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Psychosocial and Occupational Factors Associated with Carpal Tunnel Syndrome using a National Sample of United States Working Adults

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By

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DEDICATION

To

Kenneth R. and Kinsey M. Liberty

in recognition of their unwavering support and dedication.

TABLE OF CONTENTS

LIST OF TABLES

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ABSTRACT OF THE THESIS

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Carpal tunnel syndrome (CTS) is a common peripheral neuropathy with known personal, medical and biomechanical risk factors including specific work-related physical exertion. CTS accounts for approximately 10% of work-related musculoskeletal disorders (WMSDs) which make up almost 31% of all work-related injuries in the United States (US), 2015. Among the US working adults CTS injury results in a median of 28 days away from work, resulting in loss of work time, loss of earning power, low rate of returning to pre-injury status, and high cost for treatment. It is important to determine whether any work-related factors other than the known biomechanical risk factors could be potential contributing factors to CTS among working individuals in the U.S. Recent research has found that work characteristics (e.g., long work hours or non-standard employment arrangements) and occupational psychosocial factors (e.g., high job demand or work-life imbalance) could impact on a range of health outcomes either as direct risk factors or by interacting with physical or other personal or work-related risk factors. However, there has been a paucity of evidence on whether work characteristics or occupational psychosocial factors are associated with CTS in working populations with no evaluation of these factors in a general U.S. working population.

Data from the 2015 National Health Interview Survey (NHIS) and its supplementary Occupational Health Supplementary (OHS) Survey were analyzed using Chi Square for bivariate comparisons and multiple logistic regression models to examine associations between occupational psychosocial risk factors and prevalence of CTS, while controlling for demographic characteristics, relevant health comorbidities, and work-related physical exertion. The prevalence of self-reported ever CTS diagnosed by a healthcare provider was 6.3% while the prevalence of those reporting CTS symptoms in the last 12 months was 3.0%, translating to 3.4 and 1.7 million U.S. adult workers. The psychosocial factors found to be associated with ever having a diagnosis of CTS were hostile work environment, worrying about losing one's job, and work-life interference. High job demand and worrying about losing job were found to be associated with those with a past diagnosis of CTS and experiencing CTS symptoms within the last 12 months. The role of these occupational psychosocial risk factors for CTS along with physical job demands of frequent lifting and pushing at work should be evaluated further in longitudinal studies.

CHAPTER 1: INTRODUCTION AND PURPOSE

Carpal tunnel syndrome (CTS) is a medical condition due to compression of the median nerve as it travels through the wrist at the carpal tunnel, located at the base of the palm. The median nerve originates from the brachial plexus that passes through the shoulder. It includes contributions from the C6, C7, C8, and T1 nerve roots. While C6 and C7 supply the median sensory fibers that provide sensation to the thenar eminence and the first three and a half digits of the hand, roots C8 and T1 supply the motor fibers to the muscles of the forearm and hand (UpToDate, 2019). The compression of the median nerve occurs as it passes through the carpal tunnel along with nine flexor muscle tendons. Ischemia and mechanical disruption of the nerve can follow. The main symptoms of this condition are pain, numbness and tingling of the thumb, index finger, middle finger and the medial side of the ring finger. Symptoms typically start gradually at night time. Pain may extend up to the arm with weak grip strength, and long-term sequalae can include sensation loss and weakness in the digits supplied by the median nerve resulting in atrophy of the muscles at the base of the thumb.

The pathophysiology for CTS is multifactorial. Increased pressure in the carpal tunnel is key in the development of clinical CTS. While the precise etiology of this increased carpal tunnel pressure in CTS is uncertain, there is evidence to suggest anatomical compression and/or inflammation may be the mechanisms (UpToDate, 2019). Increased pressure in the carpal tunnel can injure the nerve directly, impair axonal transport, or compress vessels in the perineurium and cause median nerve ischemia (UpToDate, 2019).

CTS is the most common entrapment neuropathy of the upper extremities (Atroshi et al., 1999) with an estimated prevalence of 1 to 5 percent in the general population, 0.7 to 9.2 percent in women and 0.4 to 2.1 percent in men (UpToDate, 2019). The estimated female-to-male ratio for CTS prevalence is around three to one. The estimated annual incidence of CTS is 2.2 to 5.4 per 1000 person-years for women and 1.1 to 3 for men. A higher incidence of CTS occurs in men greater than age 65 and peaks between the age 45 to 54 in women (Stevens et al., 1988). The incidence rate of CTS in those with high level of education, having a 4-year university degree or higher, was about 60% of those with a low-level education, high school or below (Pourmemari et al., 2018).

CTS has been associated with a number of individual characteristics and medical conditions in the general adult population. The personal characteristics are female gender (Pourmemari et al., 2018), obesity (Shiri et al., 2015), and older age group. Those with the following medical conditions are at increased risk of having CTS: hypothyroidism (Shiri et al., 2014; van Dijk et al. 2003), diabetes mellites (van Dijk et al., 2003; Pourmemari et al., 2018), osteoarthritis (Shiri et al., 2016), rheumatoid arthritis and other connective tissue diseases (van Dijk et al., 2003, Barnes & Currey, 1967; Herbison et al., 1973). Trauma, certain medication use, and smoking have also been linked to CTS, although their association is less certain (UpToDate, 2019).

CTS is a prevalent musculoskeletal disorder (MSD) in the working population. In 2010, the National Health Interview Survey (NHIS) found an estimated 3.1 percent of employed adults ages 18 to 64 were diagnosed with CTS in the past 12 months (CDC, 2011). Reflecting that of the general population, which includes those employed and unemployed, the percentage of the employed adults with CTS increased with each age group. Furthermore, employed women were approximately two-fold more likely than their male counter parts to have CTS in the past 12 months (CDC, 2011). In 2015, the Bureau of Labor Statistics found that occupational or work-related CTS had the second longest days away from work among the work-related MSDs with an average of 28 days, which is second to fractures with an average of 31 days away from work (US BLS, 2016).

CTS also results in a significant impact on the economy through various costs. The estimated annual total direct cost – which is the sum of total medical, medical administrative, and indemnity administrative costs – of CTS in 2007 was $240 million (Bhattacharya, 2014). CTS is one of the more costly medical conditions in the WC system. For example, when comparing CTS WC cases to acute injuries of upper extremity, such as fractures or dermatitis in Washington state, CTS cases had far greater long-term loss of earnings (Foley et al., 2007). The cumulative excess meaning earnings loss over a 6-year period were found to $45,000 or $89,000 per CTS claimant compared with those work-related upper extremity fracture or dermatitis, respectively (Foley et al., 2007). Additionally, these same CTS claimants were found to recover a much lower fraction of their pre-injury earnings compared to their counterparts (Foley et al., 2007).

There has been consistent evidence in the literature supporting certain occupational biomechanical risk factors for developing CTS, such as repetitive bending, twisting of hands/wrists (Tanaka et al., 1995), vibration, and handgrip with high forces (Shiri et al., 2009, Kozak et al., 2015). The literature has focused on workers of certain occupations with these biomechanical risk factors for CTS (van Rijn et al., 2009). There have not been as many studies dedicated to evaluating work organization and/or workplace psychosocial factors in relation to CTS.

The importance of accounting for work organization and work psychological factors has been illustrated by Sauter and Swanson's ecological model of musculoskeletal disorders (Sauter & Swanson, 1996). In their model, those working with the video-display terminals (VDTs) or office technology encountered multiple factors linked through various pathways encompassing physical, biomechanical, psychosocial/ work organization and stress components, leading to musculoskeletal symptoms (Sauter & Swanson, 1996). The different pathways included the work organization factors encountered by those working in VDT/ office technology, which can affect both psychological and physical demands of the job, resulting in musculoskeletal symptoms (Sauter & Swanson, 1996). The model shows that increased psychological strain may facilitate biomechanical strains, increasing the risk of musculoskeletal pathology (Sauter & Swanson, 1996).

In recent years, research has examined work organization as well as workplace psychosocial risk factors in relation to CTS occurrence. Multiple literature reviews have found evidence of an association between high job demands and low social support with upper extremity symptoms (Bongers et al., 2002; Van den Heuvel et al., 2005; National Research Council, 2001), but evidence of an association between workplace psychosocial factors and CTS was lacking in these studies. A comprehensive international review conducted in 2007 found consistent physical risk factors associated with CTS, but only four studies included the assessment of psychosocial risk factors and CTS (van Rijn RM et al., 2009). A majority of the workers in these four studies were factory/ production or assembly line workers of a single work site. The psychosocial risk factors assessed were heterogenous among the four studies, ranging from one to six questionnaire items on job control, work demand, social support, and time pressure (van Rijn et al., 2009). The authors found no statistical association between any of the tested psychosocial risk factors and CTS (van Rijn et al., 2009). The authors did note that the those working in meat and fish processing and forestry industries working with chain saws and electronic assembly work had the highest of increased occurrence of CTS (van Rijn et al., 2009).

