upton and McComas 1973]. The idea of "double crush" syndrome suggests that most patients with CTS not only have compressive lesions at the wrist, but also show evidence of damage to cervical roots. "Double crush" is thought to be due to damage to axonal damage [Upton and McComas 1973]. Even though this theory has been found to be popular in chiropractic literature a recent review of literature by Russell, [2008] has quetioned its validity. Rusell, [2008] reasoned that though the motor aspects of CTS (e.g. muscle weakness) could be explained by this theory it could not explain the sensory disturbances of CTS such as pain, numbness and tingling [Russell 2008].

NERVE CONDUCTION STUDIES

Nerve conduction studies work on the principle of depolarization. When enough stimulation is applied to the polarized nerve cell, the semipermeable membrane opens its ion channels, allowing the sodium ions to enter inside the cell making the inside of the cell positively charged and the outside negatively charged. This process of changing polarity of a nerve cell, from a resting to an excited state is called depolarization. The NCS criteria used to evaluate the physiological function of nerve include, the latency of the evoked response, the amplitude of the response, and the conduction velocity of the response and the duration of the response. Various previous studies have found that the results of electrophysiologic studies are highly sensitive and specific for diagnosis of CTS. The below mentioned studies elaborate on the NCS guidelines that have been used previously.

In 1993, the Quality Assurance (QA) Committee of American Association of Neuromuscular and Electrodiagnostic Medicine (AANEM) developed practice guidelines by a critical review of literature for the use of electrophysiologic studies in the evaluation and management of CTS. They concluded that median sensory and motor NCS's were valid and reproducible clinical laboratory studies that confirmed a clinical diagnosis of CTS with a high degree of sensitivity (>85%) and specificity (>95%) [Jablecki et al., 2002; Jablecki et al., 1993]. The AAEM Guidelines recommended the following tests: median sensory or mixed nerve conduction study with determination of peak latency, onset latency, or conduction velocity of the segment of median nerve passing through the carpal tunnel and median motor conduction study to include determination of the median motor distal latency. The AANEM made an additional recommendation to exclude any other peripheral neuropathy as the cause of prolonged median sensory and/or motor latencies. They recommended that ulnar or/and radial motor and sensory NCS's should also be performed as a part of the examination of patients suspected of CTS [AANEM Quality Assurance Committee, 1993].

In 2002, AANEM with collaboration with American Academy of Neurology (AAN) Quality Standards Committee developed a second CTS literature review and summary statement. The recommendations made were identical to those made and endorsed in 1993 by AANEM QA committee. It was recommended that if the initial median sensory NCS across the wrist has a conduction distance greater than 8 cm and the result is normal, one of the following studies is recommended:

a. Comparison of median sensory or mixed nerve conduction across the wrist over a short (7 to 8 cm) conduction distance with ulnar nerve sensory nerve conduction across the wrist over the same (7 to 8 cm) conduction distance, or

b. Comparison of median sensory conduction across the wrist with radial or ulnar sensory conduction across the wrist in the same limb, or

c. Comparison of median sensory or mixed nerve conduction through the carpal tunnel to sensory or mixed NCSs of proximal (forearm) or distal (digit) segments of the median nerve in the same limb [Jablecki et al., 2002]

In a recent study, Sandin et al., [2010] developed quality measures for electrodiagnostic testing in suspected CTS. An expert multidisciplinary panel of 11 national experts on CTS reviewed and approved the measures developed. These measures are consistent with the guidelines developed by AANEM. In the present study, median mononeuropathy is defined as a median ulnar latency difference of 0.5 ms or greater to minimize the likelihood of false positives [Redmond and Rivner 1988].

A similar criterion has been used in previous studies. Monga et al., [1985] compared the results obtained by measurement of median nerve sensory latency by palmar stimulation and the results from the difference of median-ulnar nerve distal sensory latencies. Digit-wrist stimulation, palm-wrist stimulation and motor fiber stimulation were performed on 22 volunteers in the control group and 24 subjects with clinical signs of CTS. The results revealed that orthrodromic median sensory and motor latencies were diagnostic in most patients (85%) who satisfied the clinical criteria of CTS. Monga et al., [1985] also concluded that the median ulnar distal sensory latency difference (0.4 ms was the derived upper limit) parallels the sensitivity of palmar technique in detection of CTS. In another study Redmond and Rivner,

[1988] evaluated the specificity of three criteria; median motor conduction slowing across the wrist, prolonged sensory latency compared to normal and a greater than 0.3 ms difference between median and ulnar or the median and radial sensory latencies for the diagnosis of carpal tunnel syndrome. Fifty-four subjects over the age of 17, with no previous history or clinical signs of CTS participated in the study. It was found that all of the criteria examined yielded false-positive tests for CTS. Redmond and Rivner, [1998] concluded that of the three criteria evaluated, comparison of sensory latencies within the same extremity is the method with least error (false positives) and a latency difference of greater than 0.4 ms is necessary to make this method specific enough to be useful.

Werner et al., [1998] investigated the differences in demographics, anthropometrics, psychosocial profile, medical history, electrophysiologic measures, or ergonomic risks between symptomatic and asymptomatic workers who had a confirmed abnormality of the median in one or more wrists. Cases were defined as having a prolongation of the median sensory evoked response of ≥0.5 ms. Werner et al., [1998] concluded that a relatively high number of active workers (25%) had prolongation of median nerve reaction time on cross-sectional screening, yet one-half of these workers were otherwise asymptomatic. The authors suggested that a nerve should not be considered diseased based only on prolonged median sensory latency as in some cases this may not ever develop symptoms [Werner et al., 1998].

In a study by Sander et al., [1999] median and ulnar palm-wrist mixed nerve studies were performed on the hands of 33 normal controls and 50 subjects with both clinical and electrophysiologic median neuropathy. The normative values for median and ulnar palm-wrist mixed nerve conduction latencies over 8 cm were determined. Sander et al., [1999] found that the abnormal palmar latency difference cut-offs were 0.5 ms using onset latency or peak latency. The mean, standard deviation and range of peak latency and onset latency were similar within controls and also within CTS patients. The mean standard deviation and range of ulnar mixed nerve latencies were also similar within controls and within CTS patients. The study recommended that an abnormal peak latency difference cut-off of 0.5 ms be used to minimize the likelihood of false positive studies [Sander et al., 1999].

Diagnostic properties of NCS for carpal tunnel syndrome in a population-based study was evaluated by Atroshi et al., [2003]. Two sixty five symtomatic and 125 asymptomatic randomly selected responders underwent clinical and electrophysiologic examinations. The diagnostic accuracy of the nerve conduction tests in distuinguishing persons with clinically certain CTS was reported. Median-ulnar sensory latency difference had higher diagnostic accuracy as comapred to media nerve distal motor latency and median mixed sensory latency [Atroshi et al., 2003]. A combination of NCS findings and characteristic CTS symptoms is possibly be the most accurate means to establish a case definition of CTS in epidemiologic studies [Werner 2006].

HAND SYMPTOM QUESTIONNAIRE

A hand symptom questionnaire containing a hand symptom diagram is used as one component to establish a case definition of CTS in this study. Katz and Stirrat, [1990] developed the self administered hand diagram to evaluate upper extremity paresthesias. They evaluated the utility of this hand diagram in a group of patients attending a hand clinic. The diagrams were rated as having CTS if the subject indicated tingling, numbness, or decreased sensation with or without pain in at least two of the digits 1, 2, or 3 on the palmar surface of the hand. The diagram ratings of 63 patients evaluated were compared with diagnoses established independent of diagram results by objective clinical criteria. It was found that the sensitivity of the diagrams was 80% whereas the specificity was 90% [Katz and Stirrat 1990]. Based on the results of this study Katz and Stirrat, [1990] concluded that the hand diagram is valuable in the diagnosis of carpal tunnel syndrome among patients with upper extremity paresthesias. Katz et al., [1990] followed the earlier study by another study which compared the diagram ratings to nerve conduction diagnoses among 110 patients with upper extremity complaints. Katz et al. [1990] reported a high sensitivity (0.96) and specificity (0.73) for a rating of classic, probable or possible CTS. These results of both these studies indicated that the hand symptom diagram would be useful in population based studies investigating CTS.

Another study, by Franzblau et al., [1993] evaluated the usability of a hand symptom survey as screening procedure for CTS when compared with electrodiagnostic testing alone. A variety of screening procedures for CTS were used to establish a case definition of CTS among 130 workers at a manufacturing plant. It was observed that CTS case definition based on symptom survey had higher sensitivity and positive predictive value (PPV) as compared to physical examinations findings and quantitative test procedures (vibrometry, pinch grip strength, hand grip strength). Based on these results, Franzblau et al., [1993] concluded that in the absence of electrodiagnostic testing, the simplest procedure for establishing a CTS case definition would be a hand symptom survey.

The test-retest reliability of the hand symptom questionnaire was investigated by Rosecrance et al., [2002]. The study evaluated a five section questionnaire including items relating to musculoskeletal symptoms and specific job factors. The data collection occurred in to two rounds. Two hundred and sixteen employees at a plastics molding facility participated in the initial round, and 99 participated in the retest portion of the study. The fifth section of the questionnaire consisted of a hand diagram and questions regarding the presence of specific hand symptoms. Any symptom severity marked a greater than or equal to 2 on the scale of 0-10 was considered positive. Nocturnal symptoms were also evaluated. The results indicated that hand symptoms identified on the hand diagram demonstrated fair to good test-retest reliability with kappa coefficients ranging from 0.50 to 0.72. The test-retest reliability was also fair to good for the location of the hand symptoms as well as the nocturnal hand symptoms suggesting that the hand symptom questionnaire was reliable for use in epidemiologic studies [Rosecrance et al., 2002].

A study by Thomsen and Mikkelsen, (2003) evaluated the use of hand symtom questionnaire data to establish a case definition of CTS in studies. The study involved a total of 940 employees from nine different companies. The employees answered a hand symtom questionnaire and participated in clinical interviews. The investigators found a high sensitivity of the questionnaire for both the right (0.96) and left (0.88) hands. Similarly a high specificity was found for the right (0.94) and left (0.96) hands. The authors further reported that 55-65 % of those reporting tingling of the fingers in the median nerve distribution on the questionnaire had tingling in other distrubutions or less frequent symtoms when interviewed. The authors concluded that a CTS symptom interview in addition to a self-reported questionnaire may be a necessary tool in epidemiologic studies to avoid missclasification of CTS cases [Thomsen and Mikkelsen 2003].

Furthemore, Dale et al., (2008) investigated the reliability of hand diagrams for the epidemiologic case definition of CTS and found high levels of agreement among raters of the hand diagram. The authors reported weighted kappa values of 0.83 (right hand) and 0.88 (left hand). The results indicated that hand diagrams are a reliable tool for use in population based epidemilogic studies of CTS. Additionally the study also found that hand diagrams rated based on telephone interviews produced higher agreement among raters with weighted kappa scores of 0.96 (right hand) and 0.93 (left hand) [Dale et al., 2008]. The results from previous studies investigating the hand symtom questionairre definitely support its use for establishing a CTS case definition in epidemiologic studies.

MSDS IN THE DAIRY INDUSTRY

Previous studies have considered agriculture to be one of the most hazardous industries in the United States [McCurdy and Carroll 2000]. Douphrate et al., [2006] evaluated the workers' compensation claims data for non-fatal injuries among agriculture and agri-business workers in the State of Colorado. The results of this study revealed that, cattle dealers, cattle or livestock raisers and dairy farmers had high rates of injury claims. The rate of injury claims was especially higher in sectors that involved interaction with animals or livestock. Injuries related to animal handling, strains/sprains, machinery, and slips or falls were the most frequent among all occupations analyzed. The upper extremity was the most frequently injured body part among workers in all sectors [Douphrate et al., 2006].

