CE

2.5 ANCC Contact Hours

Shoulder Injuries in Commercial Truck Drivers

A Literature Review

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Musculoskeletal injuries in the occupational setting have significant impact on the worker, employer, and healthcare system. The commercial truck driver (CTD) experiences some of the highest rates of injury, missed days of work, and workers' compensation costs compared with other workers. In this population, the back is most commonly affected whereas shoulder injuries are the second but require 5 times more days away from work. Commercial truck drivers are significantly impacted by shoulder injuries; however, little is known about the unique mechanisms of injury, specific injuries, or possible preventative measures among this group of workers. This article reviews the current state of the science related to musculoskeletal disorders of the shoulder within the CTD population, to provide a better understanding of the true extent of these disorders and their impact, and to create a foundation for future research.

The National Institute for Occupational Safety and Health (NIOSH) was established in 1970 with the goal to create new knowledge that advances injury prevention and provides recommendations that prevent injury and illness within the working population (NIOSH, 2013). The National Occupational Research Agenda (NORA) is a program within NIOSH to create partnerships to stimulate the growth of occupational safety research (NIOSH, 2012). NORA created counsels for each of the 10 NIOSH sectors to create guidelines and goals for the development of research and new knowledge within their respective groups. The commercial truck driver (CTD) population is part of the Transportation, Warehousing, and Utilities (TWU) industry sector. In 2009, NORA published a report that outlined four strategic research goals for the TWU sector: (1) Reduce lost workday occupational traumatic injury and fatality rates in the TWU sector; (2) reduce the incidence and severity of work-related musculoskeletal disorders (MSDs) among workers in the TWU sector; (3) improve health and reduce premature mortality among TWU workers through workplace programs and practices; and (4) identify, evaluate, and reduce chemical, biological, and physical occupational hazards and exposures (NORA Transportation, Warehousing, and Utilities Sector Council, 2009).

In 2014, the United States Department of Labor (USDOL) reported the overall incidence rate of nonfatal occupational injuries and illness requiring days away from work to be 100 of every 10,000 full-time workers. Commercial truck drivers had the second highest incidence rate (322.8/10,000) of injury among all occupations (USDOL, 2013), representing a 14% increase from the previous year. Musculoskeletal disorders of the back most commonly are manifested in this population (35.5%), followed by shoulder injuries as the second most common MSD (15.7%) (USDOL, 2013). Workers with back injuries miss 9 days of work per incident compared with workers with shoulder injuries, who miss 46 days per incident (USDOL, 2013). There are also significant financial strains associated with MSDs of the shoulder. Workers' compensation claims related to MSDs of the shoulder are 17% higher than the average claim of all other workers' compensation claims (Davis, Dunning, Jewell, & Lockey, 2014). Davis et al. (2014) also showed that CTDs between the ages of 55 and 64 years had a median cost per claim of $15,300 for shoulder injuries, the highest cost among all age groups and all MSDs.

Musculoskeletal disorders to the shoulder have a significant impact on the CTD population. Even though these injuries account for some of the highest incidence rates, days of work missed, and costs, there is little to no research investigating MSDs of the shoulder in CTDs. This may represent a significant gap in research related to the CTD population and is directly related to the first and second strategic goals of NORA to reduce lost workdays to injury and the incidence/severity of work-related MSDs (NORA

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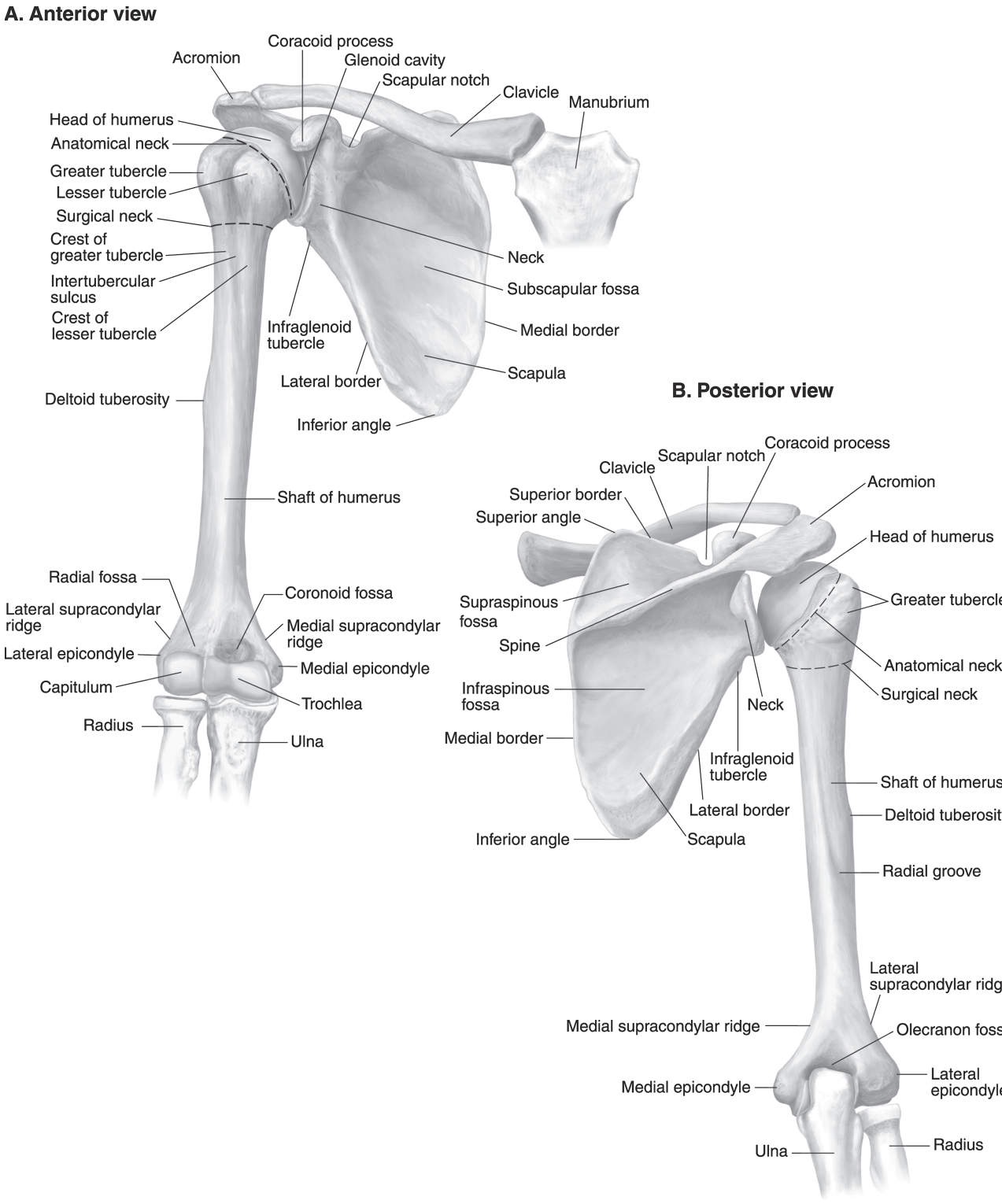

FIGURE 1. Shoulder anatomy: (A) anterior view; (B) posterior view. From Tank, P. W., & Gest, T. R. (2009). *Atlas of Anatomy*, 1st ed. Philadelphia: Lippincott Williams & Wilkins; p. 30. Reprinted with permission.