There has also been research on the association between psychosocial factors and CTS. The psychosocial measurements or screening criteria have been quite heterogeneous while the study work populations have been mostly specialized industrial or manufacture workers. These studies have yielded inconsistent and at times conflicting results of the various psychological factors and their association to CTS prevalence. Most of the studies that examined occupational psychosocial factors, did so in either a specialty work field and/or by studying biomechanical or work organization factors in conjunction (Rigouin et al., 2014; Fan et al., 2015; Harris-Adamson et al., 2013). Less than 10 case-control studies have evaluated workplace psychosocial risk factors in relation to CTS occurrence, with about 4-5 specifically addressing psychosocial risk factors. Most evaluated physical work load, time constraints when performing a certain task, ergonomics, or CTS risk associated with a specific type of work (Leclerc et al., 1998; Goodson et al., 2014; Petit et al., 2015; Harrison-Adamson et al., 2016). A recent comprehensive review published in 2017 by Mansfield et al. was conducted specifically to determine if psychosocial factors were associated with and/or predicted the onset of CTS (Mansfield et al., 2017). Only six studies met the inclusion criteria, where the psychosocial factors associated with CTS were high psychological work demand, high job strain, least influence over their work, a high job demand, low level of job control, high psychological distress, low social support, poor social network, and "type A behavior" (Mansfield et al., 2017). The authors noted that in general psychosocial factors were higher in those who reported CTS (Mansfield et al., 2017). However, the variance in the study populations, study designs, and heterogeneity of the psychosocial measures may have impacted the reliability and external validity of their findings (Mansfield et al., 2017).

The purpose of this cross-sectional study is to investigate the associations of occupational psychosocial exposures with a history of CTS diagnosis and recent symptoms of CTS among the diagnosed in a nationally representative sample of the general U.S. adult working population using the 2015 National Health Interview Survey (NHIS)–Occupational Health Supplementary (OHS) Survey data. The analysis will control for the personal characteristics, medical conditions, and the physical demands of their jobs.

CHAPTER 2: LITERATURE REVIEW

Work-related Statistics of CTS

In 2015, the leading workplace injury or illness category was sprains, strains, or tears with a total of 421,610 days-away-from-work and accounting for 37% of all work-related injury cases, at a rate of 38.0 cases per 10,000 full-time workers (U.S. BLS, 2016). Anderson et al. (2015) reported that WMSD for back, upper extremity and knee had the highest compensable claims rate in Washington State's WMSD workers' compensation (WC) claims between 2002 to 2010. The incidence rate of non-traumatic CTS was 6.4 per 10,000 full-time employees during the period between 2002 and 2010 with an average of 321 lost workdays per claim and an average annual direct cost of $48,481 per claim (Anderson et al., 2015). A surveillance study from 1999 to 2013 of the Washington State WC found that 43% of all compensable claims were due to WRMDs (Marcum et al., 2017). Among the WRMD claims, the greatest proportion of the female workers, 56% had claims for hand/wrist; CTS accounted for 10.2% of the WRMDs and women accounted for 60% of the CTS cases (Marcum et al. 2017).

Between 2007 to 2014 in the State of California, a total of 139,336 CTS cases were reported out of the annual 637,672 WC claims submitted, equating to an incidence rate of 6.3 per 10,000 full-time equivalent (FTE) in California workers (Jackson et al., 2018). The highest CTS incidence rate was among people aged 45-54 years at 8.4 cases per 10,000 FTE, and an incidence rate of women (8.2 cases per 10,000 FTEs), being 3.3 times higher than that of men (2.5 cases per 10,000 FTEs) for work-related CTS cases (Jackson et al., 2018). The rate of WC reported CTS has been decreasing over time as mirrored by a decrease in all-cause WC claims since 2004, which could be due to delayed diagnosis and thus resulting in underreporting of CTS to WC insurers (Jackson et al., 2018). The two industries with the highest rate of CTS in California, textile and fabric finishing and coating mills and apparel manufacturing, had an increased rate of CTS cases of 9.8 and 7.2 per 10,000 FTE respectively, from 2007-2010 to 2011-2014 (Jackson, et al. 2018).

Personal characteristics and CTS

A review of literature published by da Costa et al. in 2010 updated the evidence for WMSD published since NIOSH's 1997 publication, using only high-quality case-control or cohort studies. The review identified additional risk factors to the development of CTS besides biomechanical factors. These risk factors included psychosocial risk factor of high level of work-related distress, and individual risk factors of older age, female gender, smoking status, high BMI, and comorbidity (de Costa et al., 2010). Out of these risk factors, the authors found only the individual risk factors of elevated BMI, older age, and female gender to have reasonable evidence supporting their causal relationship with wrist/hand WMSD, while there was insufficient evidence for the other risk factors (de Costa et al., 2010).

In a Washington State WMSD workers' compensation surveillance study of 1999-2013, claimants with hand/wrist WMSDs had highest proportion of females at 56%, 60% for CTS, compared to other body parts (Marcum and Adams, 2017).

In a 11-year Finish longitudinal study, those with obesity (BMI > 30 kg/m^2), high waist-to-hip ratio, or hand osteoarthritis had a higher risk of carpal tunnel release surgery, when adjustment for age and gender (Pourmemari et al., 2018).

Work-related physical and biomechanical risk factors for CTS

In 1996, Blanc et al. published CTS results from the National Health Interview Survey–Occupational Health Supplement 1988 data with 544 self-reported CTS and 32,688 survey respondents without CTS among the 18-64 age general population survey population. They found that 11% reported work disability attributed to their CTS and that the workplace ergonomic risk, measured as repetitive hand or wrist bending in the occupation and industry of last employment, at 120 minutes of daily exposure, was the single most predictive factor for CTS (OR 1.7, 95% CI 1.1 – 2.6; Blanc et al., 1996).

NIOSH published a thorough review in 1997 that screened over 600 published material since 1979 for epidemiological evidence on the relationships between physical factors at work and MSDs of the neck, upper extremity and low back (Bernard et al., 1997). From thirty studies of occupational CTS (twenty-one cross-sectional studies, six case-control, and three cohort – all published between 1979 to 1997), the authors found evidence of positive associations between CTS and each of the following physical work factors: highly repetitive work, forceful work, and work involving hand/wrist vibration (Bernard et al., 1997). The authors concluded that there is strong work-related evidence of a positive association between exposure to a combination of these risk factors and CTS, and insufficient evidence of an association between CTS and extreme postures (Bernard et al., 1997). They noted that those in occupations or jobs with high manual work demands were consistently shown to have the highest rates of CTS (Bernard et al., 1997).

A subsequent systematic review that evaluated high quality case-control or cohort studies published since the 1997 NIOSH publication confirmed biomechanical risk factors via twenty-two studies of the upper limb WMSD (de Costa et al., 2010). The biomechanical risk factors identified for the development of wrist/hand WMSD, including CTS, were heavy physical work, awkward static and dynamic working postures, repetitive work, and prolonged computer work (da Costa et al., 2010).

A review by van Rijn et al., published in 2009, evaluated the association between exposure to physical risk factors and CTS using only high-quality studies with quantitative measures of both the occupational exposure and the association between the work-related risk factors and CTS. They found that frequent handling of loads, highly repetitive work with and without force requirements, hand-arm vibration, and activities with a flexed or extended wrist were associated with CTS (van Rijn et al., 2009). In the review, they noted occupations with the highest prevalence of CTS were jobs in the meat-and-fish-processing industry, chain-saw-related forestry work, and electronic assembly jobs (van Rijn et al., 2009).

Work organization factors and CTS

There was a scarcity of information on the relationship between CTS and work organization factors (Leclerc et al., 1998) until recently. Two recently published studies from France using two successive surveys of 3,700 workers of the West-Central France evaluated work organizational factors and CTS (Rigouin et al., 2014; Petit et al., 2015). Rigouin et al. conducted a cross-sectional study using the French Institute for Public Health Surveillance data on CTS gathered between 2002 and 2005, while Petit et al. conducted and compared the follow-up survey between 2007 to 2010. The working population of that region was representative of the diverse French working population with no major socioeconomic status differences from the general French working population (Rigouin et al., 2014). The personal and work-related factors were assessed using self-administered questionnaires, whereas the CTS cases were either symptom-only cases or clinically diagnosed cases by an occupational physician as per predefined definition and protocol (Rigouin et al., 2014). The prevalences of CTS in these male and female workers were 3.1% (95% CI 2.4-3.8) and 5.7% (95% CI 4.6-6.9), respectively (Rigouin et al., 2014). Among the work organization factors, they found that working with temporary workers was associated with CTS for female industrial blue-collar workers (OR 1.90, 95% CI 1.23-3.25) (Rigouin et al., 2014). Task rotation during the job (OR= 2.45 95% CI 1.41-4.24) and work pace dependent on a quantified target (OR 1.93 95% CI 1.08-3.46) were associated with CTS only for male workers (Rigouin et al., 2014). In the analyses with only clinically diagnosed CTS (excluding the symptom-only cases), the associations were stronger for women workers working with temporary workers (OR =2.29 95% CI 1.28-4.04), and stronger for men workers with task rotation during the job (OR= 2.88, 95% CI 1.52-5.46), while the work pace dependent on quantified target was not significant (OR = 1.61, 95% CI 0.84-3.09, p= 0.151) (Rigouin et al., 2014).