A survey was administered by Nonnenmann et al., [2008] to a group of dairy farmers the state of Iowa. The survey assessed the prevalence of neck and upper extremity musculoskeletal symptoms and examined associations between symptoms and dairy operations activities. Forty percent of the respondents reported wrist/hand related musculoskeletal symptoms whereas 54% of the respondents reported shoulder related musculoskeletal symptoms [Nonnenmann, et al. 2008]. Additionally, 70% of the farms included in the Iowa dairy farmers study used a stanchion milking facility and 30 % used a parlor milking facility. All the dairies participating in the current study used a parlor milking facility.

In another study Douphrate et al., [2009] analyzed the Colorado workers' compensation data to evaluate the costs, characteristics, and contributing factors associated with livestock-handling injuries among Colorado dairy farmers, cattle/livestock raisers, and cattle dealers. Of the 1,114 livestock-handling claims analyzed, claims associated with milking parlor tasks represented nearly 50% of injuries among dairy workers. Claims associated with riding horseback, sorting/penning cattle, and livestock-handling equipment represented high proportions of livestock-handling injuries among cattle/livestock raisers and cattle dealers. Claims associated with livestock-handling represented the highest percentage of high-cost and high-severity injuries in all three sectors [Douphrate et al., 2009].

In a 2006, Roquelaure et al., (2006) utilized data from the French National Istutute of Public Health Surveillance to assess the prevalence rates of MSDs in the French work force according to sex, age, economic sectors and occupation. Agriculture was one of the five occupations with the highest prevalence of upper limb MSDs among women. Twenty-eight percent of the women employed in the agriculture industry reported atleast one upper extremity musculoskeletal disorder. Among all the occupations studied, highest upper extremity MSDs prevalence rates were found in unskilled agriculture workers [Roquelaure et al., 2006].

The above studies suggest that MSDS are a topic of concern among workers in the agriculture and dairy industry. Smaller profit margins and the need to operate on larger margins have led to an industrialization of dairy operations in the United States. Additional dairy-related injury research is vital to prevent MSDS given the trend toward large industrial milking operations [Douphrate et al., 2009].

DAIRY PARLOR TASKS AND THEIR SIGNIFICANCE

WORK TASKS IN THE DAIRY PARLOR

Large-herd operations utilize a parlor milking system, as compared to the stanchion system that is used primarily in smaller operations. In a stanchion milking facility, a stanchion which is upright beam or bar is used to restrain cows by the necks and confine them to their stalls. The milker sits next to cow and performs the milking procedure by attaching the milking cluster to each cow. In a mechanized parlor, the cows enter the milking parlor and stand on an elevated platform facing away from the operator area. The milker stands at a level of about 0.8-0.9 m below the platform. The milking parlor has two different sections where cows are milked on each side with the parlor workers attaching the milking clusters to the cows from behind. Once the milking has been completed the milking clusters detach automatically and the cows are released from the dairy parlor and a new batch of cows enters the parlor.

During the normal working activities the parlor workers perform milking tasks for an average of 8 hrs per day with two or three short breaks of about five to ten minutes each (personal communication Jesus Silva, April 18th, 2009). In modern dairy parlors cows stand on an elevated platform facing away from the operator area while the parlor worker performs the milking tasks while standing in the operator area. Each milking task can be divided into five subtasks namely; (1) dipping, (2) cleaning, (3) stripping and (4) attaching the milking cluster to the cow's udder. Each subtask is performed for approximately two hours per day. While performing the subtask of "dipping", disinfecting solution is applied to the cow's teats using a disinfectant soaked cloth or a dispenser. The parlor workers are required to reach forward and upward dorsal flexing their wrist to perform this task. The “dipping” task is followed by “cleaning”, where the cow’s teats are cleaned using a cloth. The subtask of “stripping” requires the parlor workers to reach forward and upward with their hand and stimulate the udder for milk production. While performing the subtask of “stripping” the parlor workers place their wrists in a dorsal flexed and radially deviated position and pull down the cow’s teats while applying pressure. Since the area around the cow’s teats is slippery and the workers wear gloves, significant amount of force is required. Stripping is followed by the subtask of “attach” where a milking cluster weighing about 2-3.5 kg is attached to the udder of each cow present in the parlor. After the cows have been milked the milking clusters detach automatically and the cows are released and new cycle is started. This entire process requires the worker to perform forceful and repetitive movements at the wrist and shoulder.

EFFECT OF DAIRY PARLOR WORK ON THE MUSCULOSKELETAL SYSTEM

Mechanization of work tasks generally tends to decrease the physical load of the worker. However, mechanization of the milking-process still requires the parlor workers to perform many hand movements [Vos 1974]. Modern milking parlors require the dairy parlor workers to perform milking tasks in a standing position. This raises questions about the optimum pit depth; accessibility of the udder; location of handles, buttons, pedals, and levers; visibility and illumination [Vos 1974]. Large herd operations require workers to perform milking tasks for almost 8 hrs a day. This can be exhaustive and certainly repetitive.

A previous study investigated median nerve entrapment among stanchion small herd dairy parlor workers in Sweden. Stål et al., [1998] clinically examined milkers with pain, ache, and discomfort in the upper extremity. Of the 30 female subjects, 23 were clinically diagnosed as having the pronator syndrome (compression of the median nerve at the elbow).The diagnosis was based on findings of muscle atrophy, tenderness, manual muscle testing and dynamometry. Surgical release of the median nerve at the pronator teres muscle level was performed on eight milkers. On a follow-up after six months all eight milkers were found to be symptom-free. The authors observed that while performing the milking subtask of “attach” the milker had to hold the milking cluster (weighing 2-3.5 kg) in his hand with the wrist loaded statically in a dorsal flexed position and the forearm maximally supinated. In addition milking requires repetitive actions. The increased muscle tension around the elbow while performing milking and the stretched position of the pronator teres muscle could probably have led to the median nerve entrapment [Stål et al., 1998]. Based on these observations Stål et al., [1998] concluded that the performing milking tasks had contributed to the development of the nerve compression neuropathy.

In the earlier study among female dairy parlor workers Stål et al., [1998] found a high prevalence of upper extremity nerve entrapment. Hence, Stål et al., [1999] conducted another study to quantify the positions and movements of the wrist during milking. They further compared tethering and loose-housing systems in Sweden based on the positions and movements of the wrist. In the tethering system, the cows stand side by side, and the milker goes to the cows carrying the heavy milking equipment which weighs around 6 kgs. In a tethering system the milking is performed either squatting or sitting on a stool. The loose-housing system requires the cows to enter a milking parlor while the milker stands on a level about 0.8-0.9 m below the level of the cow platform. The investigators used biaxial electrogoniometers and data loggers for recording flexion and joint deviation angles of both the right and left wrist in 11 healthy milkers. High values of flexion and radial deviation were found and the velocity and repetitiveness of these values were close to those described in repetitive work with high risk of elbow and hand disorders in general industry. It was found that for 10% of the working time the right hand was in more than 46° extension position in the loose-housing system. Also, the milkers held their left hands radial deviated more than 22° for 10% of the recording time in both milking systems [Stål et al., 1999]. The load on the upper extremity was found to be significantly higher ($p<0.05$) with respect to the dorsiflexed hand position and repetitiveness when milking in modern loose-housing milking system as compared to the tethering system. The authors concluded that the change of the working position and/or the higher number of cows milked in the loose-housing system as compared to the old-fashioned tethering system may result in injuries to the wrist and hand [Stål et al., 1999].

Stal et al., [1999] quantified the positions of the wrist during machine milking. To further investigate the effect of performing machine milking tasks on the parlor workers Stal et al., [2000] evaluated the muscular load experienced by the parlor workers. Bilateral electromyographic recordings (EMG) using surface electrodes were recorded from the biceps brachii and wrist flexor and extensor muscles. The study subjects included 11 healthy subjects milking both in a stanchion and a loose-milking system. The measurements were carried out during one milking cycle and all subtasks were included. The mean recording time was 30 minutes in both systems. For all muscles evaluated, milking in the tethering system gave higher peak values (99^{th} percentile) than the loose housing system and these differences were found to be statistically significant ($p<0.05$). The mean peak load for the biceps muscle ranged from 37 to 41 maximum voluntary electromyography activity (MVE). The wrist flexors were loaded close to the maximal capacity (86% MVE) in the tethering system. The wrist extensors showed a higher static load while performing tasks in the loose housing system and this difference was statistically significant ($p<0.05$). The authors concluded that the muscle loads in combination of positions and movements of the hand and forearm, might contribute to the development of nerve injuries among workers performing milking tasks in both loose and tethering milking systems [Stål et al., 2000].

Pinzke et al., [2001] further quantified the workload on the upper extremity for each sub task during machine milking. Muscle activity for the biceps and the wrist flexors, as well as positions and movements of the wrists were simultaneously measured by electromyography and electrogonimetry for 11 milkers working in a loose-housing system milking parlor. The three main tasks; “Drying (the udder)”, “Pre-milking “ and “ Attaching (the milking cluster to the udder)”, showed high muscle load values and almost no rest time. The highest load values were seen in the biceps and wrist flexor muscles were found during the tasks “Attaching” and “Drying” respectively. The milkers held their right hands in about 42 degrees dorsal flexion for 10% of the recording time for the milking subtasks of “Pre-milking” and “Attaching”. Also both hands were more than 12 degrees radial and 15 degrees ulnar deviated for 10% of the recording time for the same tasks. Pinzke et al., [2001] concluded that high muscle loads in combination with extreme positions and movements of the hand and forearm might contribute to the development of musculoskeletal injuries among milkers. Their study also emphasized the need for technical improvements of the milking equipment to decrease the risk for arm wrist and hand disorders.

CTS AMONG DIFFERENT WORKING POPULATIONS

The CTS prevalence in the general population has previously investigated. De Krom et al., [1992] reported a CTS prevalence of 5.8% among women in Netherlands. They reported a lower overall CTS prevalence of 0.6% among men [De Krom et al., 1992]. Atroshi et al., [1999] estimated the prevalence of CTS in the Swedish general population. A gender and age-stratified sample of 3000 subjects randomly selected from the general Swedish population were sent a survey. Survey included questions on symptoms and medical history. Whole body diagrams were provided for marking pain, numbness, and tingling. Subjects were clinically examined and nerve conduction testing was conducted. Of all the respondents, 14.4% reported pain, numbness, and/or tingling in the median nerve distribution of the hands. On clinical examination, 3.8% subjects were diagnosed as having clinically certain CTS, whereas 2.7% had clinically and electro physiologically confirmed CTS. Four point nine percent of the subjects presented with median nerve symptoms and electrophysiological median neuropathy. Based on this data, Atroshi et al., [1999] suggested that, 1 in 5 symptomatic subjects would be expected to have CTS in a general population if clinical examination and electrophysiologic testing was performed. Another study investigating the relationship of work and CTS in the general population found a higher incidence rate of CTS in employed (1.7, women; 0.6, men), than in unemployed persons (0.8, women; 0.3, men). Male blue-collar workers were found to be at a greater risk of developing CTS than white-collar workers (Relative Risk 4.2). Based on the results of this study, the authors suggested CTS cases diagnosed in blue-collar workers in the study were attributable to work [Roquelaure et al., 2008].