Transportation, Warehousing, and Utilities Sector Council, 2009). The purpose of this article was to review the current state of the science related to MSDs of the shoulder within the CTD population to better understand the true extent of these disorders and their impact and to create a foundation for future research with this population.

Understanding the Shoulder

It is important to review the anatomy and function of the shoulder in order to understand the literature relevant to these types of MSDs in this population. The shoulder is a complex joint that is made up of three bones, nine muscles, and eight ligaments (see Figure 1;

Skinner & McMahon, 2014). The shoulder is a ball and socket joint that allows for an extreme range of motion (ROM); this motion makes the shoulder more unstable than other joints throughout the body. The healthy shoulder can have up to 160° of flexion/forward elevation and 60° of extension, which create a 220° arc, 180° of motion from abduction, 70° of internal rotation, and 90° of external rotation (Thompson, 2010). Because of this extreme ROM, the shoulder uses both static (ligaments) and dynamic (muscles) restraints to maintain joint stability and integrity.

The humerus and the glenoid cavity of the scapula form the central joint of the shoulder, the glenohumeral joint. The glenoid cavity is small in size when compared with the humeral head. This is what allows the shoulder to have the greatest ROM of any joint in the body (Thompson, 2010). This can be visualized as a golf ball sitting on a golf tee. It does not take much force to knock the golf ball off, and in the shoulder, this extreme motion creates a mobile but unstable joint. The glenoid cavity is surrounded by a piece of circular cartilage, called the labrum, creating a larger surface area in which the humeral head rests. This cartilage improves the stability; by using the golf ball and the tee analogy, the labrum creates a larger plate top of the tee for the golf ball to sit on. The rotator cuff is the main muscle group responsible for the motion of the glenohumeral joint. It is composed of the supraspinatus (abduction and forward flexion), infraspinatus (external rotation), teres minor (external rotation), and subscapularis (internal rotation) (Thompson, 2010). These four muscles create a capsule around the glenohumeral joint, providing stability as well as motion.

The unique anatomy of the shoulder and its required use in most occupational settings are associated with several risk factors that may result in injury. Some of these risk factors are repetitive motion during work, working with arm in elevated position, small workplaces, long periods of sustained activity, and fatigue (Ferguson, Allread, Le, Rose, & Marras, 2013; Hanvold, Waersted, & Veiersted, 2012; McDonald, Tse, & Keir, 2016; Nordander et al., 2009; Svendsen et al., 2004).

Literature Review

The literature related to MSDs and CTDs was identified by using two common databases: PubMed and CINAHL. The inclusion criteria for this literature search required the publication to be peer reviewed and written in the English language within the last 10 years. The initial search included the keywords "shoulder injury" and "commercial truck driver," which resulted in no citations. The date range was expanded to 25 years, and the key words were adjusted to include "shoulder," "injury," "musculoskeletal disorder," "truck driver," "commercial driver," and "long haul." Using the revised criteria, the search yielded 429 articles. Duplicates were removed (n = 21), and the article titles and abstracts were reviewed to make sure they addressed MSDs within the CTD population. The remaining 45 articles were then reviewed in depth to verify that they evaluated MSDs that included the shoulder. Only five articles were found to address MSDs that included the shoulder in the CTD population, including a report from the U.S. Bureau of Labor Statistics (USBLS, 2014) found during a secondary search of Google Scholar.

Because of the limited search results regarding CTDs and MSDs, a new search using the search terms "shoulder injury" and "occupational" was completed with the same initial inclusion criteria with the goal of finding current research investigating MSDs of the shoulder in non-CTD occupational settings. This search resulted in 233 articles. Duplicates were removed (n = 9), and the titles and abstracts were reviewed to verify that the articles addressed MSDs in the occupational setting and 56 articles remained. These articles were reviewed in their entirety to verify that these publications specifically addressed shoulder injuries within the occupational setting. This left 21 articles that were related to MSDs of the shoulder within the occupational setting.

In total, there were 26 articles identified for inclusion in the literature review (see Figure 2). The available publications were divided into four categories based on research population: (1) research studies related to CTD; (2) research studies of another single occupational population; (3) research studies of multiple occupational populations; and (4) research studies of biomechanics in no particular population.

Research Studies Related to CTDs

Each of the five publications regarding CTDs investigated correlations and trends related to MSDs within this unique population (see Appendix A). Research has consistently shown that in CTDs, the shoulder has the second highest incidence of injury whereas the back has the highest incidence rate (Davis et al., 2014; McCall & Horwitz, 2005; Smith & Williams, 2014; USDOL, 2013; van der Beek, Frings-Dresen, van Dijk, Kemper, & Meijman, 1992).

The first study to investigate the incidence of MSDs in CTDs was published in 1992. It was a nonexperimental, descriptive design study that assessed complaints using the Periodic Occupational Health Survey (Broersen, Weel, & van Dijk, 1989) with 534 CTDs in England. The third most common body part with complaints of pain among CTDs was the shoulder (28%). van der Beek et al. (1992) indicated that the 28% of CTDs had complaints of shoulder pain while the back (47%) and neck (29%) were the only areas with more complaints.

A study of reported shoulder injuries within a large goods transport company in Denmark (McCall & Horwitz, 2005) showed that, within the CTD population, falls from height were the most common mechanisms of injury. Stepping off of an edge was the trigger for these falls 33% of the time. A unique finding in the research was that 51% of all injuries happened to workers with less than 1 year of experience (McCall & Horwitz, 2005).

A study of ergonomic risks and discomfort of CTDs while performing common tasks outside of the cab indicated that the right shoulder is associated with the most complaints of physical discomfort whereas the left shoulder was associated with the third most common complaints (Reiman, Pekkala, Vayrynen, Putkonen, & Forsman, 2014). The mechanism of injury most commonly associated with shoulder discomfort was