In the follow-up French study, 65% of the original workers were re-examined between 2007 to 2010. The work organization factors studied were time constraints, overtime hours, work with temporary workers, lack of prior information regarding the amount of work to be done each day, variable weekly workload, and payment on a piecework basis (Petit et al., 2015). The authors found the risk factors associated with CTS were payment on a piece-work basis (OR = 3.0, 95% CI 1.5-5.9) and work pace dependent on automatic rate (OR = 2.3, 95% CI 1.0-5.6) (Petit et al., 2015). The authors stated that there may be indirect factors, such as lower socioeconomic status and higher psychological distress from job insecurity, that could have contributed to both of these associations (Petit et al., 2015), as these work organization factors were more commonly used in industries involving assembly line workers who perform highly repetitive tasks, with Taylor principles of work style, which is known to increase the risk of CTS (Petit et al., 2015; van Rijn et al., 2009).

Bao et al. (2016) examined the relationships between CTS prevalence and four work organization factors – job rotation, overtime work, having a second job, and work pacing - using three study cohorts in the U.S. There was a total of 1834 subjects covering 35 diverse facilities representing 25 different industries that included manufacturing, food processing, healthcare and office work sectors (Bao et al., 2016). Work organization data were collected through questionnaires, interviews, and on-site observations, while the clinical outcome of CTS cases was determined through interviews, physical exams and nerve conduction studies (Bao et al., 2016). They found a dominant hand CTS prevalence of 13.8%, job rotation was associated with increased risk of CTS (OR =1.23, 95% CI 1.00-1.50), while having a second job was borderline protective for risk of CTS (OR = 0.90, 95% CI 0.80-1.01), and no association was found between either overtime work or work pace and CTS (Bao et al., 2016).

Psychosocial factors and CTS

Reviews by the National Research Council (2001), Bongers et al. (2002), and Van Den Heuvel et al. (2005) concluded that high job demands, high job stress, and low social support were associated with occurrence of upper extremity disorder (van Rijn et al., 2009). Van Rijn et al., in 2009, attempted to quantify the association of work-related physical and psychosocial factors with the occurrence of CTS in occupational settings in order to evaluate the exposure-response relationships. The authors searched all literature related to CTS/median nerve and work-related psychological load/exposure in English, German, French and Dutch up to September 2007 (van Rijn et al., 2009). Their inclusion criteria for the review included CTS in occupational populations, quantitative measures of exposure/distinct exposure pattern at job level, and that there must be a quantitative measure of association between the work-related risk factors and CTS (i.e., odds ratio, relative risk, or raw data) (van Rijn et al., 2009). They found a total of 44 publications that met all of the inclusion criteria published in peer-reviewed scientific journals in the aforementioned languages, but only 4 studies reported on the association between psychosocial factors and the occurrence of CTS (2 cohort, 1 case-control, and 1 cross-sectional studies) (van Rijn et al., 2009). Three out of these four articles also reported on the association between physical risk factors and CTS. The four studies evaluated high vs. low social support, job control, job demands, and time pressure that included permanent time pressure, few breaks, task control and social support at work. None of the studies reported any statistically significant associations between the psychosocial factors and CTS (van Rijn et al., 2009).

An one-year prospective study done in Poland evaluated the relationship between psychosocial work conditions and repetitive strain injuries, and their relationships to the presence of musculoskeletal conditions in nine body regions (Bugajska et al., 2013). In this study, the Job Content Questionnaire (JCQ) (Karasek, 1985; Karasek et al,, 1998) was used to assess the psychosocial working conditions, a Nordic musculoskeletal questionnaire was used to assess musculoskeletal conditions, and provocative testing was used to diagnose the musculoskeletal conditions (Bugajska et al., 2013). The Karasek's Demand-Control model (Karasek, 1979) was the basis of the JCQ and this study set out to study its effect on WMSD diagnosis. It found psychological job demands was the strongest predictor of WMSD prevalence, including wrists complaints and wrist pain in the last 7 days. Low decision latitude (job control) was associated with the prevalence of CTS (Bugaiska et al., 2013). Additionally, this study also showed that long-term low-decision latitude was important for the occurrence of WMSDs and their development into strain injuries. The authors concluded that psychosocial factors were a positive predictor of the prevalence of WMSDs and repetitive strain injury (RSI), irrespective of personal factors (age or gender), organizational and physical factors (working hours, repetitive work, or force) (Bugaiska et al., 2013).

In the first French study, the 2002 to 2005 baseline survey assessed the psychosocial constraints at work using the validated French version of the JCQ (Rigouin et al., 2014). The work-related psychosocial factors of high psychological demand for women (OR = 1.90, 95% CI 1.17-3.09) and low skill discretion (OR=1.77, 95% CI 1.01-3.11) among men were found to be associated with CTS diagnoses (Rigouin et al., 2014). This association changed when only clinically diagnosed CTS were considered (excluding the symptom-only cases). While high psychological demand for women became borderline significant (OR = 1.76, 95% CI 0.99-3.12), low skill discretion for men was strengthened (OR = 2.12, 95% CI 1.09-4.13) (Rigouin et al., 2014).

In the second French study, a follow-up from the first, 65% of the original workers were re-examined between 2007 to 2010 with both the French JCQ and the median scores of the national French SUMER study (Niedhammer et al., 2006) in the assessment of psychosocial work factors (Petit et al., 2015). They found no psychosocial factors in the Demand-Control-Support model to be significantly associated with CTS, despite finding the aforementioned biomechanical and organization factors to be associated with CTS (Petit et al., 2015).

In a large multi-site cross-sectional study of almost 3,000 participants, Fan et al. (2015) found two out of five occupational psychosocial factors tested to be associated with CTS. Workers who were moderate to severely exhausted compared to those with none to slightly exhausted (OR = 1.64, 95% CI 1.26-2.13) and those dissatisfied with their jobs compared to those very satisfied with their jobs (OR =1.56, 95% CI 1.09-2.24) had higher prevalence of CTS. The psychosocial/work organization factors with no statistically signification relations to CTS in this study were job demand, decision latitude, supervisor or coworker support, mentally exhausted after work, receiving job training, job tenure and work shift (Fan et al., 2015).

In 2017, Mansfield et al. noted there was no systematic review done to determine whether there are any psychosocial risk factors in developing CTS in the adult population. They conducted a comprehensive literature search of English language publications of three databases (PubMed, CINAHL, and MEDLINE) from inception to May 30, 2017. Studies must have included adults (18 or older) with a clinically diagnosed CTS, excluding those related to a systemic, medical, or injury pathology, and the study had to have at least one or more psychosocial factors with a quantitative measure such as a risk or a point estimate (Mansfield et al., 2017). Over 1700 records were screened from the databases, leading to twenty-seven full-text articles assessed by two independent reviewers, which resulted in six articles meeting all of their inclusion criteria (Mansfield et al., 2017). These six studies included 12,773 participants with three cohort studies, one matched cohort study, one case-control study, and one cross-sectional survey. Participants of four studies were assembly line factory workers, and the other two studies recruited participants of different occupational background – manual work, administration, professional services, and office-based occupations (Mansfield et al., 2017). Five of the six studies reported a positive association between psychosocial factors and CTS (Mansfield et al., 2017). They found that high psychological distress (OR 4.3, 95% CI 1.0-18.6) and psychological problems (OR 2.34, 95% CI 1.42-3.85) were statistically significant in workers with CTS. They also found that high social support, high hierarchical control of work performed, more coworker support, and a high decision latitude were negatively associated with CTS or protective of CTS (Mansfield et al., 2017).

CHAPTER 3: METHODS

The source of data for this study is the National Health Interview Survey (NHIS) which is an ongoing nationwide household interview survey conducted by the National Center for Health Statistics (NCHS). The NHIS periodically includes a supplement that includes questions on occupation and occupational exposures, which is called the Occupational Health Supplementary (OHS) Survey. The last OHS survey was conducted in 2015, so this study is based on a merged data set of the NHIS survey and the OHS survey.