In a study investigating upper extremity disorders in a pork processing plant CTS accounted for 20% of the total distal upper extremity morbidity among the workers with a relative risk of 2.8 [Moore and Garg 1994]. Based on their findings Moore and Garg, [1994] suggested that CTS maybe causally associated with work. Bingham et al., [1996] examined the prevalence of abnormal median nerve conduction within the carpal tunnel in applicants for industrial jobs. Nerve conduction studies were performed on both hands of 1,021 job applicants in, meat packing, plastic assembly, food processing, furniture manufacturing and grocery warehouse industries. The applicants also completed a self-administered symptom survey for the upper extremity. A difference of more than or equal to 0.5 ms between median and ulnar sensory latencies was used as the primary electrophysiologic measurement to determine median mononeuropathy. Seventeen point five percent of the applicants were classified with median mononeuropathy in at least one hand. Based on their results, Bingham et al., [1996] suggested that a large percentage of industrial workers have objective evidence of abnormal median nerve conduction within carpal tunnel when hired.

A high CTS prevalence of 68.4% was found among sheep farmers in Italy that perform hand milking tasks. Additionally, bilateral CTS were indentified in 43% of the subjects. Even though, risk factor exposure was not conducted the authors suggested that the high CTS prevalence of CTS among sheep farmers may indicate that hand milking is a significant risk factor associated with CTS [Rosecrance et al., 2001]. Rosecrance et al., [2002] used a surveillance case definition for CTS which was based on CTS characteristic hand symptoms and the presence of median mononeuropathy across the carpal tunnel to determine the prevalence of CTS among apprentice construction workers. The prevalence of CTS among apprentices was 8.2% among which, sheet metal workers had the highest rates (9.2%). Rosecrance et al., [2002] suggested that many construction workers begin developing CTS before or during their apprenticeship. This surveillance case definition for CTS was used in yet another study by Anton et al., [2002] to determine the prevalence of CTS in a sample of 95 dental hygienists. Three case definitions used were based on presence of symptoms alone, presence of nocturnal symptoms and presence of symptoms and NCS (difference of more than or equal to 0.5 ms in the median ulnar sensory latency). Prevalence of CTS was 8.4% utilizing the case definition of symptoms and NCS, but 42% if defined by symptoms alone. Anton et al., [2002] concluded that dental hygienists are exposed to occupational factors that increase the risk of CTS and using a case definition that does not include NCS overestimates the prevalence of CTS.

Kim JY et al., [2004] reported the prevalence of CTS among meat and fish processing plant employees in Korea. The case definition of CTS was based on the results of a CTS symtom questionnaire and NCS. Kim JY et al., [2004] found a CTS prevalence of 73.9% among the meat and fish processing plant employees based on this case definition. A similar case definition based on the results of a hand symptom questionnaire and a median-ulnar sensory latency difference of more than or equal to 0.5 ms was used to investigate CTS among automobile assembly workers [Werner et al., 2005]. The authors reported a 9.9% annual incidence rate based on a 13 month follow-up. The study also identified diabetes as a significant predictor of CTS. Additonally the study also reported that obesity increased the risk of developing CTS by 2.5 times. Another study by Hou et al., [2007] found a relatively lower prevalence of CTS (3.8%) among male visual display terminal workers. Even though job seniority was associated with CTS none of the work tasks studied were found to be associated with CTS in this population. Based on the review of litreture it can be suggested that a high prevalence of CTS is found in populations that perform tasks that involve repititive motions, forceful movements and awkward postures.

CHAPTER III

METHODS

This chapter outlines methods used in this study, including the subject recruitment process, CTS case definition used, a description of the hand symptom questionnaire, guidelines followed while performing NCS and the statistical analysis methods employed.

SUBJECT RECRUITMENT

Dairy parlor and non-parlor workers employed at five large herd dairies (>500 head) in Colorado, New Mexico and Texas were recruited to participate in this study. Recruitment was performed by verbal announcements in the dairy and by posting notices in the workers lunch areas. All participants were given $ 40 for their participation in the study. Both the hand-symptom questionnaire evaluation and NCS were performed on the same day at each dairy. The 124 dairy workers participating in this study were not randomly chosen. The number of workers recruited was not very high as on an average each dairy had only 9 parlor workers (3 workers per shift) and the number of non-parlor workers was variable based on the size of the dairy. Possibility of selection bias is low as all workers in the participating dairies were included in the study. Parlor workers participating in this study performed the milking tasks while non-parlor workers performed non-milking related tasks such as, pushing the cows, nursing work, driving and feeding the cows at the dairies. The study sample consisted of both male and female subjects. In the current study all participating subjects were Latino. All workers present on the day of testing at each participating dairy were included in the study sample. A Spanish translator thoroughly informed the participants about the procedures and they signed informed consents prior to participation. The hand symptom questionnaire was administered first by the Spanish translator in an interview format. Participant's responses about presence or absence of CTS related symptoms were recorded. The hand symptom questionnaire evaluation was followed by NCS. The nerve conduction latencies were recorded for both the median and ulnar sensory nerves. The research procedures were reviewed and approved by the institutional review board at Colorado State University.

CASE DEFINITION OF CTS

A CTS case definition based on the presence of median mononeuropathy across the carpal tunnel and characteristic CTS symptoms was used in this study. A median-ulnar latency difference of ≥0.5 ms and a positive response on the hand symptom questionnaire qualified the subject for a case status. The CTS case definition used in this study is similar to the case definitions used in other CTS related epidemiologic studies. [Anton et al., 2002; Atroshi et al., 1999; Atroshi et al., 2003; Bingham et al., 1996; Rosecrance J. and Douphrate 2010; Stetson et al., 1993; Stevens et al., 2001 ; Werner et al., 2001].

HAND SYMPTOM QUESTIONNAIRE

Participants completed a hand symptom questionnaire (Fig.1.) which included a hand symptom diagram [Franzblau et al., 1993; Katz and Stirrat 1990]. Previous studies have reported that the hand symptom questionnaire had high sensitivity and specificity and was a reliable tool to establish a case definition of CTS in epidemiologic studies [Dale et al., 2008; Thomsen and Mikkelsen 2003]. A trained Spanish translator interviewed the subjects and completed the hand symptom questionnaire. The investigators trained the translator in the use of the hand-symptom questionnaire and mock interviews were conducted to verify the training. Even though the validity and reliability of using Spanish translators for the hand symptom questionnaire has not been studied, previous studies have used Spanish versions of different health-related questionnaires and found acceptable levels of reliability and validity [González et al., 1995; Weiss and Berger 2006]. Additionally, the use of the hand symptom questionnaire in an interview format has been shown to be a reliable option [Dale et al., 2008; Thomsen and Mikkelsen 2003].

The questionnaire was designed to elicit general information on demographics, medical conditions, employment history and specific hand symptoms. The subjects were instructed to rate hand and wrist symptoms, such as numbness, tingling, or ache, on a 0-10 scale (0-2=none; 3-7=moderate; 8-10=severe), and shade the appropriate symptoms as per their location on a hand diagram. Symptoms needed to be rated by the subject as 2 or greater on the rating scale to be considered positive for a case status. The rating of 2 or greater has been used in previous studies investigating CTS [Anton et al., 2002; Bingham et al., 1996; Rosecrance et al., 2002] and was also used by Katz and Stirrat [1990] who designed the hand diagram. Hands were classified as having characteristic CTS symptoms if subject indicated numbness, tingling, pain, and /or burning localized in two or more of the first four fingers corresponding to median nerve distribution and if they had occurred sometime in the past 12 months, and were present for the last 2 weeks. Franzblau et al., [1997] found that CTS symptoms that occurred in the past 12 months and were present for the last two weeks are more reproducible than symptoms present for shorter amount of time. The median distribution consisted of the ventral aspect of the digits 1, 2, 3, ventral-radial aspect of the 4^{th} finger, as well as the dorsal aspect of the distal phalanx of each of these digits. This symptom classification is similar to that used in other epidemiological studies of CTS [Franzblau et al., 1993; Katz and Stirrat 1990; Rempel et al., 1998].

The Hand-symptom questionnaire has also been used as a part of larger questionnaire in previous studies [Bingham et al., 1996]. Furthermore, previous research has shown that the hand symptoms questionnaire has good test-retest reliability for use in epidemiological studies [Rosecrance 2002]The hand symptom questionnaire further included questions regarding the duration of hand symptoms, nocturnal symptoms, and pain aggravating activities. Additionally, the questionnaire required the subjects to provide information regarding their employment history namely; type of work performed at the dairy, number of years spent performing current job and number of hours spent per week performing current job. The questionnaire required subjects to provide information regarding their past and current medical history as well as smoking and drinking habits. Questions regarding current pregnancy status, past fractures were also included in the questionnaire. Subjects that were pregnant or suffered from diabetes, rheumatoid arthritis and hypothyroidism were not included in the study due to previously reported associations between these personal risk factors and CTS [Werner 2006]. Subjects that were pregnant, suffered from diabetes, rheumatoid arthritis and hypothyroidism were excluded from the study sample so as to exclude subjects who had CTS unrelated to parlor work. Four participants (3.2%) were excluded from the data analyses because they had a self-reported co-morbidity (diabetes, hypothyroidism, and rheumatoid arthritis) associated with CTS. Of these four participants one was a parlor worker while the other three were non-parlor workers.

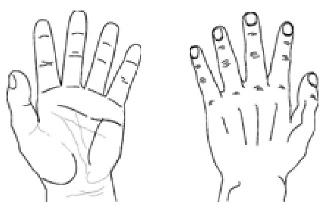
ID ________ Name ______________________________________

Circle the type of symptoms and the severity (0-10 scale) that you have experienced for either hand.

LEFT HAND

Circle your symptoms and the severity (0-10 scale)

	None	Moderate	Severe
Numbness	0 1 2 3 4 5 6 7 8 9 10		
Tingling	0 1 2 3 4 5 6 7 8 9 10		
Sore/Ache	0 1 2 3 4 5 6 7 8 9 10		



Shade-in the area of the hand where you have (had) the symptoms circled above.

How long have you had these symptoms? ________

When was the last time you had these symptoms? _______

Are the symptoms worse at night? yes no

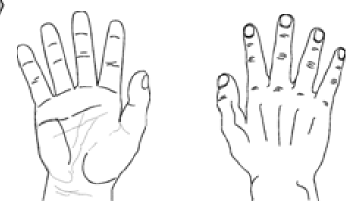
Does hand discomfort wake you from your sleep? yes no

What activities make your symptoms worse? ________________

RIGHT HAND

Circle your symptoms and the severity (0-10 scale)

	None	Moderate	Severe
Numbness	0 1 2 3 4 5 6 7 8 9 10		
Tingling	0 1 2 3 4 5 6 7 8 9 10		
Sore/Ache	0 1 2 3 4 5 6 7 8 9 10		



How long have you had these symptoms? ________

When was the last time you had these symptoms? ______

Are the symptoms worse at night? yes no

Does hand discomfort wake you from your sleep? yes no

What activities make your symptoms worse? ________________

____

ID ________ Name ______________________________________

HT= _______ WT= _______ AGE=______

Employment History

\# hours you work in the parlor per week _______

Job title (last 5-10 years)	How long?
Current Job	
Previous	
Previous	
Previous	

Medical History

Do you have:

diabetes	☐ no	☐ yes
hypothyroidism	☐ no	☐ yes
rheumatiod arthritis	☐ no	☐ yes
history of alcoholism	☐ no	☐ yes
any chronic illness	☐ no	☐ yes

List any medications you have taken in last 48 hours

____

Do you use tobacco products (chew, cigarettes, cigars, pipe)?