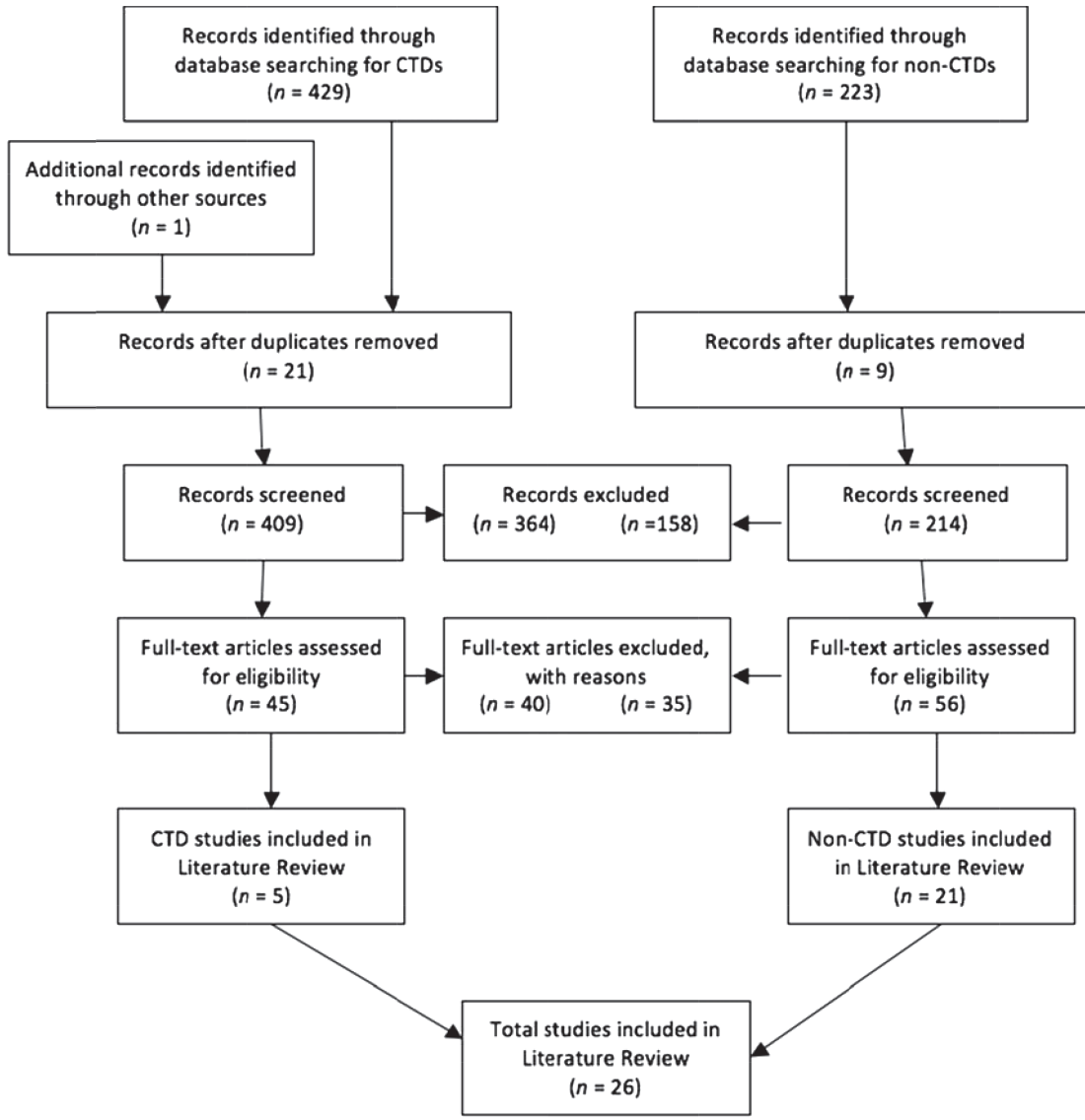

Figure 2. Literature review flow chart.

overexertion and/or repetitive motion and was most often reported during unloading cargo at the delivery site (Reiman et al., 2014).

Two studies evaluated the effects of MSDs on CTDs using data from workers' compensation claims. The shoulder was associated with one of the highest incidence rates of work-related injury; these claims were some of the costliest (Davis et al., 2014; Smith & Williams, 2014). Commercial truck drivers had a higher incidence of injury to the shoulder than nontrucking populations. They also had an increased risk of developing partial or total disability related to occupational MSDs (Smith & Williams, 2014). Davis et al. (2014) reported that CTDs had a higher number of claims related to the shoulder, and these claims had a 20% higher mean cost compared with any other profession. In fact, the commercial driver industry sector had the highest average cost per workers' compensation claim for all age groups and all occupational sectors (Davis et al., 2014).

A 2013 USDOL report addressing Occupational Safety and Health Administration (OSHA) reportable injuries and illnesses indicated that the second most common injury reported by CTDs was to the shoulder (15.7%), with each incident leading to an average of 46 missed days of work. Although work-related back injuries were found to be two and half times more likely than shoulder injuries, shoulder injuries required five times as long to recover compared with back injuries. The most common type of injury was either a sprain or strain, and the mechanism or event with the highest incidence was overexertion or body reaction (USDOL, 2013).

Research Studies Including Different Occupational Population

Several different studies investigated shoulder injuries in occupational settings outside of the CTD population. Of these publications, 10 concentrated on an individual occupation (see Appendix B). Three studies evaluated MSDs of the shoulder within the construction worker population. The shoulder was one of the two most commonly injured regions of the body in this group (Borstad

et al., 2009; Soares, Jacobs, Minna, & Mika, 2012). Construction workers' complaints of shoulder pain ranged from 17.8% to 55.6% (Borstad et al., 2009; Soares, Jacobs, Minna, et al., 2012). In this group, shoulder discomfort was more common when working above shoulder level and there was some evidence that the type of foundation the worker was standing on may have caused a difference in discomfort (Phelan & O'Sullivan, 2014). This difference in discomfort could have been due to the compensation of shoulder muscles while on different work platforms. An example of this is the changes in deltoid muscle use while standing on a ladder versus solid platform (Phelan & O'Sullivan, 2014). Injury prevention was evaluated in two of the studies, and it was found that the use of occupational health services at job initiation (Soares, Jacobs, Minna, et al., 2012) and preventative exercise programs (Borstad et al., 2009) may be useful in decreasing complaints and MSDs of the shoulder. When occupational health services, such as education on work posture, performance, or tools, were received by construction workers, there was a significant decrease in the incidence of MSDs to the shoulder or arm ($p = .024$; Soares, Jacobs, Minna, et al., 2012).

Electricians often worked with their arms raised above shoulder height, and the shoulder was the most common body region where they experienced pain (12.69%; Trotta, Ulbricht, & Silva, 2014). Interestingly, taller utility workers experienced less pain unloading and loading ladders than shorter workers doing the same activity; pulling an item above shoulder height required more force (Soares, Jacobs, Moriguchi, et al., 2012). The force required during the simulated task of pulling an object is increased with changes in elevation (Soares, Jacobs, Moriguchi, et al., 2012), and this represents daily tasks performed by electricians in the field (Moriguchi, Carnaz, Miranda Junior, Marklin, & Gil Coury, 2012).

In 2014, it was shown that the second most common MSD within the nursing workforce was related to the upper extremity (Bhimani, 2016). Shoulder injuries in nurses were explained by the pushing and pulling of patients. This finding may be related to CTDs when compared with the finding that the main complaints CTDs have while loading and unloading goods occurred during pushing-and-pulling motions (van der Beek et al., 1992). In the nursing population within this study, 48% of the participants acknowledged having an MSD, yet they did not initially report it because they felt it was a minor injury (Bhimani, 2016). Taxi drivers are also at an increased risk for MSDs of the shoulder. A study completed by Bulduk, Bulduk, Süren, and Ovali in 2014 found that taxi drivers had an increased risk of exposure for MSDs of the neck, shoulder, and arm.