National Health Interview Survey data information

The National Health Interview Survey (NHIS) is a cross-sectional household interview survey conducted annually with the target population being the civilian non-institutionalized population residing in the United States at the time of the interview (NCHS, 2016). It excludes persons in long-term care institutions, correctional facilities, U.S. nationals living in foreign countries as well as active-duty Armed Forces personnel, although not their civilian family members (NCHS, 2016). The weighted estimated cover only the civilian non-institutionalized household population. NHIS is one of the major data collection programs conducted by the National Center for Health Statistics (NCHS) (NCHS, 2016).

The NHIS annual health interview originated the year after the passing of the National Health Survey Act of the 1956, which provided for a continuing survey and special studies to secure accurate and current statistical information on the amount, distribution, and effects of illness and disability in the U.S. and the services rendered for or because of such conditions (NCHS, 2016). The major objective of the NHIS is to monitor the health of the U.S. population through the collection and analysis of survey data on a broad range of health topics. The NHIS data are widely used throughout the Department of Health and Human Services (DHHS) for monitoring trends in illness and disability, as well as tracking progress toward achieving national health objectives (NCHS, 2016). The data are also used by the public health research community for epidemiological and policy analysis on timely issues such as characterizing those with various health conditions, determining barriers to accessing and utilizing appropriate health care and evaluating federal health programs (NCHS, 2016). The sample design is designated after each decennial census, so census data can be used to create the necessary weights to estimate national population distributions based on responses of the sampled survey participants (Parsons et al., 2014).

The NHIS Core questionnaires are mostly unchanged from year to year and consist of four main components: the Household Composition section, the Family Core, the Sample Child Core, and the Sample Adult Core (NCHS, 2016). The Household Composition section collects basic demographic and relationship information about all persons in the household. The Family Core questionnaire collects socio-demographic information, basic indicators of health status, activity limitations, injuries, health insurance coverage, access to and utilization of health care services for all persons in the family (NCHS, 2016). From each family, one "sample child" is randomly selected, if there is a child age 17 years or less, and one "sample adult" aged 18 years or more is also randomly selected. The information collected about the sample child and the sample adult consist of basic information on health status, health care services, and health-related behaviors (NCHS, 2016).

NHIS-OHS data information

Each year the NHIS includes supplementary questions – one or more questions sponsored by NCHS and/or other agencies added to the Core questionnaire. This research used the Sample Adult Core from 2015 and the supplementary of Adult Occupational Health Supplementary (OHS) Survey. The two datasets were merged via three unique variables for the subjects.

The 2015 NHIS sample contained data for 41,493 households that included 103,789 persons in 42,288 families, with the number of sampled adults being 33,672 (NCHS, 2016). The total household response rate was 70.1%, and the response rate for the Sample Adult was 79.7% (NCHS, 2016). The final response rate of 55.2% for the Sample Adult was calculated by multiplying the conditional rate of 79.7% by the final family response rate of 69.3% (NCHS, 2016).

The study population used for analyses of this study was defined as 18 to 69 year-old adults who reported working for pay at a job or business during the week prior to their OHS interview. The final sample size for the study was 17,132 for all analyses.

Definition of Carpal Tunnel Syndrome

CTS was assessed in four questions of the NHIS-OHS questionnaire, each question assessed a particular CTS history or status. All answer choices for the CTS status were “yes”, “no”, “Refused”, “Not ascertained” or “Don’t know”. The first question was “Have you EVER been told by a doctor or other health professional that you have a condition affecting the wrist and hand called carpal tunnel syndrome?” Those answering “yes” to this question were then asked a second self-reported CTS question that assess CTS occurrence in the past 12 months, “DURING THE PAST 12 MONTHS have you had carpal tunnel syndrome?” with the same answer choices as above. If the answer was “yes” to this question, a third question was asked, “Have you been told by a doctor or other health professional that your carpal tunnel syndrome was probably work-related?” If the answer to the third question was “no”, the fourth question was then asked. “Did YOU ever discuss with a doctor or other health professional whether your carpal tunnel syndrome was probably caused by your work?” Since the current study is interested in evaluating the association between CTS and work psychosocial exposures and work organization factors, and this association may not currently be recognized by doctors or health professionals, this study did not use the third or the fourth questions. The study evaluated the first two questions on EVER diagnosed CTS and self-reported CTS DURING THE PAST 12 MONTHS.

Demographic characteristics and socioeconomic status

Demographic variables used in the analysis included age, gender, race-ethnicity, and education level. Age was coded into 5 categories: 18-29, 30-39, 40-49, 50-59, and 60-69 years, with exclusion of those over age 69. Gender was categorized as male or female. The race and ethnicity variables were used to classify subjects initially into five groups: non-Hispanic White, non-Hispanic Black, Hispanic, non-Hispanic Asian, and non-Hispanic Other. Socioeconomic status (SES) variables were education and income. This analysis used only education as the measure of socioeconomic status. While income and occupation can also be used as SES in health research, education precedes and could determine both occupation and income (Johnson-Lawrence et al., 2017). Furthermore, development of CTS could lead to changes in occupation and consequently income, so there could be a potential for reverse causality using cross-sectional data. Education was evaluated using three categories: those with an education up to a high school diploma, some college or an associate degree, and those with a bachelor's degree or more.

<u>Health conditions</u>

The NHIS survey include two questions about health conditions that have been associated with CTS – weight and arthritis. The survey recorded weight as body mass index (BMI). BMI was coded into three categories: Underweight and Normal Weight (BMI up to 25), Overweight (BMI 26 to 30) and Obese (BMI greater than 30). The survey also asked participants whether they had ever been told they have arthritis. The responses were coded as "yes" or "no".

<u>Workplace Physical Exertion</u>

Two variables asked about work-related physical exertion – frequency of standing or walking; and frequency of lifting, pushing, pulling or bending. Frequency of standing or bending was reported as never, seldom, sometimes, often, or always. This variable was recoded as frequent (often or always) or not frequent (never, seldom, sometimes). The variable on frequency of lifting, pushing, pulling or bending was also reported with five response categories from never to always. This variable was also recoded as frequent (often or always) or not frequent (never, seldom, sometimes).

<u>Workplace Psychosocial Factors</u>

The potential risk factors for CTS available in the OHS dataset included occupational psychosocial exposure variables of job demand, job control, hostile work environment, work place perceived as unsafe, work-life interference, and worrying about losing job. Job Demand was based on the question “I have enough time to get the job done.” Response categories were strongly agree, agree, disagree, and strongly disagree. High Job Demand was defined as disagree or strongly disagree. Job Control was based on the question “My job allows me to make a lot of decisions on my own.” Response categories were strongly agree, agree, disagree, and strongly disagree. Low Job Control was defined as disagree or strongly disagree. Hostile Work Environment was based on the question “DURING THE PAST 12 MONTHS, were you threatened, bullied or harassed by anyone while you were on the job.” The response categories were yes or no. Workplace Perceived as Unsafe was based on the question “Overall, how safe do you think your workplace is? Would you say…” The response categories were very safe, safe, unsafe, and very unsafe. An unsafe workplace was defined as unsafe or very unsafe responses. Work-life Interference was based on the question “The demands of my job interfere with my personal or family life.” Response categories were strongly agree, agree, disagree, and strongly disagree. Work-life interference was defined as strongly agree or agree responses. Worry About Losing Job was based on the question “Are you worried about losing your [current, MAIN job]? The responses were yes or no. All of the variable responses were recoded to “0” or “1” for the analyses, with “1” representing affirmation of the exposure.

Work Organization Characteristics

The work organization factors included frequent night work (based on frequency in the past 30 days: 1-5 times, 6-10 times, 11-19 times, or 20-30 times), non-standard work arrangement (categorized as independent contractor, independent consultant, or freelance worker, temporary agency or subcontractor), shift work (anything other than a regular daytime schedule), and supervisory responsibility (yes or no). The variables were recoded to “0” or “1”, where “0” represented those who answered “no” and “1” represented those with “yes” answers.

The work organization characteristics included in this study were frequent night work, non-standard work arrangement, shift work or alternative shift, and supervisory responsibility.

Statistical Analysis

The statistical analysis used the Stata software program procedures designed for survey sampling design such as that used by the NHIS. In order to achieve sampling efficiency, the NHIS sample design followed a multistage area probability design that permits representative sampling of households and non-institutional group quarters (e.g., college dormitories). Because of the complex survey design, the statistical analysis used data analysis procedures designed specifically for analysis of such data. The NHIS data bases include information on population weights, so the responses of the survey participants can be weighted to represent the US general non-institutional population (NCHS, 2016). Furthermore, the clustering protocols that are used in the multistage selection of the NHIS sample require special methods to estimate the variance of the variables. The variance estimation methods available in Stata are balanced repeated replication (BRR), the bootstrap, the jackknife, successive difference replication, and first-order Taylor linearization. For this study, the Taylor series linearization method was used as the variance estimation method (Stata Corp, 2017). All analyses used the NHIS survey weights and variance estimation procedures, so the results are weighted to be representative of the U.S. adult working population.