______yes ______no amount per day_________

number of years_________

FIGURE. 1. Hand Symptom Questionnaire

NERVE CONDUCTION STUDIES

After the subjects completed the hand symptom questionnaire, NCS were performed on both hands of each subject. Nerve conduction measurements were recorded using Cadwell Sierra II Wedge nerve conduction equipment (Cadwell Labs, Kennewick, WA). The choice of electrophysiologic studies was based on the recommendations set forth by the American Association of Electrodiagnostic Medicine [Jablecki et al., 1993; Jablecki et al., 1993; Jablecki et al., 2002].

PROCEDURE FOR NCS

Subjects were assigned an ID number which along with the date of test, nerves tested and sites of stimulation were recorded at the time of testing.

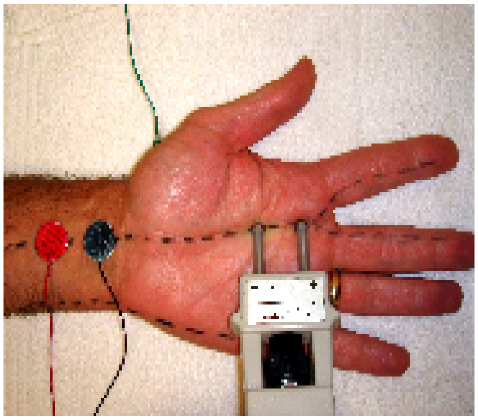
SKIN PREPARATION

The skin area where recording, ground, and stimulating electrodes were placed was cleansed using an alcohol swab. The subjects were positioned with the arm supine (palm up) and the wrist and forearm exposed. The sites for placement of the stimulating and the recording electrode were marked. Temperature was measured using a skin temperature probe (Cadwell Laboratories Inc). Temperature was measured at the web space of the palm between the first and second metacarpal. Hands below 30˚C were warmed using warm water. The subjects were asked to wash their hand for a minute with warm water and temperature was re-recorded till the desired temperature of 30˚C was achieved.

PLACEMENT OF ELECTRODES

Orthodromic, midpalmar- wrist mixed nerve latencies were determined for median and ulnar sensory nerves by performing supramaximal stimulation in the palm with a handheld bipolar stimulator. An orthrodromic electrical impulse travels in the same direction as normal physiologic conduction (e.g., when a motor nerve electrical impulse is transmitted toward the muscle and away from the spine or a sensory impulse travels toward the spine) [Weiss et al., 2004].

Median mixed nerve latencies were recorded, with the stimulating electrode placed on the palm with the anode angled toward the web between the index and middle finger. A bar type recording electrode was secured 8 cm proximal to the cathode on the center of the wrist, directly over the median nerve proximal to the distal wrist crease. The ground electrode was placed on the dorsum of the hand, between the stimulating and recording electrodes as shown in Fig.2. Ulnar nerve sensory latency was recorded with the bipolar stimulator placed on the medial palm with the anode angled toward the web between the fourth and fifth finger. A bar type recording electrode was secured on the medial side of the wrist, directly over the ulnar nerve in the groove between the ulna bone and the flexor carpi ulnaris tendon, proximal to the wrist crease, with the recording electrode distal to the reference as shown in Fig.3. The intensity of the stimulus was gradually increased to a supramaximal level. The supramaximal level is defined as the point at which an increase in stimulus no longer increases the amplitude of the waveform.



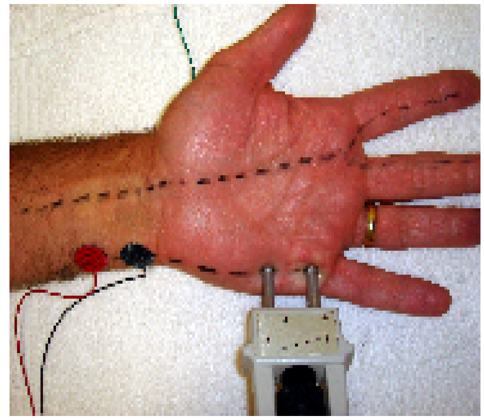


Figure.2. Median Sensory

Figure.3. Ulnar Sensory

Orthrodromic median motor latencies were obtained by supramaximal stimulation of the median nerve. The active recording electrode (negative) was placed over the belly of the abductor pollicis brevis muscle and the reference electrode was placed at the base of the thumb. The bipolar stimulator was placed 8cm from the recording electrode on the median nerve at the wrist between the tendons of the flexor carpi radialis and the palmaris longus as shown in Fig.4.

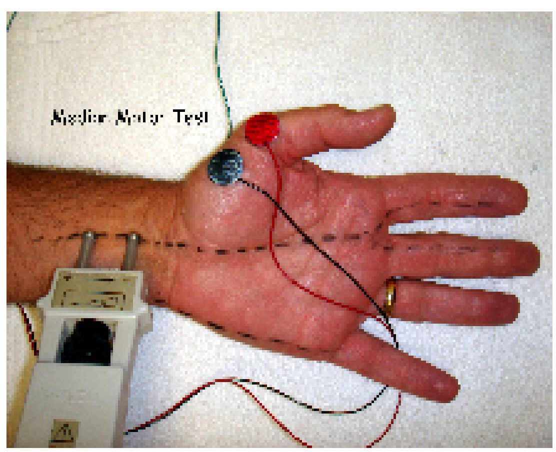


Figure.4. Median Motor

CRITERION FOR MEDIAN MONONEUROPATHY

Peak mixed nerve latency is defined as the time interval between the stimulus artifact until the peak of the negative aspect of the mixed nerve action potential. For subjects that had median and ulnar latency measurements recorded, the median-ulnar latency difference (MULD) was calculated. Median mononeuropathy was defined as a difference equal or greater than 0.5 ms, which is similar to the criterion used in other studies [Bingham et al., 1996; Monga et al., 1985; Redmond and Rivner 1988; Sander et al., 1999; Stevens et al., 2001 ; Werner et al., 1998; Werner et al., 2001]. In case we were unable to obtain a median mixed nerve latency because of conduction block in the carpal tunnel, a 8 cm median motor orthrodromic latency greater than 4.4 ms was used as the criterion for median mononeuropathy. Both tests were performed for all the subjects. As the ulnar nerve was also be evaluated in this study, it served as an internal control for the influences of hand temperature, age, and systemic disease and there was no need to adjust for the same [Jablecki et al., 2002; Jablecki et al., 1993; Jablecki et al., 2002]. All NCS were performed by two physical therapists experienced in conducting electrophysiologic exams for CTS.

STATISTICAL ANALYSIS

All descriptive data for the demographic and occupational variables were reported as means and standard deviations, or frequencies and percentiles. Frequencies and percentiles were also obtained for the case and non-case status for the CTS definition for all subjects, as well as for each group of workers. Prevalence rates were obtained for CTS, median mononeuropathy and CTS based only on symptoms among both parlor and non-parlor workers. The prevalence of CTS in each group of workers was determined by dividing the number of workers with CTS in the group of workers by total number of participants in that group of workers. The prevalence of median mononeuropathy and only characteristic CTS symptoms among parlor and non-parlor workers was similarly determined. The prevalence of CTS, median mononeuropathy and CTS characteristic of symptoms only among parlor and non-parlor workers were compared using a χ^2 test for proportions and odds ratios (OR) with their 95% confidence interval (CI) determined among the parlor and non-parlor workers.

Additionally, logistic regression analysis were performed univariately to assess the association of CTS prevalence with BMI, age, sex, number of years worked and number of hours worked per week individually . A Wald-Chi square test was used to determine the significance of associations to determine if CTS was associated with any of the demographic variables. Due to the small sample size of the present study a logistic regression analysis could not be used to assess the association of CTS with demographic and job variables in one model as this would have led to a complete separation of the model. All data in this study was analyzed using per SAS, Version 9.2 for PC software (SAS Institute, Cary, NC).

CHAPTER IV

RESULTS

STUDY SAMPLE

The study sample consisted of 124 dairy workers from 6 dairies located in Texas, New Mexico and Colorado. Three of the participating dairies were located in Texas and New Mexico while the other three were located in Colorado. Among the 124 dairy workers that participated in this study, sixty-six were dairy parlor workers (53.2 %) and fifty-eight were non-parlor workers (46.7%). Parlor workers consisted of employees performing the milking task whereas non-parlor workers were workers performing other tasks at the dairy chiefly veterinary work, driving, feeding and pushing cows into the dairy parlor.

All the participants in this study were Latino. Twelve percent (n=15) of the participants were females. Among the non-parlor workers 10.3% (n=6) were females whereas among parlor workers 13.6 % (n=9) were females. Four participants (3.2%) were excluded from the data analyses because they had a self-reported co-morbidity (diabetes, hypothyroidism, and rheumatoid arthritis) associated with CTS. Of these four participants one was a parlor worker while the other three were non-parlor workers.

DEMOGRAPHIC VARIABLES

The participants ranged in age from 26 to 44 years with a mean of 36.8 (SD 8.9) years (Table 1). The mean age of the parlor workers was 29.8 years (SD= 7.8yrs) and of the non-parlor workers was 33.6 yrs (SD=9.3yrs). The mean body mass index (BMI; kg/m^2) of the participants of this study was 28.4 kg/m^2 (SD 5.5). And it ranged from 22.8 kg/m^2 to 36.2 kg/m^2. The mean BMI for the parlor workers was 25.2 kg/m^2 (SD 3.9) and of the non-parlor workers was 28.1 kg/m^2 (SD 5.8). The dairy parlor workers had been performing parlor work for a mean of 4.5 years (SD 3.7) whereas the non-parlor workers had been performing non-parlor tasks for a mean of 5.5 years (SD 5.4). The parlor workers worked for a mean of 48.8 hours (SD 3.1) per week whereas the non-parlor workers worked a mean of 53.1 hours (SD 8.8) per week.

Ninety-six percent of the subjects were right handed. Among the parlor workers 96.9 % (N= 63) of the employees were right handed and 3.1 % (N=2) of the employees were left handed. Whereas among non-parlor workers 94.5 % (N= 52) employees were right handed and 5.5 % (N=3) were left handed. Twenty eight percent (N=34) of the subjects used tobacco products. Thirty four percent (N=19) of the non-parlor workers used tobacco products whereas 23 % (N= 15) of the parlor workers used tobacco products.

Table 1: Baseline characteristics of dairy workers

Baseline characteristics	Parlor workers (N=65)	Non-parlor workers (N=55)	P-value
Age, years ±SD	29.8±7.8	33.6±9.3	0.014*
Body Mass Index (kg/m^2) ±SD	25.2±3.9	28.1±5.8	0.001*
Height(m) ±SD	1.6±0.1	1.7±0.09	0.155
Weight (Kg) ±SD	72.7±10.6	83.3±18.2	0.001*
Gender, n (%)			
Males	56 (86.1)	49 (89.7)	-
Females	9 (13.6)	6 (10.3)	-
Number of years worked ±SD	4.5±3.7	5.5±5.4	0.211
Number of hours worked per week ±SD	48.8±3.1	53.1±8.8	0.001*

***signifies difference at p<0.05 level**

NERVE CONDUCTION VARIABLES

The mean latencies for the right and left hand median sensory, ulnar sensory and median motor nerves among parlor and non-parlor workers are presented in Table 2. The right hand mean median sensory latency for the parlor workers (2.12 ms) was higher than the right median sensory latency of the non-parlor workers (2.07 ms). The right hand mean ulnar nerve sensory latency was similar for both parlor (1.80 ms) and non-parlor (1.83 ms) workers. The right hand mean median motor nerve latency of the parlor workers (4.0 ms) was higher than the mean median motor nerve latency of the non-parlor workers (3.87 ms). None of the differences were statistically significant.