Research Studies of Multiple Occupational Populations

Six studies evaluated MSDs of the shoulder in populations that included more than one occupation (see Appendix C). As was found in studies looking at individual occupations, the shoulder was a common body region affected by MSDs (Asundi, Harbin, Shenoy, Garcia, & Olson, 2011; Bovenzi, 2015; Hegmann et al., 2014; Herin, Vézina, Thaon, Soulat, & Paris, 2012; Nordander et al., 2009). A study evaluating custodial staff found that the most common mechanism of injury seen in MSDs of the shoulder were sprains/strains related to overexertion (Asundi et al., 2011). Also, workers in occupational settings that require them to perform repetitive tasks within a constrained environment were more at risk of developing MSDs of the shoulder than in occupations with varied environments and more mobility (Herin et al., 2012; Nordander et al., 2009).

Several mechanical factors have been shown to be related to MSDs of the shoulder. In patients with chronic shoulder pain, 24% were seen to have constraints in movement and 24% experienced a physical space constraint when having to apply forceful movement (Herin et al., 2012). Occupational settings that require a worker to experience whole-body vibration, lift greater than 15 kg more than 45 minutes in a workday, or work with hands above head for more than 60 minutes in workday have been shown to be significantly related to shoulder pain (Bovenzi, 2015).

The variations in case definitions can have a possible impact on epidemiological studies regarding shoulder injuries. Hegmann et al. (2014) discussed the difficulty conducting epidemiological studies related to MSDs of the shoulder by highlighting how the differences in definitions of injuries complicate investigations. In their study, they found that 23% of the time rotator cuff tendinitis presented only with pain and 8% of the time it presented with pain and a positive supraspinatus test (Hegmann et al., 2014).

Research Studies of Shoulder Biomechanics

Some research was not conducted on a specific population group but rather evaluated the biomechanics of the shoulder during routine tasks commonly seen in the working environment of CTDs (see Appendix D). The CTD often deals with many different environmental demands that cause physical stress or strain: whole-body vibration while driving, loading and unloading cargo, using tarps and chains to secure the cargo, and pushing and pulling heavy weights. Many of these activities require them to work with their arms above shoulder level. Elevating the arm to shoulder height or above increases stress and load of the muscles that cross the shoulder joint (Antony & Keir, 2010; Au & Keir, 2007; Blache, Desmoulins, Allard, Plamondon, & Begon, 2014). When the arm raises from 30° to 90°, shoulder muscle activity increases by 84% (Antony & Keir, 2010). Blache et al. (2014) showed that the supraspinatus and infraspinatus muscle force decreased as the arm moved from shoulder level to eye level while the subscapularis muscle force increased.

Physiological fatigue had an effect on shoulder muscle function, joint ROM, and adaption (Fuller, Lomond, Fung, & Cote, 2009; McDonald et al., 2016). As the shoulder became fatigued, the amount of flexion during tasks decreased while abduction increased (Blache et al., 2014). Muscle activity and joint ROM were significantly affected during tasks that required pushing and pulling when fatigued (McDonald et al., 2016). During activities that required the arm to be above shoulder height, the muscle that elevated the shoulder became fatigued quicker than the others muscles of the shoulder (Fuller et al., 2009).

Discussion

The purpose of this literature review was to evaluate and assess what research is available regarding MSDs in CTDs concentrating on the shoulder and what has been learned from this research. Because of the limited research evaluating the shoulder of CTDs, the review was expanded to include research evaluating the shoulder in occupations outside the CTD population. On the basis of the current research, the shoulder is consistently the second most common body part injured in CTDs (Davis et al., 2014; Smith & Williams, 2014; USBLS, 2014; van der Beek et al., 1992). This is a significant finding because it was found in five different populations that included CTDs. This review has shown that shoulder injuries have a high incidence rate and there is a significant impact on CTDs and their industry. Injuries to the shoulder require an extended time away from work when compared with injuries involving other body regions (Davis et al., 2014; McCall & Horwitz, 2005; USDOL, 2014) and are among the most expensive workers' compensation claims (Davis et al., 2014; McCall & Horwitz, 2005; Smith & Williams, 2014).

Despite the impact of shoulder injuries to CTDs shown in this review, significant gaps in the literature were still noted. First, the studies discussed common injured body regions, common causes of injuries, and time of work missed; however, none looked at these variables in relation to each other. Even though sprains/strains are some of the most common types of MSDs, it is not known whether they are the most common mechanisms of injury of the shoulder. It was not shown how many days of work are missed for a sprain/strain when compared with a fracture or contusion, or if overexertion was the most common mechanism for shoulder injuries. This information is critical to understanding MSDs of the shoulder.

A second important gap is that there is minimal research investigating MSDs of the shoulder in CTDs. Research of similar occupational stressors on the shoulder in different professions (e.g., nursing, construction work, and electricians) has indicated some of the highest incidence rates of MSDs in occupational groups (Bhimani, 2016; Borstad et al., 2009; Bulduk et al., 2014; Soares, Jacobs, Moriguchi, et al., 2012; Trotta et al., 2014). Many things can be learned from the current research in other occupations. Occupations that require repetitive tasks and environments that require tasks to be performed above shoulder height increase stress on the shoulder and may lead to the onset of MSDs (Antony & Keir, 2010; Au & Keir, 2007; Blache et al., 2014; Borstad et al., 2009; Reiman et al., 2014; Soares, Jacobs, Minna, et al., 2012). It has also been found that individuals experiencing fatigue compensate by altering shoulder biomechanics, further stressing the shoulder joint. (Fuller et al., 2009; McDonald et al., 2016).

It is important to understand that although these professions may experience similar stressors, the stresses are not exactly the same as those experienced by CTDs. There is a lot to be learned regarding shoulder injuries in CTDs. This review has highlighted the gap in current research regarding CTDs and reinforces the need to develop nursing research to create new knowledge and help fill this gap. This research may be used to determine common characteristics associated with shoulder injuries in CTDS, define the specific biomechanical function of the CTDs' shoulders related to the unique work environments, and determine whether there are risk factors or variables that are associated with or contribute to shoulder injuries in the population differ from other populations.

This research will inform the development of interventions to decrease injury rates or to speed recovery. Occupational services have been shown to be effective in decreasing shoulder injuries and complaints in occupations other than CTDs (Asundi et al., 2011; Soares, Jacobs, Moriguchi, et al., 2012). These studies again highlight the serious gaps in the current understanding of shoulder injuries in CTDs.

Conclusion

This review has shown that shoulder injuries have a significant impact on CTDs including missed work, increased financial costs, and possible disability (Davis et al., 2014; Smith & Williams, 2014; USBLS, 2014). Many studies have been published outside of the CTD population that not only highlight high incidence rates of MSDs of the shoulder but also investigate the epidemiology, biomechanics, and preventative measures. Within the CTD population, there is a need for the development of new knowledge of the risk factors, biomechanics, and variables associated with shoulder injuries among CTDs. Once this knowledge is synthesized, the goal will be to develop specific prevention, intervention, and rehabilitative strategies that will help create evidence-based practice. This evidence-based practice could positively impact the CTD population.