The first step of the analysis was to generate descriptive frequency distributions of the responses to all of the variables included in the study based on the variable recodes previously described. These variables included the demographic and socioeconomic characteristics, health condition, work-related physical exertion variables, and occupational psychosocial exposure variables. These variables are collectively considered to be the independent variables.

The second step was to calculate the prevalence of each of the two CTS outcome variables for each response category of the independent variables. Because the independent variables were all coded as categorical variables and the CTS outcomes were coded as dichotomous variables (yes or no), the statistical associations between prevalence of the CTS outcomes by the independent variable categories were assessed using Chi-square test.

The third step was to develop multivariable logistic regression models to assess the associations between the CTS outcome variables and the occupational psychosocial exposure variables while controlling for demographic and socioeconomic characteristics, relevant health conditions, and work-related physical exertion exposures. Separate analyses were conducted for each of the two CTS outcome variables – EVER diagnosed with CTS, and self-reported CTS DURING THE PAST 12 MONTHS.

Before conducting logistic models for the occupational exposures, a baseline logistic regression analysis was completed with the demographic variables, and the medical condition variables of BMI and arthritis. The purpose was to assess whether previously recognized personal risk factors for CTS were observed in the data. This analysis was followed by the three logistic models developed for the occupational psychosocial exposure variables.

Model 1 included the occupational psychosocial exposure variable (e.g., high job demand) and demographic variables (age, gender, race-ethnicity, and education), as well as health condition variables (BMI and history of arthritis). Model 1 included these variables to control for potential confounding by the demographic characteristics and health conditions.

Model 2 include the Model 1 independent variable plus the work-related physical exertion variables (frequency of standing or walking; and frequency of lifting, pushing, pulling or bending). This model included the occupational physical exertion variables to also control for potential confounding by these occupational exposures. Model 3 included the Model 2 variables plus all of the other occupational psychosocial exposure variables other than the primary exposure variable being analyzed in the model. The purpose of Model 3 was to explore whether any perceived associations between any specific psychosocial exposure variable and CTS was due to confounding with another correlated occupational psychosocial exposure variable. As previously noted, all analyses were conducted using Stata with the survey design data procedures.

CHAPTER 4: RESULTS

The adult sample size of the OHS dataset was 33,672, however, the sample size was reduced to 17,978, because of the inclusion criterion of working for pay the week prior to their interview. Of the 17,978 survey participants, information on the two CTS outcome variables of interest was available for 17,961 subjects. After eliminating subjects with missing data from any of the variables used for the analyses, the sample was 17,132. This final sample was used in all of the analyses. Because of the NIHS sample design and population weighting, this study population represented a general U.S. working population of almost 53.7 million U.S. adult workers. A total of 1,087 (6.3%) of the study population reported CTS diagnosed by a healthcare provider at some point in their adult lives. And among them, 509 (3.0%) reported that they had experienced CTS in the previous 12 months. These values represent an estimated 3.4 million and 1.7 million U.S. adult working population with a diagnosis of CTS at some point in their lives, and half of them also reported having CTS symptoms in the previous 12 months, respectively.

<u>Distribution of adult workers by demographics characteristics and relevant health conditions</u>

The demographic characteristics and SES variable were age, gender, race-ethnicity, and education. Details of the descriptive information can be found in Table 1. The U.S. adult working population (based on the weighted NHIS sample population) ages ranged from 18 to 69 years with a rather even distribution of around the lower twentieth percent per decade, except for the 60-69 age group, which had about half of the subjects compared to each of the other age groups. The gender distribution was 51.8% men and 48.2% women. Race-ethnicity was initially divided into 5 categories, however, due to much lower numbers of subjects in the Non-Hispanic

Asian and the Non-Hispanic Other categories, the latter two categories were collapsed into one category for the analysis. Thus, the final distribution of race-ethnicity groups was approximately 67% Non-Hispanic White, 12% Non-Hispanic Black, 14% Hispanic, and 7% Non-Hispanic Other. The education distribution was approximately 28% high school graduate or less, 33% with some college or an associate degree, and 40% with a bachelor's degree or more.

For the health conditions, the BMI distribution was 36% underweight and healthy weight, 35% overweight, and about 30% obese. The proportion of workers reporting a medical history of arthritis was 14%.

<u>Prevalence of CTS by demographic characteristics and health conditions</u>

The percentage of those with either a history of CTS ever or CTS symptoms during the past 12 months are also shown in Table 1. Each variable was tested for its association with the two CTS variables by the Chi-square test in determining if there was an association between it and either one of the CTS variables. The Chi-square test showed statistically significant associations for all the demographical variables when compared with either of the two CTS variables.

As shown in Table 1, the highest prevalence of adult workers experiencing CTS symptoms during the last 12 months belonged to the age range of 50-59 (3.8%), females (4.0% versus 1.8% for males), Non-Hispanic Black (3.8%), those with less than a bachelor's degree (3.2% for high school graduate or less, and 3.3% for those with some college or an associate degree). Among health conditions, the highest prevalence was among those with a BMI in the obese range (4.5%), which was greater than twice that of those in overweight range.

The demographic distributions were similar although higher in percentage among workers with a past diagnosis of CTS than those with CTS symptoms of the last 12 months. Those in the latter two age groups had higher about four times those in the 18-29 age group of a history of diagnosed CTS. Women with more than twice the percentage than men, and Non-Hispanic Black continued to be the highest race ethnicity group to have experienced a CTS diagnosis. Those with less than a college degree had higher percentage of a past CTS diagnosis compared to those with a bachelor's degree or more.

Those with obese BMI were also associated with a higher percentage of past CTS diagnosis compared with those with a lesser BMI. The proportion of workers reporting a medical history of arthritis was 6% with a past CTS diagnosis and 2.8% with a diagnosis of CTS in the past 12 months

Table 1: Demographic characteristics, health conditions, and prevalence of CTS based on NIHS sample of US adult working population

Variable	**Frequency (%)**	**CTS Ever Diagnosed (%)**	**CTS last 12 months (%)**
Demographic characteristic			
Age (years)		(p<0.0001)	(p<0.0001)
18-29	21.6	2.14	1.43
30-39	23.8	4.97	2.84
40-49	22.1	5.83	3.00
50-59	21.1	9.78	3.76
60-69	11.4	10.54	3.49
Gender		(p<0.0001)	(p<0.0001)
Male	51.8	3.70	1.75
Female	48.2	8.74	3.97
Race-ethnicity		(p=0.0002)	(p=0.0310)
Non-Hispanic White	66.9	6.45	2.78
Non-Hispanic Black	11.6	7.19	3.85
Hispanic	14.2	4.28	2.46
Non-Hispanic Other	7.3	5.04	2.20
Education		(p= 0.0030)	(p=0.0020)
High school Graduates or less	27.9	6.32	3.17
Some college or associate degree	32.5	7.09	3.34
Bachelor’s degree or more	39.6	5.21	2.14
Health Condition			
Weight		(P<0.0001)	(P<0.0001)
Underweight/healthy weight	35.6	4.44	2.04
Overweight	34.9	4.95	2.22
Obese	29.5	9.56	4.46
Ever told arthritis		(P<0.0001)	(P<0.0001)
Yes	14.3	13.96	6.17
No	85.7	4.83	2.26

Distribution of work-related physical and psychosocial factors and prevalence of CTS

Table 2 shows there were significant associations between physical exertion at work such as frequent lifting, pushing, pulling, or bending and CTS (ever diagnosed and symptoms over the last 12 months). Table 2 shows the proportion of workers with physical exertion at work such as frequent lifting, pushing, pulling, or bending was 40.5%, and 6.7% of them reported ever been diagnosed with CTS while 3.5% report CTS symptoms over the last 12 months. Frequent standing and walking was significantly associated with CTS symptoms over the last 12 months, while it was not significantly associated with ever diagnosed CTS. The proportion of workers reporting frequent standing and walking as a physical exertion exposure at work were 65.4%, and 6.4% of them reported ever been diagnosed with CTS while 3.1% reported CTS symptoms over the last 12 months.

Table 2 shows that most of the psychosocial occupational exposures were significantly associated with CTS (ever diagnosed and symptoms over the last 12 months). However, low control was not associated with either CTS outcome. Table 2 also shows that the proportion of workers reporting psychosocial occupational exposures of high job demand and low job control were 14.5%, and 86.9%, respectively. Of those reporting high job demand, 8.7% and 4.2% of them reported ever been diagnosed with CTS and experienced CTS symptoms in the past 12 months, respectively. Of those reporting low job control, 6.1% and 2.8% reported ever diagnosed with CTS and experienced CTS symptoms in the past 12 months. The proportion of those who perceived their workplace to be unsafe was 4.3%, of whom 8.4% and 4.6% reported ever been diagnosed with CTS and experienced CTS symptoms in the past 12 months, respectively. Slightly more workers reported a hostile work environment at 7.0%, of whom 11.0% and 4.8% had a diagnosis of CTS and experienced CTS symptoms in the past 12 months, respectively. Eleven percent of the workers reported job insecurity and among them, 9.0% and 5.3% reported a diagnosis of CTS and experienced CTS symptoms in the past 12 months, respectively. About a quarter (25.8%) of the workers reported work interfered with family life, and of them 7.7% and 3.6% reported a past diagnosis of CTS and experienced CTS symptoms in the past 12 months, respectively.