Table 2: Descriptive Statistics of the Nerve Conduction Latencies

Job Description	Median Sensory Latency(ms)		Ulnar Sensory Latency(ms)		Median Motor Latency(ms)	
	Right	**Left**	**Right**	**Left**	**Right**	**Left**
Parlor-worker (Mean±SD)	2.12±0.41	2.04±0.31	1.80±0.15	1.88±0.19	4.0±0.84	3.86±0.64
Non-parlor worker (Mean±SD)	2.07±0.28	2.08±0.25	1.83±0.17	1.88±0.15	3.87±0.78	3.81±0.57

Thirteen diary workers that had hand symptoms characteristic of CTS were also classified as having median mononeuropathy across the carpal canal in at least one hand. The overall prevalence of CTS in at least one hand among all the dairy workers was 10.8 % (13/120). The prevalence of CTS was found to be 3.3 % (n=4) among females. All of the female workers classified as a CTS case were parlor workers. Of all the workers with CTS, 46 % (n=6) had CTS in their right hand, 23% (n=3) had CTS in their left hand and 30.7% (n=4) had CTS in both hands. Among non-parlor workers with CTS one had CTS in the right hand and the other had CTS in both hands whereas 5 parlor workers had CTS in their right hand, 3 had CTS in their left hands and 4 had CTS in both hands.

Among the parlor workers the prevalence of CTS in at least one hand was 16.9% (n=11) while among the non-parlor workers it was found to be 3.6% (n=2). There was a significant difference ($p<0.05$) between the mean ages of parlor workers (29.8 years) and non-parlor workers (39.6 years). There was also a significant difference ($p<0.05$) between the mean BMI of parlor workers (25.2 Kg/m^2) and non-parlor workers (28.1 Kg/m^2). Additionally there was a significant difference ($p<0.05$) between the number of hours worked per week for parlor workers (48.8 hours) and non-parlor workers (53.1 hours) though there was no significant difference between the number of years worked as a parlor worker (4.5 years) and a non-parlor worker (5.5 years).

A univariate analysis that included all dairy workers indicated no significant association ($P> 0.1$) between CTS and age, BMI, number of years worked performing the dairy tasks or number of hours worked per week. There was no significant difference between the ages of workers with CTS (35.3 years) and without CTS (31.1years) ($p>0.1$). Also no significant difference was found between the BMI of workers with CTS (26.3 kg/m^2) and workers without CTS (28.09 kg/m^2) ($p>0.1$). Additionally no significant difference was found in the number of hours worked between workers with CTS (50 hours) and workers without CTS (51 hours) ($P>0.1$) and between number of years worked in the dairy industry for workers with CTS (5.8 years) and workers without CTS (4.9 years) ($P>0.1$). Hence age, BMI, number of years worked performing dairy tasks and numbers of hours worked per week were not controlled while calculating the odds ratios.

The difference in prevalence of CTS between the parlor workers and non-parlor workers was found to be statistically significant ($\chi^2 = 5.44$, $P = 0.01$) in the univariate analysis. The risk of having CTS among parlor worker was five times greater (OR= 5.3; 95% CI= 1.14-25.52) as compared to non-parlor workers. Abnormal nerve conduction studies indicating median mononeuropathy across the carpal canal were found in 24.6 % (n=16) parlor workers and 18% (n=10) non-parlor workers. The prevalence rate of CTS based exclusively on the characteristic hand symptoms was 27% (n=18) among parlor workers and 11% (n=6) among non-parlor workers (Figure 5).

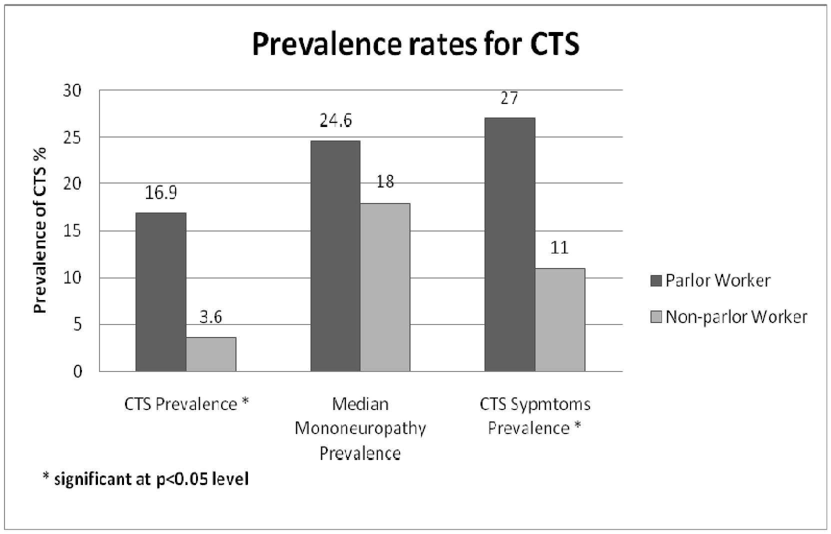


Figure 5: Prevalence rates for CTS

If the criterion for defining median mononeuropathy is changed by increasing or decreasing the cutoff for median-ulnar latency difference, the prevalence of CTS also changed. This change in the prevalence rates and the association of work task and CTS prevalence is illustrated in Table 3. This Table indicates that with each 0.1 ms change in the cutoff criterion for defining median mononeuropathy the CTS prevalence changes by approximately 3%. The change in CTS prevalence is most dramatic when the cut-off criterion is increased from 0.5ms to 0.6 ms.

Table 3: Increment in Median-Ulnar Latency Criterion Cutoffs and Effect on CTS Prevalence

Cutoff criterion	CTS Prevalence % (n)		p value	OR	95%CI
	Parlor worker	Non-parlor worker			
0.3 ms	20.0(13)	5.4(3)	0.01	4.3	1.6-16.1
0.4 ms	18.4(12)	5.4(3)	0.03	3.9	1.1-14.7
0.5 ms	16.9(11)	3.6(2)	0.01	5.3	1.1-25.5
0.6 ms	10.7(7)	3.6(2)	0.13	3.1	0.6-16.0
0.7 ms	9.2(6)	1.8(1)	0.08	5.4	0.6-47.0
0.8 ms	9.2(6)	1.8(1)	0.08	5.4	0.6-47.0

CHAPTER V

DISCUSSION

To our knowledge, this epidemiologic study is the first to report the prevalence of CTS among US dairy workers. In the present study, we determined that CTS prevalence was 16.9% among dairy parlor workers and 3.6% among non-parlor dairy workers. Only one previous study has reported on median nerve entrapment syndrome in the upper-extremity among dairy parlor workers. Stål et al., [1998] found a high prevalence of median nerve entrapment syndrome in the upper-extremity among female parlor workers in Sweden. The investigators used a questionnaire designed to identify specific musculoskeletal symptoms for recruiting the subjects. Only 41 out of 81 female subjects who reported symptoms from the upper extremity were selected for clinical examination. The mean age of the workers was 41.6 years which is about 11 years older than the participants of the present study. Of the 41 subjects included in Swedish study 30 were diagnosed as having a median nerve entrapment syndrome in the upper-extremity. Twenty-three were diagnosed as having pronator syndrome (i.e. compression of the median nerve at the forearm) and six women were diagnosed as having compression of the median nerve at the carpal tunnel. The diagnosis of median nerve entrapment was based on clinical examination by a hand surgeon and self reported symptoms. Unlike the present study no electrophysiologic tests were performed to confirm the neuropathy. The older age of the workers combined lack of electrophysiologic testing likely accounted for this higher prevalence of median nerve entrapment in the Swedish parlor workers than in the present study.

A 68.4% prevalence of CTS was found among Italian sheep farmers performing hand milking by Rosecrance et al., [2001]. The authors used a case definition for CTS that is similar to the present study case definition. This CTS prevalence rate was much higher than the CTS prevalence rate among dairy parlor workers in our study. Many factors can explain this discrepancy. Rosecrance et al., [2001] conducted this study on a non-randomized sample at just two milking co-ops, which may have resulted in higher number of subjects with hand symptoms. Also, the Italian sheep farmers in this study performed hand milking which involves more repetitive motion and forceful exertions than machine milking [Stål et al., 1999]. Higher mean age (47.5) among the Italian sheep farmers along with the above mentioned reasons could possibly explain the higher prevalence rates.

In a questionnaire based study of 813 Iowa dairy farmers Nonnenmann et al., [2008} reported wrist or hand musculoskeletal symptoms in 40 % of the dairy workers tested. The mean age of the workers 49.6 years and 90% of the workers were female and the average number of years working on a dairy farm was 32.4 years, about 27 years more than the years worked by the workers in the present study. Young males have been considered to be at low risk for developing CTS [Tanaka et al., 1995]. Additionally, 70% of the farms included in the Iowa dairy farmers study used a stanchion milking facility and 30 % used a parlor milking facility. All the dairies participating in the current study used a parlor milking facility. Large-herd operations utilize a parlor milking system, as compared to the stanchion system that is used primarily in smaller operations. The prevalence of CTS among all the dairy workers based solely on the hand symptoms was found to be 20% in the present study which is quite high considering the small sample size. Since the present study only documents hand symptoms related to CTS and it is quite possible that other hand wrist symptoms unrelated to CTS may be present in the population and are unaccounted for. This together with the difference in the mean age of the participants, milking facility design and the number of years spent performing dairy work could explain the lower prevalence of hand or wrist symptoms in the present study as compared to study by Nonnenmann et al., [2008].

The estimated prevalence of CTS among the general population ranges from 0.6% to 4.9% [Atroshi et al., 1999; De Krom et al., 1992]. In the present study the prevalence of CTS among dairy parlor workers was 16.9% which is much higher than the CTS prevalence in the general population. CTS accounted for 20% of the total distal upper extremity morbidity in a cross-sectional study analyzing jobs at a pork-processing plant [Moore and Garg 1994]. The percentage is higher than that of the present study. As Moore and Garg, [1994] calculated the prevalence of CTS only among workers with distal upper extremity morbidity and not among all the workers at the pork-processing plant the CTS may not necessarily be comparable to the present study results. Additionally unlike our study Moore and Garg, [1994] included subjects having CTS bilaterally twice in their analysis which may explain the higher prevalence of CTS.

In surveillance study of 665 workers in a meat packing plant high prevalence and incidence of CTS was found [R. G. Gorsche et al., 1999]. The case-definition of CTS was based on fulfillment of two criterions namely, a positive response for a hand symptom questionnaire similar to the one used in the current study as well as an examination test. The prevalence of CTS was found to be 21% in this population. The higher prevalence of CTS among meat packers as compared to dairy parlor workers in our study could be explained by the smaller sample size of our study, lack electrophysiologic tests to confirm neuropathy and the debatable reliability of physical examination without confirmation with electrodiagnostic tests [Hou et al., 2007]. A very high CTS prevalence of 73.9% was found among meat and fish processing workers [Kim JY et al., 2004]. The case definition was based on physical examination and NCS findings. The NCS criterion did not involve the testing and comparing of median nerve sensory latency with another sensory nerve in the same hand. This could have resulted in an overestimation of median mononeuropathy and consequently the prevalence of CTS.