References

Antony, N. T., & Keir, P. J. (2010). Effects of posture, movement and hand load on shoulder muscle activity. *Journal of Electromyography & Kinesiology*, *20*(2), 191–198. doi:10.1016/j.jelekin.2009.04.010

Asundi, K., Harbin, G. L., Shenoy, C., Garcia, A., & Olson, J. C. (2011). Shoulder injury reduction with post-offer testing. *Work*, *39*(2), 113–123.

Au, A. K., & Keir, P. J. (2007). Interfering effects of multitasking on muscle activity in the upper extremity. *Journal of Electromyography & Kinesiology*, *17*(5), 578–586. doi:10.1016/j.jelekin.2006.06.005

Bhimani, R. (2016). Understanding work-related musculoskeletal injuries in rehabilitation from a nursing perspective. *Rehabilitation Nursing*, *41*(2), 91–100.

Blache, Y., Desmoulins, L., Allard, P., Plamondon, A., & Begon, M. (2014). Effects of height and load weight on shoulder muscle work during overhead lifting task. *Ergonomics*, *58*(5), 748–761.

Borstad, J. D., Buetow, B., Deppe, E., Kyllonen, J., Liekhus, M., Cieminski, C. J., & Ludewig, P. M. (2009). A longitudinal analysis of the effects of a preventive exercise programme on the factors that predict shoulder pain in construction apprentices. *Ergonomics*, *52*(2), 232–244. doi:10.1080/00140130802376091

Bovenzi, M. (2015). A prospective cohort study of neck and shoulder pain in professional drivers. *Ergonomics*, *58*(7), 1103–1116. doi:10.1080/00140139.2014.935487

Broersen, J., Weel, A., & van Dijk, F. (1989). *Periodic Occupational Health Survey: Means and standards*. Amsterdam, the Netherlands: Study Centre on Work and Health.

Bulduk, E. T., Bulduk, S., Süren, T., & Ovali, F. (2014). Assessing exposure to risk factors for work-related musculoskeletal disorders using Quick Exposure Check (QEC) in taxi drivers. *International Journal of Industrial Ergonomics*, *44*(6), 817–820.

Davis, K., Dunning, K., Jewell, G., & Lockey, J. (2014). Cost and disability trends of work-related musculoskeletal disorders in Ohio. *Occupational Medicine London*, *64*(8), 608–615. doi:10.1093/occmed/kqu126

Ferguson, S. A., Allread, W. G., Le, P., Rose, J., & Marras, W. S. (2013). Shoulder muscle fatigue during repetitive tasks as measured by electromyography and near-infrared spectroscopy. *Human Factors*, *55*(6), 1077–1087.

Fuller, J. R., Lomond, K. V., Fung, J., & Cote, J. N. (2009). Posture-movement changes following repetitive motion-induced shoulder muscle fatigue. *Journal of Electromyography & Kinesiology*, *19*(6), 1043–1052. doi:10.1016/j.jelekin.2008.10.009

Hanvold, T. N., Waersted, M., & Veiersted, K. B. (2012). Long periods with uninterrupted muscle activity related to neck and shoulder pain. *Work*, *41*(Suppl. 1), 2535–2538. doi:10.3233/wor-2012-0494-2535

Hegmann, K. T., Thiese, M. S., Wood, E. M., Garg, A., Kapellusch, J. M., Foster, J., …Kendall, R. (2014). Impacts of differences in epidemiological case definitions on prevalence for upper-extremity musculoskeletal disorders. *Human Factors*, *56*(1), 191–202.

Herin, F., Vézina, M., Thaon, I., Soulat, J. M., & Paris, C. (2012). Predictors of chronic shoulder pain after 5 years in a working population. *Pain*, *153*(11), 2253–2259. doi:10.1016/j.pain.2012.07.024

McCall, B. P., & Horwitz, I. B. (2005). Occupational vehicular accident claims: A workers' compensation analysis of Oregon truck drivers 1990–1997. *Accident Analysis & Prevention*, *37*(4), 767–774. doi:10.1016/j.aap.2005.03.018

McDonald, A. C., Tse, C. T., & Keir, P. J. (2016). Adaptations to isolated shoulder fatigue during simulated repetitive work. Part II: Recovery. *Journal of Electromyography & Kinesiology, 29*, 42–49. doi:10.1016/j.jelekin.2015.05.005

Moriguchi, C. S., Carnaz, L., Miranda Junior, L. C., Marklin, R. W., & Gil Coury, H. J. (2012). Are posture data from simulated tasks representative of field conditions? Case study for overhead electric utility workers. *Ergonomics*, *55*(11), 1382–1394. doi:10.1080/00140139.2012.708439

National Institute for Occupational Safety and Health. (2012). *About NORA … Partnerships, research and practice*. Retrieved from http://www.cdc.gov/niosh/nora/about.html

National Institute for Occupational Safety and Health. (2013). *About NIOSH*. Retrieved from http://www.cdc.gov/niosh/about.html

NORA Transportation, Warehousing, and Utilities Sector Council. (2009). *National transportation, warehousing, and utilities agenda*. Retrieved from http://www.cdc.gov/niosh/nora/comment/agendas/transwareutil/pdfs/TransWareUtilAug2009.pdf

Nordander, C., Ohlsson, K., Akesson, I., Arvidsson, I., Balogh, I., Hansson, G. A., …Skerfving, S. (2009). Risk of musculoskeletal disorders among females and males in repetitive/constrained work. *Ergonomics*, *52*(10), 1226–1239. doi:10.1080/00140130903056071

Phelan, D., & O'Sullivan, L. (2014). Shoulder muscle loading and task performance for overhead work on ladders versus mobile elevated work platforms. *Applied Ergonomics*, *45*(6), 1384–1391. doi:10.1016/j.apergo.2014.03.007

Reiman, A., Pekkala, J., Vayrynen, S., Putkonen, A., & Forsman, M. (2014). Participatory video-assisted evaluation of truck drivers' work outside cab: Deliveries in two types of transport. *The International Journal of Occupational Safety and Ergonomics*, *20*(3), 477–489.

Skinner, H., & McMahon, P. (2014). *Current diagnosis and treatment in orthopedics* (5th ed.). New York, NY: McGraw-Hill.

Smith, C. K., & Williams, J. (2014). Work related injuries in Washington State's trucking industry, by industry sector and occupation. *Accident Analysis & Prevention*, *65*, 63–71. doi:10.1016/j.aap.2013.12.012

Soares, M., Jacobs, K., Minna, S., & Mika, N. (2012). Relationship between construction workers' musculoskeletal disorders and occupational health service activities. *Work*, *41*, 3753–3756.

Soares, M., Jacobs, K., Moriguchi, C., Carnaz, L., de Miranda, L., Marklin, R., & Coury, H. (2012). Biomechanical analysis of loading/unloading a ladder on a truck. *Work*, *41*, 2492–2495.