Work organization characteristics of frequent night work, non-standard work arrangement (independent contractor or freelance, and temporary agency or subcontractor), shift work, and supervisory responsibilities were tested in the bivariate analyses with each of the two CTS outcomes. No statistically significant association was found among any of these work organization variables for either of the CTS outcomes.

Table 2. Work-related physical exertion, psychosocial occupational exposures, and prevalence of CTS based on NHIS sample of US adult working population.

Variable	**Frequency (%)**	**CTS Ever Diagnosed (%)**	**CTS last 12 months (%)**
Physical Exertion			
Frequent lifting, pushing, pulling or bending		(P= 0.0347)	(P=0.0006)
Low	60.0	5.8	2.4
High	40.5	6.7	3.5
Frequent standing or walking		(P=0.1263)	(P= 0.0135)
Never to sometimes	34.6	5.7	2.3
Often or always	65.4	6.4	3.1
Psychosocial Exposures			
Job Demand		(P< 0.0001)	(P=0.0002)
Low	85.5	5.7	2.6
High	14.5	8.7	4.2
Job Control		(P=0.9747)	(P=0.3343)
Low	86.9	6.1	2.8
High	13.1	6.2	3.2
Workplace perceived as unsafe		(P=0.0302)	(P=0.0169)
Low	95.7	6.0	2.7
High	4.3	8.4	4.6
Hostile work environment		(P< 0.0001)	(P=0.0016)
No	93.0	5.8	2.7
Yes	7.0	11.0	4.8
Worry about losing job		(P<0.0001)	(P<0.0001)
No	89.0	5.8	2.5
Yes	11.0	9.0	5.3
Work-life interference		(P<0.0001)	(P=0.0021)
No	74.2	5.6	2.5
Yes	25.8	7.7	3.7

Multiple variable logistic regression models of CTS prevalence

Table 3 shows a logistic regression analysis of each CTS outcome variable with the demographic variables and health condition variables without the work-related variables. This model serves as a baseline evaluation of the logistic regression analyses. The analysis found that all the age categories, being female, those with less than a college degree educational status, obese weight category and having arthritis were statistically significantly associated with ever diagnosed with CTS, while the risk of having ever diagnosed with CTS was reduced among Hispanics. For those with CTS symptoms over the past year, the analysis showed shows similar results of age categories with the oldest age group being borderline in association. Female gender, both categories of education below a bachelor's degree or more, obese weight category, and having a history of arthritis were all significantly associated with increased risk of experiencing CTS symptoms over the last year.

As a next step, the two work-related physical exertion variables were included in the baseline logistic regression model. In this model, the demographic and health condition associations were essentially unchanged from the baseline model. The work-related physical exertion variable "frequent lifting, pushing, pulling or bending" was associated with a statistically significant increase in "Ever Diagnosed with CTS" (OR 1.24; 95% CI 1.04 - 1.48) and in "CTS symptoms in the past 12 months" (OR 1.39; 95% CI 1.08 – 1.78). However, the physical exertion variable "Frequent standing or walking" was not associated with either CTS outcome variable (OR 1.07; 95% CI 0.90 – 1.28 and (OR 1.11; 95% CI 0.85 – 1.45, respectively).

Table 3: Logistic regression model of ever diagnosed with CTS and CTS symptoms in the last 12 months with demographic and health condition factors.

Variables	CTS ever diagnosed (OR, 95% CI)	(p-value)	CTS in last 12 months (OR, 95% CI)	(p-value)
Demographic characteristic				
Age (years)				
18-29	-	-	-	-
30-39	2.29 (1.65, 3.19)	<0.0001	1.90 (1.25, 2.90)	0.003
40-49	2.46 (1.79, 3.38)	<0.0001	1.82 (1.19, 2.80)	0.006
50-59	3.82 (2.78, 5.26)	<0.0001	1.98 (1.31, 3.00)	0.001
60-69	3.79 (2.70, 5.34)	<0.0001	1.66 (0.99, 2.80)	0.053
Gender				
Male	-	-	-	-
Female	2.56 (2.16, 3.02)	<0.0001	2.33 (1.83, 2.97)	<0.0001
Race-ethnicity				
Non-Hispanic White	-	-	-	-
Non-Hispanic Black	0.96 (0.76, 1.22)	0.757	1.15 (0.84, 1.56)	0.385
Hispanic	0.75 (0.59, 0.94)	0.011	0.90 (0.67, 1.22)	0.512
Non-Hispanic Other	1.02 (0.78, 1.33)	0.909	1.00 (0.63, 1.59)	0.988
Education				
High school Graduates or less	1.25 (1.02, 1.52)	0.030	1.48 (1.12, 1.97)	0.006
Some college or associate degree	1.34 (1.10, 1.63)	0.003	1.49 (1.11, 2.00)	0.009
Bachelor's degree or more	-	-	-	-
Health Condition				
Weight				
Underweight/healthy	-	-	-	-
Overweight	1.14 (0.90, 1.44)	0.267	1.12 (0.82, 1.53)	0.460
Obese	2.00 (1.59, 2.51)	<0.0001	1.93 (1.42, 2.62)	<0.0001
Ever told arthritis				
Yes	2.01 (1.65, 2.45)	<0.0001	2.18 (1.67, 2.84)	P<0.0001
No	-		-	-

Table 4 and Table 5 show the associations between the two CTS outcomes, respectively, and the work-related psychosocial variables using three logistic regression models. All of the models in these tables include as covariates the demographic characteristics and health conditions variables to control for potential confounding. Models 2 and 3 in each table also include the work-related physical exertion variables to control for potential confounding by these variables. Table 4 shows the three models using the "Ever Diagnosed with CTS" outcome, while Table 5 is the same analysis with "CTS in the past 12 months" as the outcome variable. Model 1 focused on the association between CTS and a set of work-related variables, controlling for demographic variables and the relevant medical conditions. Model 1 of Table 3 indicated that those workers who were exposed to high job demand (OR 1.38; 95% CI 1.13 - 1.69), hostile job environment (OR 1.79; 95% CI 1.39 - 2.31), workplace perceived as unsafe (OR 1.41; 95% CI 1.01 – 1.96), worrying about loss of job (OR 1.48; 95% CI 1.18-1.85), and work-life imbalance (OR 1.45; 95% CI 1.22 - 1.73), had significantly higher risk for being diagnosed with CTS at some point in their lives. Model 1 of Table 5 indicated that those workers who were exposed to high job demand (OR 1.57; 95% CI 1.20-2.07), hostile job environment (OR 1.67; 95% CI 1.13 - 2.45), workplace perceived as unsafe (OR 1.64; 95% CI 1.04-2.59), worrying about loss of job (OR 2.00; 95% CI 1.51 – 2.65), and work-life imbalance (OR 1.50; 95% CI 1.17 – 1.93), had significantly higher risk for report CTS symptoms the past 12 months. Low job control was not found to be significantly associated with either of the CTS outcomes in Model 1.

Model 2 examined the workplace-related psychosocial factors while controlling for the variables of Model 1 (demographic factors, socioeconomic status, and medical conditions) and the two physical work exertion exposures of frequent lifting, pushing, pulling or bending as well as frequent standing or walking. Model 2 of Table 5 indicated that those workers who were exposed to high job demand (OR 1.36; 95% CI 1.11 - 1.67), hostile job environment (OR 1.71; 95% CI 1.32 - 2.21), worrying about loss of job (OR 1.45; 95% CI 1.16-1.82), and work-life imbalance (OR 1.41; 95% CI 1.19 - 1.69), had significantly higher risk for being diagnosed with CTS at some point in their lives. Model 2 of Table 5 indicated that those workers who were exposed to high job demand (OR 1.54; 95% CI 1.17-2.03), hostile job environment (OR 1.55; 95% CI 1.05 - 2.28), worrying about loss of job (OR 1.94; 95% CI 1.46 – 2.57), and work-life imbalance (OR 1.44; 95% CI 1.12 – 1.85), had significantly higher risk for report CTS symptoms the past 12 months. Neither low job control nor workplace perceived as unsafe were found to be significantly related to either CTS outcome.