Previous studies have found lower prevalence of CTS in other industry workers performing tasks that involve repetitive motion and awkward postures as compared to the current study. A case definition similar to the present study was used to assess the relationship between both personal and work-related risk factors and median neuropathy in newly hired construction workers. A lower prevalence of median neuropathy (15%) and CTS (3%) was found [Armstrong et al., 2008]. Since the group on workers were healthy, young (mean age =25.6 years) and newly hired the prevalence of CTS in the study by Armstrong et al., [2008] was lower. Another study found a CTS annual incidence rate of 4.5% among automobile assembly workers [Werner et al., 2005]. Since this rate was based on just a 13 month follow-up the prevalence rates of CTS in this population would be similar.

According to the U.S. Bureau of Labor Statistics annual survey of non-fatal occupational injuries and illnesses, the incidence rate of work-related musculoskeletal disorders involving the wrist for 2008 in the private industry was 2.2 cases per 10,000 full-time equivalent workers [BLS, 200]). The incidence rate of work-related CTS for 2008 in the private industry was 1.1 cases as compared to the agriculture industry at 0.7 cases per 10,000 full-time equivalent workers [BLS, 2009]. Currently no occupational injury incidence data is available specifically for the dairy industry. The results of the national surveys suggest that agriculture industry workers are not at high risk of developing CTS. However, the present study results indicate a high prevalence of CTS among dairy workers. A 16.9% prevalence of CTS and a 24.6% prevalence of median mononeuropathy were found among dairy parlor workers. These prevalence rates are also higher than those found by other studies focusing on occupations with high risk of CTS, like fish processing workers (15%), dental hygienists (8.4%), apprentice construction workers (8.2%) and poultry processing workers (12%) [Anton et al., 2002; Harn-Che Chiang et al., 1993; Rosecrance J. et al., 2002; Rosecrance J. and Douphrate 2010]. The studies focusing on dental hygienists, apprentice construction workers and poultry processing workers used a similar case definition for CTS. The study focusing on fish processing workers used a symptom questionnaire and clinical examination without NCS to determine the prevalence of CTS.

The milking task performed by the dairy parlor workers involves significant amount of repetitive motion, forceful exertions and awkward wrist movements [Pinzke et al., 2001]. Exposure to these factors has been suggested to increase the risk of CTS [Aptel et al., 2002; Franzblau and Werner 1999; Siverstein et al., 1987 ; Stål et al., 1999; Van Rijn et al., 2009]. Additionally a causal relationship between performance of a high repetition task and development of CTS has been established in an animal model [Clark Brian D. et al., 2004]. Previous studies among Swedish dairy parlor workers also indicate that performing dairy parlor milking tasks may results in high prevalence of upper-extremity musculoskeletal disorders [Stål et al., 1998; Stål et al., 2003; Stål et al., 2003]. In the present study the overall prevalence of CTS in at least one hand of the dairy workers was 10.8 % (13/120). As expected there was a significant difference in the prevalence of CTS among parlor and non-parlor workers ($\chi^2 = 5.444$, $P = 0.01$). As compared to the non-parlor workers the parlor workers are nearly five times likely to develop CTS.

Parlor workers perform milking tasks for an average of 8 hrs per day with two or three short breaks of about five to ten minutes each on an average working day (personal communication Jesus Silva, April 18th, 2009). A study by Stål et al., [1999] quantified the wrist positions and movements during machine milking in Sweden. The authors found that the wrist was dorsiflexed more than 46 degrees for about 10% of the time and radially deviated more than 22 degrees for 10% of the time performing machine milking. As a result, the authors suggested that there was an increased load on upper-extremity with respect to extreme wrist positions while performing mechanized milking and an increased risk of CTS, elbow and hand disorders in parlor workers [Stål et al., 1999]. Stål et al., (2003) reported that in a rotary milking system hands rested only 1 to 1.4 % of the milking time. Performing milking tasks in a modern milking system puts considerable demands on the hand and wrist due to high repetition [Stål et al., 2003]. A previous study on machine milking reported that milkers held their hands at 42 degrees of dorsiflexion and 12 degrees of radial deviation for 10% of the time while performing the milking subtasks of stripping and attaching the milking cluster. The highest muscle loads on the forearm flexors were reported for the cleaning and attaching the milking cluster subtasks. The study concluded that the parlor workers were exposed to high hand and forearm muscle loads, extreme wrist positions and high wrist velocities more than half of the time they were performing the milking tasks [Pinzke et al., 2001].The high muscle loads in combination with extreme positions and movements of the hand and forearm might contribute to the development of CTS among parlor workers.

In a prior study the current investigators performed risk exposure assessment using the semi-quantitative tools of Strain Index and the American Conference of Governmental Industrial Hygienists (ACGIH) Hand Activity Level (HAL) on the parlor and non-parlor workers [Patil et al., 2010]. In previous studies, Moore and Garg, [1995] have found a positive relationship between Strain Index scores of five and greater and occurrence of upper extremity musculoskeletal disorder. Additionally, the Strain Index has shown good sensitivity and specificity to classify jobs according to the risk for upper extremity musculoskeletal disorders [Moore and Garg 1995; Rucker and Moore 2002]. The non-parlor tasks are a combination of non-cyclic multiple tasks which may or may not require extensive upper extremity movement. Since the validity of Strain Index for evaluation of multitask jobs is questionable Strain Index evaluation was not performed for non-parlor workers [Moore and Garg 1995]. The dominant hand mean scores for the subtask dip, clean, strip and attach were 7.3, 12, 12 and 16 respectively. The findings revealed that job tasks in the parlor are high risk for developing upper extremity musculoskeletal disorders as most SI scores were above 7. Also, in a previous study hand or wrist postures evaluated using Strain Index have been associated with clinical cases of upper-extremity disorders [Spielholz et al., 2008].

The ACGIH TLV considers the worker's hand activity level (HAL) and peak hand force used and whether it exceeds the set Threshold Limit Value (TLV) [American Conference of Govermental Industrial Hygienists 2003]. The TLV categories have been found to be positively associated with diagnosed carpal tunnel syndrome in a previous study [Franzblau et al., 2005]. The ACGIH HAL scores were assigned for both parlor and non-parlor workers. The ACGIH HAL scores for the parlor workers exceeded the Threshold Limit Values (TLV) for the dominant hand in all cases whereas the HAL scores for non-parlor workers were within the TLV [Patil et al., 2010]. Parlor workers perform tasks which require awkward wrist postures, high repetition and forceful movements [Pinzke et al., 2001; Stål et al., 2003]. These findings along with findings from the Swedish studies could explain the higher prevalence on CTS among parlor workers as compared to the non-parlor workers.

In the present study case definition of CTS is based on the results of a hand symptom questionnaire and a difference in median-ulnar latency of more than 0.5 ms. The median-ulnar latency cut-off criterion for CTS has been previously used in several population based studies [Anton et al., 2002; Bonauto et al., 2008; Rosecrance J. et al., 2002; Werner et al., 2005]. Using the cut-off criterion of >0.5 ms the prevalence of CTS in both parlor and non-parlor workers was found to be 16.9% and 3.6% respectively. Though, some investigators have used a more rigid cut-off of 0.8 ms [Atroshi et al., 1999; Atroshi et al., 2003], many others have used a cut-off criterion of 0.5 ms [Werner et al., 1998; Werner et al., 2001]. The difference in prevalence among the two groups was found to be statistically significant. The difference in prevalence would have remained significant even if a more sensitive criterion of >0.3 ms would have been chosen for a positive nerve conduction test. Twenty percent of the parlor workers and 5.4% of the non-parlor workers would have been classified with CTS in atleast one hand if the median-ulnar sensory latency criterion was reduced to >0.3 ms. Redmond and Rivner, [1988] recommended that a median-ulnar sensory latency difference of 0.5 ms be used as an electrodiagnostic criterion for slowing of median nerve to avoid false positive tests for CTS. Approximately 24% of the parlor workers and 18% of the non-parlor workers were classified as having median mononeuropathy applying the >0.5 ms media-ulnar sensory latency difference criterion.

Even so, the results of the present study suggest that some subjects with positive NCS results had CTS symptoms but did not report them. These subjects might have considered the symptoms too mild or transient to be reported. Additionally, the subjects might have attributed the symptoms to some other causes and failed to report them. Previous studies have reported asymptomatic median neuropathy of approximately 15% in industrial workers [Bingham et al., 1996; Werner et al., 1998]. In our study only the prevalence of median mononeuropathy in the absence of symptoms was found to be 10 %. The lower prevalence of median mononeuropathy may be due to a difference in subject population and also due to the much smaller sample size of current study. A study by Werner et al., [2001] determined that workers with prolonged median sensory latency were more likely to develop symptoms of CTS than those with normal electrophysiologic findings. There is a high possibility that these workers with asymptomatic CTS may continue being exposed to risk factors associated with CTS. This in turn could result in a higher prevalence of CTS among dairy workers than estimated in the current study. Research analyzing the work exposures and CTS causality would be beneficial in reducing the prevalence of CTS in this population.

LIMITATIONS

There were several challenges in this cross-sectional study. The most important limitation of this study was the small sample size. With a larger sample size several risk factors may have been studied. Also the large confidence interval for the odds ratio (1.14-25.52), comparing the CTS prevalence among parlor and non-parlor workers suggests low power. Since, this study is a cross-sectional study it does not separate cause and effect relationships in the associations established. It is difficult to determine causality as we are not aware of prior exposures which could have been responsible for the worker having CTS and not parlor work. The worker might have developed or started developing CTS at his previous job nd not while performing parlor work but it is difficult to know that in a cross-sectional study. Additionally, the present study being a cross-sectional study provides a measure of CTS prevalence at a single point of time. Certain subjects with CTS may not have symptoms continuously. Accordingly, subjects with transient hand symptoms and transient electrophysiological symptoms may not have been symptomatic on the day of the testing. It is also possible that some subjects considered their symptoms to mild to be reported. Both these scenarios could have lead to an underestimation of the CTS prevalence rates.

Even though, all employees at each dairy recruited participated in the study (100% participation rate) workers who were absent due to illness, personal leave or had left the work force were not included in the study. Inability to perform the work tasks due to CTS related symptoms may have been one of reasons to leave the work force and this could have lead to an underestimation of the CTS prevalence. All the subjects participating in this study were Spanish speaking Latino workers. A trained Spanish translator interviewed each subject and filled out the hand-symptom questionnaire. Even though a trained translator performed these interviews some under-reporting or over-reporting of hand symptoms may have occurred leading to either under or estimation of the CTS prevalence. Since a hand symptom survey was used in this study there is a possibility of reporting bias.

In the current study, individuals with co-morbidities associated with CTS were excluded from the study. Even so, it is possible that subjects with certain undiagnosed CTS related co-morbidities may have been included in the study resulting in overestimation of CTS prevalence. This overestimation of CTS prevalence could occur in both parlor and non-parlor workers and if so the bias would not be of significance. The present study included relatively young Latino workers (mean age 36.8 years) who have been working in the dairy industry for a relatively short amount of time (5.5 years). Also the sample consisted of very few women (12 %). Additionally, the dairies that participated in the study were large herd dairy operations from Colorado, Texas and New-Mexico and may or may not have similar working practices as other dairy operations in the United States. Hence, generalization to other groups even those performing similar work tasks, is limited.