Svendsen, S. W., Gelineck, J., Mathiassen, S. E., Bonde, J. P., Frich, L. H., Stengaard-Pedersen, K., & Egund, N. (2004). Work above shoulder level and degenerative alterations of the rotator cuff tendons: A magnetic resonance imaging study. *Arthritis & Rheumatism*, *50*(10), 3314–3322. doi:10.1002/art.20495

Thompson, J. C. (2010). *Netter's concise orthopaedic anatomy* (2nd ed.). Philadelphia, PA: Saunders Elsevier.

Trotta, J., Ulbricht, L., & Silva, J. L. H. (2014). *Incidence of musculoskeletal symptoms in industry workers*. Paper presented at the Occupational Safety and Hygiene II—Selected Extended and Revised Contributions from the International Symposium Occupational Safety and Hygiene, SHO 2014.

U.S. Department of Labor (USDOL). (2013). *Nonfatal occupational injuries and illnesses requiring days from work, 2012*. Retrieved from http://www.bls.gov/iif/oshcdnew.htm

U.S. Department of Labor (USDOL). (2014). *Nonfatal occupational injuries and illnesses requiring days away from work*. Retrieved from http://www.bls.gov/iif/oshcdnew.htm

van der Beek, A. J., Frings-Dresen, M., van Dijk, F. J. H., Kemper, H., & Meijman, T. (1992). Loading and unloading by lorry drivers and musculoskeletal complaints. *International Journal of Industrial Ergonomics*, *12*(1), 12–23.

Yoo, I.-G., Lee, J., Jung, M.-Y., & Yang, N.-Y. (2011). Neck and shoulder muscle activation in farm workers performing simulated orchard work with and without neck support. *Work*, *40*(4), 385–391.

Appendix A. Research Studies of Commercial Truck Drivers

Author	Variables	Research Questions or Hypotheses	Design/Methods	Sample/Setting	Measurement	Findings
van der Beek et al. (1992)	Height Weight Age Working history Pain and stiffness Body regions	How is loading and unloading related to musculoskeletal complaints?	Nonexperimental, descriptive research design 36-question survey created from the Periodic Occupational Health Survey The survey mailed to participants	Convenience sample of commercial drivers from two sectors in England $N = 534$	Descriptive statistics Logistic regression used, with the p value set to $p < .05$ 95% CI presented for two-sided testing	Prevalence of regular pain: back, 47%; neck, 29%; shoulder, 28%; knee, 23%; upper arm, 16% Prevalence of difficulty: pulling, 52%; pushing, 49% Shoulder had higher odds of complaint than back, but there is only a p value of $<.01$.
U.S. Bureau of Labor Statistics [USBLS] (2014)	Occupation Missed days Type of injury or event Event exposure Body region	What are incidences and causes of occupational injuries by work and how many days of work do the workers miss?	Nonexperimental, descriptive research design Data collected from injury and illness cases reportable to OSHA	All reportable OSHA cases in the United States Cases within Bureau of Labor Statistics databases $N \geq 3{,}000{,}000$ reported cases in 2013	Descriptive statistics Statistical significance was found using 95% CI	15.7% of all CTD MSDs are to the shoulder (second to the back: 35.5%) MSDs to the shoulder have median 46 days of work missed (second to the wrist 71 days) Sprain/strains have the highest incidence in both the private and government settings. Overexertion and bodily reaction were the most common event exposure.
Davis et al. (2014)	Age Gender Industry Body region Injury type Financial costs Missed workdays	Purpose of this study was to determine the age-related trends associated with state-affiliated workers' compensation claims for all industries.	Retrospective, nonexperimental, descriptive research design Data collected from all claims submitted to Ohio Bureau of Workers' Compensation from 1999 to 2004 Claims involving workers younger than 16 years and/or lacerations or fractures were excluded	Ohio Bureau of Workers' Compensation covers 70% of all employers in Ohio. State of Ohio employees of a 5-year period $N = 572{,}508$ claims	ANOVA used for variance The χ^2 test was used for trends between variables. The p value set to $<.05$.	55% of claimants were 25–44 years old. Mean claim of $5,130 for all. Shoulder MSDs had a mean of $6,136. TWU had the highest cost per claim among the 35–44 years age group ($p < .05$). Days of work missed with a shoulder MSD increased from 93 (16–24) to 127 (55–64), as did claims with surgery from 2% (16–24) to 24% (>65). TWU shoulder claims were significantly higher than those for other fields. Days missed for shoulder injuries increased in each age range with all groups. Data only representative of Ohio workers' compensation claims.

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Appendix A. Research Studies of Commercial Truck Drivers (*Continued*)

Author	Variables	Research Questions or Hypotheses	Design/Methods	Sample/Setting	Measurement	Findings
Smith and Williams (2014)	Age Gender Industry Body region Injury type Financial costs Missed workdays Disability	Purpose of this study was to report injuries associated with state-affiliated workers' compensation claims related to CTDs.	Retrospective, nonexperimental, descriptive research design Data collected from all workers' compensation claims related to CTDs from 2005 to 2010	Workers' compensation claims with Washington State Department of Labor and Industries WSDL&I is the sole provider of all state employees workers' compensation claims Data collected from 2005 to 2010 $N = 10,171$	Descriptive statistics Statistical significance and the odds ratio were found using 95% CI	CTDs have the highest cost and rates of workers' compensation claims at $10,449. CTDs had higher rates of injury than nontrucking persons, with an incidence rate of 4.11. 34.4% of all reported injuries to CTDs were MSDs. (Falls from elevation, 11.7%; falls from same level, 9.9%; struck by, 14.5%.) More likely to have partial or total disability than other industries. Odds ratio of 1.02 and 1.31, respectively.
McCall and Horwitz (2005)	Age Gender Work history Injury type Injury trigger	Purpose of this study was to determine the trends associated with CTD injuries on and around the vehicle.	Prospective, nonexperimental, descriptive research design Data collected from all workers' MSD claims in Oregon	MSD claims reported to the company collected and entered into the database Only MSDs requiring at least 1 missed workday were included Data were collected from 2002 to 2004 $N = 523$	Descriptive statistics Statistical significance was found using 95% CI	Nontraffic accidents attribute to 92.6% of occupational accidents. Falls most common type of accident in truck drivers and accounted for 22.3% of claims. 33% of claims trigger by a step off edge; this is the most common trigger. 51% of all injuries were related to 1 year or less of job tenure.
Reiman et al. (2014)	Age Gender Perceived discomfort Joint motion Mechanisms of discomfort	Identify risks and ergonomics discomfort in truck drivers' work outside a cab and to compare drivers' identification of discomfort in two types of truck driving work.	Prospective, nonexperimental design Using participatory ergonomics, subjective assessment was done by video- and computer-based work analysis (VIDAR)	Professional short or local haul truck drivers in Finland Mean 35 years of age Mean 7.4 years of work experience $N = 8$	Mean values used The χ^2 test measured associations Significance set at $p < .05$	Reported physical discomfort was related to overexertion and/or repetitive motion. The right shoulder had the highest average value for physical discomfort (3.4/10), with the left shoulder third (3.2/10). 47/80 reported physical discomfort occurred during unloading the truck at the delivery site.