Model 3 examined the work-related psychosocial factors while controlling for demographic characteristics, medical conditions, work-related physical factors, as well as other work-related psychosocial factors. Three psychosocial variables of hostile work environment (OR 1.52; 95% CI 1.16 – 1.99), worrying about losing job (job insecurity) (OR 1.32; 95% CI 1.04 – 1.67), and work-family imbalance (OR 1.27; 95% CI 1.06 – 1.53) were found to be associated with ever diagnosed with CTS, as illustrated by Model 3 of Table 4. Model 3 of Table 5 shows that only high job demand (OR 1.37; 95% CI 1.03 – 1.82) and worrying about job loss (OR 1.78; 95% CI 1.34 – 2.36) were significantly associated with reporting CTS symptoms in the past 12 months.

Table 4: Logistic regression models of ever diagnosed with CTS and work-related psychosocial factors.

Variable	**Model 1*** OR (95% CI)	**Model 2**** OR (95% CI)	**Model 3***** OR (95% CI)
High Job Demand	1.34 (1.08, 1.65) P=0.007	1.32 (1.07, 1.63) P= 0.010	1.18 (096, 1.46) P= 0.124
Low Job Control	1.0 (0.81, 1.23) P=0.978	0.98 (0.80, 1.22) P=0.868	0.88 (0.71, 1.10) P= 0.270
Workplace Perceived as unsafe	1.36 (0.97 – 1.89) P=0.075	1.28 (0.92 – 1.79) P= 0.142	1.01 (0.71, 1.43) P= 0.962
Hostile Work Environment	1.70 (1.32 – 2.20) P=0.000	1.64 (1.26 – 2.13) P=0.000	1.46 (1.11 – 1.92) P=0.006
Worry About Losing Job	1.46 (1.16 – 1.83) P=0.001	1.43 (1.14 – 1.80) P= 0.002	1.32 (1.04, 1.67) P=0.023
Work-Life Interference	1.43 (1.19 – 1.70) P=0.00	1.39 (1.16 – 1.66) P=0.000	1.26 (1.05 – 1.52) P=0.012

* Model 1 includes the psychosocial variable with covariables: age, gender, race-ethnicity, education, BMI, and arthritis.

** Model 2 includes the Model 1 variables plus work-related physical exertion variables.

*** Model 3 includes the Model 2 variable plus all other work-related psychosocial variables.

Table 5: Logistic regression models of CTS symptoms in the last 12 months and work-related psychosocial factors.

Variable	**Model 1** OR (95% CI)	**Model 2** OR (95% CI)	**Model 3** OR (95% CI)
High Job Demand	1.52(1.15, 2.01) P=0.004	1.49 (1.13, 1.97) P=0.005	1.33 (1.00, 1.78) P=0.049
Low Job Control	1.07 (0.81, 1.42) P= 0.620	1.04 (0.79, 1.39) P=0.742	0.90 (0.68, 1.18) P=0.431
Workplace Perceived as unsafe	1.58 (0.997, 2.50) P=0.052	1.45 (0.92, 2.31) P= 0.107	1.11 (0.69, 1.80) P=0.658
Hostile Work Environment	1.57 (1.06, 2.32) P= 0.024	1.47 (0.996, 2.18) P= 0.052	1.20 (0.80, 1.80) P = 0.374
Worry About Losing Job	1.96 (1.48, 2.61) P= 0.000	1.91 (1.44, 2.54) P=0.000	1.78 (1.34 – 2.36) P=0.000
Work-Life Interference	1.47 (1.14, 1.90) P=0.003	1.42 (1.10, 1.82) P=0.007	1.22 (0.93, 1.61) P= 0.147

* Model 1 includes the psychosocial variable with covariables: age, gender, race-ethnicity, education, BMI, and arthritis.

** Model 2 includes the Model 1 variables plus work-related physical exertion variables.

*** Model 3 includes the Model 2 variable plus all other work-related psychosocial variables.

CHAPTER 5: DISCUSSION

This study used data from the 2015 NHIS and its supplementary OHS dataset that represents an estimated 54 million working adults in the U.S. In this study population, 6.13% reported a history of CTS diagnosis by a health care professional, with an approximately 47% of those also reported experiencing CTS symptoms in the past 12 months. The demographic and health factors of age, female gender, less education, obese BMI and having arthritis were all found to be associated with either of the CTS outcomes. These findings were consistent throughout the univariate as well as the multivariate analyses. The demographic factors of being female, in the 5th decade of life, being non-Hispanic black, having lower education status, and having an obese range BMI were associated with a statistically significant higher likelihood of experiencing CTS symptoms in the last 12 months. However, when these demographic factors were evaluated in Model 2 and Model 3 with the work-related factors only female gender, obese BMI, and the various age groups were still significantly associated with CTS prevalence. The race-ethnicity and educational factors were not as prominently associated in the multivariate analyses with the work-related factors.

There were two general occupational physical exposures or factors obtained in this dataset and used as variables in the analyses: frequent lifting, pushing, pulling or bending, and frequent standing or walking. Of these two physical risk factors, only the former showed consistent association with those exhibiting CTS symptoms over the last 12 months but not those having ever been diagnosed with CTS. This pattern is consistent with the literature on CTS risk due to work-related physical exertion.

In this study a number of important work-related psychosocial factors were used to evaluate their relationship to the CTS symptoms of the past 12 months and those ever reported of

CTS. The occupational related psychosocial factors available for evaluation were job demand, job control, perception of work safety, hostile work environment, job insecurity, or work-family imbalance. Of these variables job control was not statistically associated with either of the CTS outcomes. When multivariate analyses were done, those in Model 1 showed that most psychosocial variables were statistically associated with CTS over the past 12 months as well as ever being diagnosed with CTS. However, as these variables were placed into Model 3, where all the psychosocial factors, physical factors, health conditions as well as demographic factors were controlled, only two variables continue to show statistically significant associations with CTS symptoms in the past 12 months. The two psychosocial variables found to be associated with working adults reporting symptoms of CTS were high job demand and worrying about job loss. There were three work-related psychosocial variables associated with an ever diagnosis of CTS: hostile work environment, worrying about job loss, and work-life imbalance. A history of arthritis was also statistically significantly associated with both CTS outcomes. Sensitivity analyses was conducted for currently pregnant and those women who were pregnant within the past year and the results of these findings did not change.

Using the 1988 NHIS-OHS data, Tanaka et al. (1995) compared the association of the occupational vs. personal (non-occupational) risk factors with the prevalence of CTS among U.S. workers. They found that among the 127 million workers who worked during the 12 months prior to the survey, there was a prevalence of 1.87 million (1.47%) workers with self-reported CTS symptoms over the last 12 months (Tanaka et al., 1995). The prevalence of the current study is over three times higher at 6.3% for the 18-69 year-old US adult who reported working for pay the week prior to survey whose ever been diagnosed with CTS by a health care provider, and almost half of them also reported experiencing CTS symptoms in the past 12 months, overall prevalence of 3.0%. These percentages translate to an estimated 3.4 million and 1.7 million US general adult work population. The findings of the current study are almost identical to those found from NHIS-OHS 2010 by Luckhaupt et al. (2013), where the CTS outcome were obtained using the same 2 questions with very similar samples sizes (current study 17,132 vs. NHIS-OHS 2010 study 17,524) and sample adult response rates (current study 55.2% vs. NHIS-OHS 60.8%) (Luckhaupt et al., 2013). In the NHIS-OHS 2010 study, they found the lifetime prevalence of self-reported clinician-diagnosed CTS among current/recent workers to be 6.7% and 12-month prevalence of CTS based on symptoms was 3.1%, representing 4.8 million workers with current CTS.

Furthermore, the authors of the 1988 NHIS-OHS study found that bending/twisting of the hand/wrist many times per hour on the job was a stronger risk factor than the non-occupational risk factors of race, age, BMI, educational and income status (Tanaka et al., 1997). Nevertheless, they also found that among the demographic variables, females, white race, age group of 45-54, education group of 12 years, and BMI greater than or equal to 25 to have the highest current CTS prevalence (Tanaka et al., 1997).

The NHIS-OHS 2010 study also showed the prevalence of current CTS among females (4.5%) was more than two times that of males (1.9%), which is consistent with the current study (3.97% females vs. 1.75% males) (Luckhaupt et al., 2013). The age group in the NHIS-OSH 2010 study with the highest prevalence of current CTS was age group 45-64, compared to those in baseline age group of 18-29, also consist with current study of highest current CTS prevalence in the 50-59 age group. Among the race-ethnicity groups, non-Hispanic Black had the highest CTS prevalence (3.6%), followed by non-Hispanic White (3.5%), and Hispanic (1.9%), the same order of current CTS prevalence is noted in the current study. Similar to the current study, those with less than a college degree had higher prevalence of current symptoms of CTS, the same was noted in the NHIS-OHS 2010 study, although in the current study, those with some college or associate degree had slightly higher CTS prevalence than those with high school degree or less (Luckhaupt et al., 2013).