CONCLUSIONS

The results of this study indicate that CTS is a significant problem for dairy workers. The prevalence of CTS was found to be higher in parlor workers as compared to the non-parlor workers. Even though mechanized milking equipment is used in large herd dairy operations, there is a significant amount of repetitive motion, forceful exertions and awkward wrist movements involved while performing the milking tasks. Non-parlor workers do not perform activities that necessarily involve the same amount of repetitive motion, forceful exertions and awkward wrist movements as the parlor workers, and this could be the reason for a lower prevalence of CTS in that group. Among all the dairy workers age, height and type of job performed were associated with delayed nerve conduction latency. Also, females were found to have significantly slower nerve conduction latencies than males. These findings emphasize the need for ergonomic intervention in the dairy industry, especially reducing the weight of the milking cluster, modifying the parlor design to accommodate individuals of shorter stature and reducing the work hours. A future cohort study involving periodic NCS and assessment of both occupational and non-occupational risk factors suspected of causing CTS in this population namely, forceful exertions, repetitive movements and awkward postures would be beneficial to further our knowledge of CTS and its causality.

References

Al-Shatti T, Barr AE, Safadi FF, Amin M, Barbe MF. 2005. Increase in inflammatory cytokines in median nerves in a rat model of repetitive motion injury. Journal of neuroimmunology 167: 13-22.

American Conference of Govermental Industrial Hygienists. 2003. Threshold limit values for chemical substances and physical agents & biological exposure indices. Hand Activity Level (HAL) Cincinnati, Ohio: ACGIH.

Anton D, Rosecrance J., Merlino L, Cook T. 2002. Prevalence of Musculuskeletal Symptoms and Carpal Tunnel Syndrome Among Dental Hygienists. American Journal of Industrial Medicine 42: 248-257.

Anton D, Rosecrance JC, Merlino L, Cook T. 2002. Prevalence of musculoskeletal symptoms and carpal tunnel syndrome among dental hygienists. American Journal of Industrial Medicine 42 248-257.

Aptel M, Aublet-Cuvelier A, Claude Cnockaert J. 2002. Work-related musculoskeletal disorders of the upper limb. Joint Bone Spine 69: 546-555.

Armstrong T, Dale AM, Franzblau A, Evanoff BA. 2008. Risk factors for carpal tunnel syndrome and median neuropathy in a working population. Journal of Occupational and Environmental Medicine 50: 1355-1364

Atroshi I, Gummesson C, Johnson R, Ornstein E, Ranstam J, Rosén I. 1999. Prevalence of carpal tunnel syndrome in a general population. JAMA: The Journal of the American Medical Association 282: 153-158.

Atroshi I, Gummesson C, Johnsson R, Ornstein E. 2003. Diagnostic properties of nerve conduction tests in population-based carpal tunnel syndrome. BMC Musculoskeletal Disorders 4: 9.

Atroshi I, Gummesson C, Johnsson R, Ornstein E, Ranstam J, Rosen I. 1999. Prevalence of carpal tunnel syndrome in a general population. JAMA 282: 153 - 158.

Barr AE. 2006. Tissue pathophysiology, neuroplasticity and motor behavioural changes in painful repetitive motion injuries. Manual therapy 11: 173-174.

Bernard BP. 1997. Musculoskeletal Disorders and Workplace Factors: A Critical Review of Epidemiologic Evidence for Work-Related Disorders of the Neck, Upper Extremities, and Low Back

Bingham R, Rosecrance J, Cook T. 1996. Prevalence of abnormal median nerve conduction in applicants for industrial jobs. Am J Ind Med 30: 355 - 361.

Bingham RC, Rosecrance JC, Cook T. 1996. Prevalence of abnormal median nerve conduction in applicants for industrial jobs. American Journal of Industrial Medicine 30: 355-361.

Bland JDP. 2005. The relationship of obesity, age, and carpal tunnel syndrome: More complex than was thought? Muscle & Nerve 32: 527-532.

Blumenthal S, Herskovitz S, Verghese J. 2006. Carpal tunnel syndrome in older adults. Muscle & Nerve 34: 78-83.

Bonauto DK, Silverstein BA, Fan ZJ, Smith CK, Wilcox DN. 2008. Evaluation of a symptom diagram for identifying carpal tunnel syndrome. Occupational Medicine 58: 561-566.

Clark BD, Barr AE, Safadi FF, Beitman L, Al-Shatti T, Amin M, Gaughan JP, Barbe MF. 2003. Median Nerve Trauma in a Rat Model of Work-Related Musculoskeletal Disorder. Journal of Neurotrauma 20: 681-695.

Clark Brian D., Al-ShattiTalal A., Barr Ann E., Amin Mamta, F. BM. 2004. Performance of a High-Repetition, High-Force Task Induces Carpal Tunnel Syndrome in Rats. The Journal of orthopaedic and sports physical therapy 34: 244-253.

D'Arcy CA, McGee S. 2000. Does This Patient Have Carpal Tunnel Syndrome? JAMA: The Journal of the American Medical Association 283: 3110-3117.

Dale A, Strickland J, Symanzik J, Franzblau A, Evanoff B. 2008. Reliability of hand diagrams for the epidemiologic case definition of carpal tunnel syndrome. Journal of Occupational Rehabilitation 18: 233-248.

Daniell WE, Fulton-Kehoe D, Chiou LA, Franklin GM. 2005. Work-related carpal tunnel syndrome in Washington State workers' compensation: Temporal trends, clinical practices, and disability. American Journal of Industrial Medicine 48: 259-269.

Daniell WE, Fulton-Kehoe D, Franklin GM. 2009. Work-related carpal tunnel syndrome in Washington State workers' compensation: Utilization of surgery and the duration of lost work. American Journal of Industrial Medicine 52: 931-942.

De Krom MCTFM, Knipschild PG, Kester ADM, Thijs CT, Boekkooi PF, Spaans F. 1992. Carpal tunnel syndrome: Prevalence in the general population. Journal of Clinical Epidemiology 45: 373-376.

Douphrate DI, Rosecrance J, Stallones L, Reynolds SJ, Gilkey DP. 2009. Livestock-handling injuries in agriculture: An analysis of Colorado workers’ compensation data. American Journal of Industrial Medicine 52: 391-407.

Douphrate DI, Rosecrance J, Wahl G. 2006. Workers’ compensation experience of Colorado agriculture workers, 2000-2004. American Journal of Industrial Medicine 49: 900-910.

Dunning KK, Davis KG, Cook C, Kotowski SE, Hamrick C, Jewell G, Lockey J. 2010. Costs by industry and diagnosis among musculoskeletal claims in a state workers compensation system: 1999–2004. American Journal of Industrial Medicine 53: 276-284.

Elliott MB, Barr AE, Clark BD, Wade CK, Barbe MF. 2010. Performance of a repetitive task by aged rats leads to median neuropathy and spinal cord inflammation with associated sensorimotor declines. Neuroscience 170: 929-941.

Foley M, Silverstein B, Polissar N. 2007. The economic burden of carpal tunnel syndrome: Long-term earnings of CTS claimants in Washington State. American Journal of Industrial Medicine 50: 155-172.

Franzblau A, Armstrong TJ, Werner RA, Ulin SS. 2005. A Cross-Sectional Assessment of the ACGIH TLV for Hand Activity Level. Journal of Occupational Rehabilitation 15: 57-67.

Franzblau A, Werner RA. 1999. What Is carpal tunnel syndrome? JAMA: The Journal of the American Medical Association 282: 186-187.

Franzblau A, Werner RA, Valle J, Johnston E. 1993. Workplace surveillance for carpal tunnel syndrome: A comparison of methods J Occ Rehab 3: 1-14.

González VM, Stewart A, Ritter PL, Lorig K. 1995. Translation and validation of arthritis outcome measures into spanish. Arthritis & Rheumatism 38: 1429-1446.

Hamann C, Werner R, Franzblau A, Rodgers P, Siew C, Gruninger S. 2001. Prevalence of carpal tunnel syndrome and median mononeuropathy among dentists. J Am Dent Assoc 132: 163-170.

Harn-Che Chiang, Yin-Ching Ko, Shun-Shen Chen, Hsin-Su Yu, Trang -Neng Wu, Chang. P-Y. 1993. Prevalence of shoulder and upper-limb disorders among workers in the fish-processing industry. Scand J Work Environ Health 19: 2-31.

Hou W-H, Hsu J-H, Lin C-H, Liang H-W. 2007. Carpal tunnel syndrome in male visual display terminal (VDT) workers. American Journal of Industrial Medicine 50: 1-7.

Jablecki C, Andary M, Floeter M, Miller R, Quartly C, Vennix M, Wilson J. 2002. Second AAEM literature review of the usefulness of nerve conduction studies and needle electromyography for the evaluation of patients with carpal tunnel syndrome. Muscle Nerve 26 (suppl): S1 - S53.

Jablecki C, Andary M, Floeter MK, Miller RG, Quartly CA. 2002. Second AAEM literature review of the usefulness of nerve conduction studies and needle electromyography for the evaluation of patients with carpal tunnel syndrome. Muscle & Nerve 26 (suppl): S1-S53.

Jablecki C, Andary M, So Y, Wilkins D, Williams F. 1993. American Association of Electrodiagnostic Medicine (AAEM) Quality Assurance Committee: Literature review of the usefulness of nerve conduction studies and electromyography for the evaluation of patients with carpal tunnel syndrome. . Muscle Nerve 16: 1392-1414.

Jablecki C, Andary M, So Y, Wilkins D, Williams F. 1993. Literature review of the usefulness of nerve conduction studies and electromyography for the evaluation of patients with carpal tunnel syndrome. Muscle Nerve 16: 1392 - 1414.

Jablecki CK, Andary MT, Floeter MK, Miller RG, Quartly CA, Vennix MJ, Wilson JR. 2002. Practice parameter: Electrodiagnostic studies in carpal tunnel syndrome: Report of the American Association of Electrodiagnostic Medicine, American Academy of Neurology, and the American Academy of Physical Medicine and Rehabilitation. . Neurology 58: 1589-1592.

Katz J, Stirrat C. 1990. A self-administered hand diagram for the diagnosis of carpal tunnel syndrome. J Hand Surg Am 15: 360 - 363.

Kim JY, Kim JI, Son JE, SK. Y. 2004 Prevalence of carpal tunnel syndrome in meat and fish processing plants. J Occup Health 46: 230-234.

Lam N, Thurston A. 1998 Association of obesity, gender, age and occupation with carpal tunnel syndrome. Aust N Z J Surg 68: 190-193.

Letz R, Gerr F. 1994. Covariates of human peripheral nerve function: I. Nerve conduction velocity and amplitude. Neurotoxicology and Teratology 16: 95-104.

Maghsoudipour M, Moghimi S, Dehghaan F, Rahimpanah A. 2008. Association of Occupational and Non-occupational Risk Factors with the Prevalence of Work Related Carpal Tunnel Syndrome. Journal of Occupational Rehabilitation 18: 152-156.

Manktelow RT, Binhammer P, Tomat LR, Bril V, Szalai JP. 2004. Carpal tunnel syndrome: cross-sectional and outcome study in Ontario workers. J Hand Surg Am 29: 307-317.

McCurdy SA, Carroll DJ. 2000. Agricultural injury. American Journal of Industrial Medicine 38: 463-480.

Moghtaderi A, Ghafarpoor M. 2009. The dilemma of ulnar nerve entrapment at wrist in carpal tunnel syndrome. Clinical neurology and neurosurgery 111: 151-155.