Note. ANOVA = analysis of variance; CI = confidence interval; CTD = commercial truck driver; MSD = musculoskeletal disorder; OSHA = Occupational Safety and Health Administration; TWU = Transportation, Warehousing, and Utilities; WSDL&I = Washington State Department of Labor and Industries.

Appendix B. Research Studies of One Occupational Population

Author	Variables	Research Questions or Hypotheses	Design/Methods	Sample/Setting	Measurement	Findings
Bhimani (2016)	Demographics Body region Perceived reasons of injury Injury reporting status	Work-related MSD is a concern for nurses, but there is a gap in literature to understand specific patterns in injuries. The purpose of this study was to evaluate nurses and to understand their concerns.	Cross-sectional, descriptive research design using paper surveys with a convenience sample of nurses on rehabilitation unit	Nursing staff on the rehabilitation floor in the hospital setting $N = 58$	Quantitative—Descriptive statistics of injury frequency and percentages Qualitative study was done using Patton's inductive analysis.	Upper extremity is the second most common area injured 18% behind the back at 63%. 48% did not report their injury, with the main reason felt to be minor injury (97%) and 3% to much paper work.
Borstad et al. (2009)	Exercise program Shoulder pain	Construction apprentices are at risk for shoulder pain and their increasing exposure to overhead work contribute to shoulder pain. Can a preventive exercise program help decrease new-onset shoulder pain complaints?	Prospective cohort study The intervention group was given a stretching and exercise program; the control group was given nothing. Follow-up every year for 2 years 15-question pre- and posttests given	Construction apprentices were recruited, and the participation was voluntary $N = 268$	Work-related variables analyzed w/two-factor ANOVA Yes/No responses were analyzed with the χ^2 test. Regression analysis used to determine predictive variables	The control group had higher rates of shoulder complaints (17.9% vs. 10.8%). Four predictive factors found: previous neck pain ($p = .047$), extreme weather ($p = .002$), height ($p = .046$), and bending and twisting at back ($p = .038$).
Bulduk et al. (2014)	Demographics QEC tool results Body part at risk Work setting Work experience	WMSDs are a significant problem in occupational settings. The taxi driver profession needs to understand risk factors better. The aim of this study was to evaluate taxi drivers in Turkey using the QEC tool to assess risk factors for WMSDs.	Prospective, nonexperimental design Taxi drivers were evaluated using the QEC tool. This was a one-time assessment.	Taxi drivers $N = 382$	The χ^2 test was used. Significance set at $p < .05$	The tool showed drivers had an increased exposure risk, with risk to the neck, wrist/hand, and shoulder/arm very high. Significant association between prevalence and age ($p < .05$)
Ferguson, Allread, Le, Rose, and Marras (2013)	Seated vs. current assembly process MSD risk	MSD risks are increased in automotive assembly due to work and body positions. Can the use of a cantilever chair help decrease risk for MSDs in this profession?	Prospective, experimental, repeated-measures design The subjects completed both activities and had truck position and trunk, abdomen, and shoulder muscles measured by EMG.	Automotive assembly workers from one company $N = 10$	Linear regression used to calculate position data Linear models used for statistical significance	The use of the chair decreased spine load but increased muscle activation of the shoulder ($p = .026$).

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Appendix B. Research Studies of One Occupational Population (*Continued*)

Author	Variables	Research Questions or Hypotheses	Design/Methods	Sample/Setting	Measurement	Findings
Moriguchi et al. (2012)	Simulated vs. actual work environments Arm and neck flexion as measured with inclinometers and the time of work needed	Assess and compare neck and shoulder activities in real-world vs. simulated environments.	Three common tasks within the field of electric utility workers were measured in a simulated setting and the actual work setting. The participants were split into two groups (simulated = 12; actual = 12). Postural exposure data were processed as a function of real time according to the Exposure Variation Analysis.	Electricians $N = 24$	The Shapiro–Wilk test was used to determine the normality of the distribution of the data sets.	Two of the three tasks were equally represented in the simulation (stated but the p value was not given). Given simulated setting may allow for inconsistency from the actual work environment, so this should be taken into account when creating a simulated laboratory setting.
Phelan and O'Sullivan (2014)	Ladder vs. mobile flat platform Shoulder discomfort and EMG studies	Compare overhead work and loading while using a ladder and mobile platform to see whether there are any differences in the settings.	A field study of electricians working on both ladders and flat mobile platforms. A discomfort survey was administered, and electromyograms were used to assess muscle use.	Convenience sample of electricians at a pharmaceutical plant $N = 19$	With a paired t test to compare ladders to MEWP Wilcoxon's signed rank test was used for discomfort data. Two-way ANOVA done to assess the platform and participants. The p value set at $p < .05$.	The mean discomfort was slightly higher on the ladder but not statistically significant ($p = .693$). There was a statistically significant difference in the use of the deltoid while on the ladder ($p < .01$). There was an increase in the use of a trap but not quite as significant ($p < .05$).
Soares, Jacobs, Moriguchi, et al. (2012)	Lifting during loading and unloading a ladder out of a truck Posture, force used, and perceived exertion	The objective of the present study was to evaluate the posture, forces required, and perceived exertion when loading and unloading a ladder on a utility truck.	Shoulder motion and force assess while unloading and loading a ladder from a truck	Convenience sample of male electrical line workers $N = 13$	The mean of three values was collected and used. The Kolmogorov–Smirnov test, Pearson's correlation test was used to verify the correlation. Paired t tests used for comparison	Older workers were found to have an increased perceived exertion ($p = .04$). Taller workers were shown to require less force to work ($p = .05$). Shoulder elevation angle and pulling force were correlated ($p = .02$).

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Appendix B. Research Studies of One Occupational Population (*Continued*)

Author	Variables	Research Questions or Hypotheses	Design/Methods	Sample/Setting	Measurement	Findings
Soares, Jacobs, Minna, et al. (2012)	HS MSDs disorders	The aim of this study was to determine whether a relationship exists between construction workers' MSDs and OHS activities in the construction industry.	Phone interview was used to assess the occurrence of MSDs and use of OHS.	Sample of construction workers in Finland *N* = 261	The *p* value was set at $p = .05$. The χ^2 test was used for variable differences.	Those who felt that they had received enough information, advice, or guidance from OHS concerning work posture, work performance, or work tools were more often those who had not suffered from shoulder or arm disorders ($p = .024$). 55.6% of workers complained of neck/shoulder MSDs, with 44.8% complaining of shoulder/arm MSDs.
Trotta et al. (2014)	Demographics Body region Attitude	To establish the incidence and prevalence of MSDs and relationships in the electromechanical industry.	Self-administered questionnaire used with 13 questions	Convenience sample of electromechanical industry workers in metropolitan region in Brazil *N* = 1,253	Descriptive statistics Confidence interval not stated	Most body parts affected by pain were the shoulders (12.69%), legs (11.65%), spine (11.09%), neck (7.58%), feet (7.18%), hands (7.18%), and arms (6.78%). Employees in this company had decreased participation with the occupational health service.
Yoo, Lee, Jung, and Yang (2011)	Neck support Muscle activation in the shoulder and neck	Does neck support help decrease neck muscle activation required for activities? Can it help rest muscle by requiring less force?	Prospective, experimental, repeated-measures design Four muscles were measured by EMG in a simulated orchard work with and without neck support.	Convenience sample of migrant farmers *N* = 14	Paired T-test used with *p* value set at 0.05	The anterior and middle deltoids had increased activity with neck support, whereas the upper trap had decreased activity with support.