Both obesity and hand osteoarthritis were found to be associated with an increased incidence of CTS in a population based Finnish study using Hospital Discharge Registry by Pourmemari et al. (2018), which is consistent with findings of the current study. In fact, a 7-year cohort study of 3,515 participants of primarily manufacturing, production, service and construction by Harris-Adamson et al. (2013) found that a BMI greater than or equal to 30 kg/m^2 almost doubled the risk of CTS. Increasing age was associated with greater CTS risk, which is consistent with a study by Harris-Adamson et al. (2013) which found that those over 50 years old had a CTS incidence rate of more than three times that of those under 30 years of age. They identified "a near-linear relationship between CTS incidence and both age and BMI" (Harris-Adamson et al., 2013). They also found no evidence of effect modification by gender of the associations with age, BMI, or any medical condition (diabetes mellitus, thyroid disease, rheumatoid arthritis, and pregnancy).

Werner et al. (1998) found that women with jobs that have higher ergonomic risk and no history of diabetes were more likely to have reported CTS symptoms. Fan et al. (2015) found that there was significant association between being moderately to severely physically exhausted after work and CTS prevalence (Fan et al., 2015). In this study, the physical exertion of work with frequent lifting, pushing, pulling, or bending was associated with both CTS outcomes, which is consistent with literature on the biomechanics of work-related CTS (Kozak et al., 2015).

In the systematic review that evaluated the relationship between psychosocial risk factors and CTS by Mansfield et al. (2017) with international study populations mostly from industrial assembly line and mixed occupational backgrounds, four out of the six studies used JCQ, while the others used GHQ-12 and Langner's screening questionnaire. Five out of the six studies reported a positive association between the following psychosocial risk factors: high psychological work demand, high job strain, least influence over their work, a high job demand, low level of job control, high psychological distress, low social support, poor social network, "type A behavior", and CTS. This review also found negative/inverse association between the psychological factors of high decision latitude, high hierarchical control of work, more coworker support, and high social support and incidence of CTS (Mansfield et al., 2017). As noted by the authors, due to the high heterogeneity of the six studies, results must be interpreted with caution (Mansfield et al., 2017)

In the current study, the two psychosocial risk factors found to be statistically significantly associated with CTS after controlling for all other factors were high job demand and worrying about losing job. High psychological job demand was found to be associated with CTS in a mostly specialty industries and a general French work population using JCQ (Silverstein et al. 2010; Bugajska et al., 2013; Harris-Adamson et al., 2013; Rigouin et al., 2014). Lower job satisfaction has been found in workers with CTS in numerous studies (Goodson et al., 2014; Leclerc et al., 1998), however, very few studies have found job insecurity and WMSD, specifically CTS. Three studies of specialized workers found job insecurity to be associated with WMSDs - neck/shoulder pain in the past month, hand/wrist pain in the past month, elbow and wrist/hand pain in the past 12 month and past 7 days but none for CTS (Wang et al., 2009; Surawera et al., 2013; Bugaiska et al., 2013). Petite et al. (2015) had noted in their conclusion that the association found between CTS and work organization characters of payment on a piecework basis and/or work pace dependent on automated rate could very well be mediated by lower socioeconomic status and higher psychological distress due to job insecurity. To the best of my knowledge, the current study is the only one to have demonstrated a statistically significant association between job insecurity and CTS in a nationally representative U.S. adult working population.

It's not yet clear how psychosocial working conditions increase the risk of CTS. However, the ecological model of musculoskeletal disorders by Saunter and Swanson proposed a pathway where the biomechanical strain and musculoskeletal outcomes could be attributed by factors of psychological strain as well as by the individual and work organizational factors (Saunters & Swanson, 1996). In addition, Landsbergis et al. (2017), suggested two possible mechanisms by which occupational stressors such as those evaluated in this study increase the risk of work-related musculoskeletal disorders (WMSDs), even when controlling for the physical demands of the job. The two mechanisms mentioned in chapter 14 of the 7th edition of Occupational and Environmental Health work organization shapes exposure to WMSD risk factors including those that increase work demands, which could contribute to inadequate recovery time (Landsbergis et al., 2017). The second mechanism is the body's response to stress, including stress-related tension causing increased static load of muscles, reduced pain tolerance, along with other disturbance that leads to reduction in both immune function and capacity to heal microtrauma associated with work (Landsbergis et al., 2017). Ultimately, workers under stress may alter their work behavior that could lead to increasing the risk of work-related musculoskeletal disorders (Landsbergis et al., 2017). In the future, more mechanistic studies for the associations between psychosocial working conditions and CTS are needed.

This study implies that not only biomechanical work exposures, but also psychosocial work exposures need to be considered for the primary prevention of CTS in working populations. WMSDs such as CTS are preventable, while there have been preventions recommendations in implementing ergonomic changes, the findings of the current studies suggest that optimal workload ("I have enough time to get the job done") and responsible organizational restructuring (Casico, 2002) ("Are you worried about losing your job?") may be important strategies for preventing and reducing the risk of CTS in U.S. working populations. As far as secondary prevention and tertiary prevention, the clinician may consider inquiring and discussing how the work-related psychosocial factors can hinder one's recovery.

Limitations of the study

The limitations of this study include all the limitations associated with a cross-sectional study because the study is based on the cross-sectional NHIS-OHS 2015 dataset. The limitations of a cross-sectional study include no causation can be derived from the associations seen in this study. The health outcome of past CTS diagnosis was based on a single self-reported question and each subject's awareness of his/her diagnosis. Those answering yes to the question, were then asked if he/she has had symptoms of CTS during the last 12 months. This also relies on the respondent having excellent recall, as well as an understanding of CTS symptoms.

The psychosocial factors obtained in this study were single question items, which is unlike the JCQ and other standardized questionnaires that have multi-item standard scales to assess numerous work-related psychosocial aspects. In this dataset, job control was a single item question (vs. nine items in the standard JCQ scale for job control) which asked about one's ability to make his/her own decisions at the job. Thus, this one-item question (addressing only one subscale – decision authority - of job control as a combination of decision authority and skill discretion) was unlikely to adequately ascertain a comprehensive definition of job control, nor the job control factor based on the traditional Demand-Control Model. Hence, this could be a reason why the job control was not found to be significantly associated with the outcome of interest. The single question that assess job demand (“I have enough time to get the job done”) in this survey suggests that time pressure, may actually be interpreted as an insufficient amount time to get the job done resulting in increased job load. However, it is a single item and limited, compared to the standard JCQ five-item psychological job demands scale. Thus, the single-item questions of these two questions do not adequately assess the true job demand and job control.

There was also strength in this study, it is a nationally representative dataset that has been collected annually over last two decades, with detailed published standardized methodology of the data collection processes. The occupational portion of this national survey is also standardized to be representative of the national working population and conducted every five years, with the 2015 OHS dataset being the most recent. Compared to the NHIS-OHS 2010 study, the CTS prevalences among those with symptoms over the last 12 months were similar and consistent. The demographic factors were also consistent. The physical features of each individual’s job such as frequent lifting, pushing, pulling, or bending as well as the frequency of walking and standing were accounted, and controlled for with these 2 items. Thus, this study evaluated both physical and psychosocial risk factors, instead of only physical or psychological risk factors. Additionally, despite the limitations of self-reported past diagnosis of CTS, seeking information on the CTS symptoms among those with a self-reported CTS does produce more consistent and reliable information on symptoms experienced. As noted in the literature, the prevalence is much higher with only subjective reporting of symptoms rather than objective diagnosis. Thus, seeking CTS symptoms among those with a past diagnosis result in more reliable analyses of the work-related factors and CTS outcome.

Future research should include more longitudinal studies to evaluate the directionality of these associations/ to address any reverse causality. A more comprehensive and validated psychosocial measurement tool, one that is validated and reliable such as JCQ should be used for more accurate psychosocial assessment. In addition, a more clinical or objective measure for CTS, or perhaps an agreed upon standard for diagnosing CTS would be available to use. Lastly, more long-term pathophysiology studies are needed to elucidate the mechanisms of occupational psychosocial factors to CTS.

CHAPTER 6: CONCLUSION

While there is strong evidence for biomechanical risk factors for CTS, evidence on the role of occupational psychosocial risk factors has been less consistent or evident. This study using a U.S.-based nationally representative sample of adult working population showed that there is evidence supporting associations of some work psychosocial factors with CTS. Specifically, while controlling for demographic factors, health conditions, and physical work exertion, this study found that hostile work environment, worrying about losing one's job, and work-life interference were associated with elevated odds of having a past self-reported CTS diagnosis. Job demand and worrying about losing one's job were also associated with experiencing CTS symptoms in the past 12 months. These findings suggest that some psychosocial work stressors may increase predisposition or risk to developing CTS. Thus, it is prudent for those in power of designing work parameters or controlling working social environments, as well as those treating CTS patients to appreciate the potential role of occupational psychosocial factors in identifying workers at higher risk of developing CTS for primary and secondary prevention.

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