Monga TN, Shanks G.L., B.J. P. 1985. Sensory palmar stimulation in the diagnosis of carpal tunnel syndrome. Arch Phys Med Rehabil 66: 598-600.

Moore J, Garg A. 1995. The Strain Index: a proposed method to analyze jobs for risk of distal upper extremity disorders. Am Ind Hyg Assoc J. 56: 443-458.

Moore S, Garg A. 1994. Upper extremity disorders in a pork processing plant: relationships between job risk factors and morbidity. American Industrial Hygiene Association Journal 55: 703 - 715.

N.R.C. 2001. National Research Council: Musculoskeletal disorders and the workplace. Washington, DC: National Academy Press.

Nonnenmann MW, Anton D, Gerr F, Merlino L, Donham K. 2008. Musculoskeletal symptoms of the neck and upper extremities among Iowa dairy farmers. American Journal of Industrial Medicine 51: 443-451.

Padua L, Aprile I, Caliandro P, Carboni T, Meloni A, Massi S, Mazza O, Mondelli M, Morini A, Murasecco D, Romano M, Tonali P. 2001. Symptoms and neurophysiological picture of carpal tunnel syndrome in pregnancy. Clinical neurophysiology : official journal of the International Federation of Clinical Neurophysiology 112: 1946-1951.

Palmer KT, Harris EC, Coggon D. 2007. Carpal tunnel syndrome and its relation to occupation: a systematic literature review. Occupational Medicine 57: 57-66.

Patil A, Gilkey D, Rosecrance J, Douphrate D. 2010. Risk exposure assessment of dairy parlor workers. 54th Annual Meeting of the Human Factors and Ergonomics Society San Fransisco, California. p 1916- 1920.

Perkins BA, Olaleye D, Bril V. 2002. Carpal Tunnel Syndrome in Patients With Diabetic Polyneuropathy. Diabetes Care 25: 565-569.

Pinzke S, Stål M, Hansson G-Å. 2001. Physical Workload On Upper Extremities In Various Operations During Machine Milking Ann Agric Environ Med 8: 63–70.

Pinzke S, Stal M, Hansson G. 2001. Physical workload on upper extremities in various operations during machine milking. Ann Agric Environ Med 8 63-70.

R. G. Gorsche, J. P. Wiley, R. F. Renger, R. F. Brant, T. Y. Gemer, Sasyniuk TM. 1999. Prevalence and incidence of carpal tunnel syndrome in a meat packing plant. Occup Environ Med 56: 417–422.

Redmond HD, Rivner MH. 1988. False positive electrodiagnostic tests in carpal tunnel syndrome. Muscle Nerve 11: 511-517.

Redmond M, Rivner M. 1988. False positive electrodiagnostic tests in carpal tunnel syndrome. Muscle Nerve 11: 511 - 518.

Rempel D, Evanoff B, Amadio P, de Krom M, Franklin G, Franzblau A, Gray R, Gerr F, Hagberg M, Hales T, Katz J, Pransky G. 1998. Consensus criteria for the classification of carpal tunnel syndrome in epidemiologic studies. Am J Public Health 88: 1447 - 1451.

Roquelaure Y, Ha C, Leclerc A, Touranchet A, Sauteron M, Melchior M, Imbernon E, Goldberg M. 2006. Epidemiologic surveillance of upper-extremity musculoskeletal disorders in the working population. Arthritis Care & Research 55: 765-778.

Roquelaure Y, Ha C, Pelier-Cady M-C, Nicolas G, Descatha A, Leclerc A, Raimbeau G, Goldberg M, Imbernon E. 2008. Work increases the incidence of carpal tunnel syndrome in the general population. Muscle & Nerve 37: 477-482.

Roquelaure Y, Mechali S, Dano C, Fanello S, Benetti F, Bureau D, Mariel J, Martin Y-H, Derriennic F, Penneau-Fontbonne D. 1997. Occupational and personal risk factors for carpal tunnel syndrome in industrial workers. Scand J Work Environ Health 23: 364-369.

Rosecrance J, Cook TM, Anton D, Merlino L. 2002. Carpal tunnel syndrome among apprentice construction workers. American Journal of Industrial Medicine 42: 107-116.

Rosecrance J, Douphrate DI. 2010. Hand and wrist disorders among U.S. poultry processing workers. International Conference Ragusa SHWA2010 - September 16-18, "Work safety and risk prevention in agro-food and forest Systems" Ragusa Ibla Campus- Italy.

Rosecrance J, Marras Teresa, Baldasseroni Alberto, Riccardo. T. 2001. Carpal tunnel syndrome among italian farmers. The society for engineering in agricultural, food, and biological systems Annual International Meeting, Paper no. 01-8070 Sacramento, California.

Rosecrance J., Cook T, Anton D, Merlino L. 2002. Carpal tunnel syndrome among apprentice construction workers. American Journal of Industrial Medicine 42: 107-116.

Rosecrance J., Douphrate DI. 2010. Hand and Wrist Disorders Among U.S. Poultry Processing Workers. International Conference Ragusa SHWA2010 - September 16-18, "Work Safety and Risk Prevention in Agro-food and Forest Systems" Ragusa Ibla Campus- Italy.

Rosecrance JC, Ketchen K, Merlino L, Anton D, Cook TM. 2002. Test-retest reliability of a musculoskeletal symptoms and job factors questionnaire used in ergonomics research. . Appl Occup Environ Hyg 17: 613-621.

Rosecrance JC, Ketchen, K., Merlino, L., Anton, D., Cook, T.M. 2002. Test-retest reliability of a musculoskeletal symptoms and job factors questionnaire used in ergonomics research. . Appl Occup Environ Hyg 17: 613-621.

Rucker N, Moore JS. 2002. Predictive validity of the strain index in manufacturing. Applied Occupational and Environmental Hygiene 17: 63-73.

Russell B. 2008. Carpal tunnel syndrome and the "double crush" hypothesis: a review and implications for chiropractic. Chiropractic & Osteopathy 16: 2.

Sander HW, Quinto C, Saadeh P, Chokroverty S. 1999. Median and ulnar palm-wrist studies. . Clinical Neurophysiology : official journal of the International Federation of Clinical Neurophysiology 110: 1462-1465.

Sedal L, McLeod JG, Walsh JC. 1973. Ulnar nerve lesions associated with the carpal tunnel syndrome. Journal of Neurology, Neurosurgery & Psychiatry 36: 118-123.

Silver M, Gelberman R, Gellman H, Rhoades C. 1985. Carpal tunnel syndrome: associated abnormalities in ulnar nerve function and the effect of carpal tunnel release on these abnormalities. J Hand Surg Am 10: 710 - 713.

Siverstein BA, Fine LJ, Armstrong TJ. 1987 Occupational factors and carpal tunnel syndrome. Am J IND Med 24: 175-189.

Spielholz P, Bao S, Howard N, Silverstein B, Fan J, Smith C, Salazar C. 2008. Reliability and Validity Assessment of the Hand Activity Level Threshold Limit Value and Strain Index Using Expert Ratings of Mono-Task Jobs. Journal of Occupational and Environmental Hygiene 5: 250 - 257.

Stål M, Hagert C, Moritz U. 1998. Upper extremity nerve involvement in Swedish female machine milkers. Am J Ind Med 33: 551-559.

Stål M, Hansson G, Moritz U. 1999. Wrist positions and movements as possible risk factors during machine milking. Applied Ergonomics 30 527-533.

Stål M, Pinzke S, Hansson G. 2003. The effect on workload by using a support arm in parlour milking. International Journal of Industrial Ergonomics 32: 121-132.

Stål M, Pinzke S, Hansson G, Kolstrup C. 2003. Highly repetitive work operations in a modern milking system. A case study of wrist positions and movements in a rotary system. Ann Agri Environ Med 10: 67-72.

Stetson DS, Silverstein BA, Keyserling WM, Wolfe RA, Albers JW. 1993. Median sensory distal amplitude and latency: Comparisons between nonexposed managerial/professional employees and industrial workers. American Journal of Industrial Medicine 24: 175-189.

Stevens JC, Witt JC, Smitt BE, Weaver AL. 2001 The frequency of carpal tunnel syndrome in computer users at a medical facility Neurology 56: 1568-1570.

Tanaka S, Wild DK, Cameron LL, Freund E. 1997. Association of occupational and non-occupational risk factors with the prevalence of self-reported carpal tunnel syndrome in a national survey of the working population. American Journal of Industrial Medicine 32: 550-556.

Tanaka S, Wild DK, Seligman PJ, Halperin WE, Behrens VJ, Putz-Anderson V. 1995. Prevalence and work-relatedness of self-reported carpal tunnel syndrome among U.S. workers: Analysis of the occupational health supplement data of 1988 national health interview survey. American Journal of Industrial Medicine 27: 451-470.

Thomsen JF, Mikkelsen S. 2003. Interview data versus questionnaire data in the diagnosis of carpal tunnel syndrome in epidemiological studies. Occupational Medicine 53: 57-63.

Tong HC, Werner RA, Franzblau A. 2004. Effect of aging on sensory nerve conduction study parameters. Muscle & Nerve 29: 716-720.

Upton A, McComas A. 1973. The double crsuh in nerve entrapment syndromes. Lancet 2: 359-362.

Van Rijn R, Huisstede B, Koes B, Burdorf A. 2009. Associations between work-related factors and the carpal tunnel syndrome—a systematic review. Scandinavian Journal of Work, Environment and Health 35: 19–36.

Vos HW. 1974 Some ergonomic aspects of parlour milking. Canadian Agricultural Engineering 16: 45-48.

Weiss L, Silver J, Weiss J. 2004. Easy EMG: A Guide to Performing Nerve Conduction Studies and Electromyography.

Weiss T, Berger R. 2006. Reliability and Validity of a Spanish Version of the Posttraumatic Growth Inventory. Research on Social Work Practice 16: 191-199.

Werner R. 2006. Evaluation of Work-Related Carpal Tunnel Syndrome. Journal of Occupational Rehabilitation 16: 201-216.

Werner RA, Albers JW, Franzblau A, Armstrong TJ. 1994. The relationship between body mass index and the diagnosis of carpal tunnel syndrome. Muscle & Nerve 17: 632-636.

Werner RA, Andary M. 2002. Carpal tunnel syndrome: pathophysiology and clinical neurophysiology. Clinical neurophysiology : official journal of the International Federation of Clinical Neurophysiology 113: 1373-1381.

Werner RA, Franzblau A, Albers JW, Armstrong TJ. 1998. Median mononeuropathy among active workers: Are there differences between symptomatic and asymptomatic workers? . Am J Ind Med 33: 374-378.

Werner RA, Franzblau A, Gell N, Hartigan AG, Ebersole M, Armstrong TJ. 2005. Incidence of carpal tunnel syndrome among automobile assembly workers and assessment of risk factors. Journal of Occupational and Environmental Medicine 47: 1044-1050

Werner RA, Franzblau A, Gell N, Hartigan AG, Ebersole M, Armstrong TJ. 2005. Incidence of Carpal Tunnel Syndrome Among Automobile Assembly Workers and Assessment of Risk Factors. Journal of Occupational and Environmental Medicine 47: 1044-1050 1010.1097/1001.jom.0000171065.0000117288.a0000171060.

Werner RA, Gell N, Franzblau A, Armstrong TJ. 2001 Prolonged median sensory latency as a predictor of future carpal tunnel syndrome. . Muscle Nerve 24: 1462-1467.