Note. ANOVA = analysis of variance; EMG = electromyography/electromyographic; HS = Health Services; MEWP = mobile elevated work platform; MSD = musculoskeletal disorder; OHS = occupational health service; QEC = Quick Exposure Check; WMSD = work-related musculoskeletal disorders.

Appendix C. Research Studies of Multiple Occupational Populations

Author	Variables	Research Questions or Hypotheses	Design/Methods	Sample/Setting	Measurement	Findings
Asundi et al. (2011)	Post offer physical assessment and placement Shoulder injuries and complaints	Study was designed to determine whether shoulder injury rates are lowered when employees are placed at jobs they demonstrate the physical ability to perform.	Randomized, controlled, prospective, interventional study	N = 757 control (historical = 256; concurrent = 497), 248 interventions	Fisher's exact test and the χ^2 test for equality of distribution in comparison	Major mechanism associated with shoulder injuries was sprain/strain due to overexertion, followed by slips and falls. The interventional group had significantly less shoulder injury (p = .035).
Bovenzi (2015)	Demographics Work history Medical history Neck and shoulder pain Whole-body vibration	To investigate the occurrence of neck and shoulder pain and the relation between neck and shoulder pain and individual and work-related factors.	4-year prospective cohort study Participants were selected from the ongoing Risk of Occupational Vibration Injuries study. Utilized VIBRISKS questionnaire for general and medical information and the modified Nordic questionnaire for musculoskeletal symptoms.	Italian professional drivers (i.e., quarries, paper mills, and dockyards) N = 628	One-way analysis of variance The χ^2 test for categorical data Logistical regression used for OR	Whole-body vibration was significantly associated with shoulder pain (OR = 1.53); lifting >15 kg more than 45 minutes/day (OR = 2.48); work with hands above head >1 hour/day (OR = 2.0); and moderate psychological distress (OR = 2.26). Shoulder pain had an incidence rate of 21/100.
Hegmann et al. (2014)	Diagnosis Case definitions	Evaluate case definitions used for epidemiological studies of MSDs.	Multicenter, prospective cohort study Participants completed a survey of symptoms at baseline and then two independent physical examinations.	Analyzed data from the WISTAH study of MSDs Workers from 15 employers N = 1,227	Wilcoxon's rank sum tests for continuous data and χ^2 tests for continuous data	Rotator cuff tendinitis; 23% had glenohumeral shoulder pain compared with 8.0% having both pain plus a positive supraspinatus test. Comprehensive, systematic health assessments resulted in differences in the prevalence of three of the most common upper extremity MSDs.
Herin et al. (2012)	Shoulder pain Occupation, demographics	Evaluate the predictive value of work-related psychological and mechanical factors on chronic shoulder pain.	Prospective, longitudinal, epidemiological investigation with 5-year follow-up	Randomly selected from 400 volunteer occupational physicians N = 18,695	Descriptive statistics Wald's test was used, and the p value set at p <.05	16%–30% of cohorts reported chronic shoulder pain. 50% of all were overweight. 24% had movement constraint, 24% had forceful effort constraint, and 41% had posture constraint.
Nordander et al. (2009)	Work type Medical history Pain Diagnoses on physical examination	Assess and calculate the risk for MSDs among workers with repetitive/constrained work as compared with workers with varied mobile work.	Prospective, epidemiological study Questionnaires were used to assess general, medical, and workload information. The Nordic questionnaire was used to assess for musculoskeletal complaints. Half of the groups received standardized physical examinations.	40 female and 15 male occupational groups Questionnaire N = 4,961 (female = 3,720; male = 1,241) Physical examination N = 1,677 (female = 1,762; male = 915)	Mean prevalence and prevalence ratios used 95% CI	Pain in the shoulder/neck region within the last 7 days was the most common in constrained and repetitive work and varied and mobile but was higher in repetitive and constrained. Rotator cuff tendonitis was the second most common diagnosis during physical examination (10.4%).

Note. CI = confidence interval; MSD = musculoskeletal disorder; OR = odds ratio.

Appendix D. Research Studies of Shoulder Biomechanics

Author	Variables	Research Questions or Hypotheses	Design/Methods	Sample/Setting	Measurement	Findings
Antony and Keir (2010)	Handgrip Muscle force Shoulder ROM	The influence of external factors such as arm posture, hand loading, and dynamic exertion on shoulder muscle activity is needed to provide insight into the relationship between internal and external loading of the shoulder joint. It was hypothesized that the addition of a grip force would decrease deltoid activity and that muscle activity would be proportional to the speed of movement.	Participants performed isometric and dynamic exertions in three different shoulder elevations with the right arm. They were measured using EMGs of eight muscles.	Healthy students in a university setting $N = 16$	The mean EMG was analyzed. ANOVA was used with each muscle to compare variables. A four-way ANOVA was used to check data quality. The α was set to .01, and Bonferroni's correction was used to get $p < .002$.	Handgrip changed the activation muscles within the shoulder during activity. It decreased the use of anterior and middle deltoids by 2% and posterior deltoid, infraspinatus, and trap increased 2% and biceps brachii by 6%. Raising the arm from 30° to 90° doubled the mean static shoulder moment and elicited a mean increase in activity of 84% (range = 69%–109%).
Au and Keir (2007)	Multitasking activity and grip strength Upper extremity muscle activity	Purpose of this study was to examine the effects of multitasking on muscular activity in the upper extremity by examining simultaneous shoulder and grip exertions with increased task precision and mental processing demands.	Participants completed two testing periods and orientation and the final test. Grip strength, isometric shoulder, and wrist motion were measured over 24 different conditions with and without distraction using the modified Stroop test	Convenience sample of healthy adults $N = 16$	Mixed ANOVAs used to test for gender differences on relative grip forces, shoulder moments, and EMG of each of the eight muscles. The p value was not stated. The modified Bonferroni correction factor was used for further evaluation.	Women required greater shoulder movement ($p = .006$). Shoulder loads of 40% MVC increased extrinsic wrist flexor and extensor activities ($p = .0001$). While 40% shoulder exertions elevated forearm muscle activity, hand exertions did not increase shoulder EMG in a similar fashion ($p = .02$). 30% grip force and the Stroop test significantly reduced deltoid activity under all conditions ($p = .001$).
Blache et al. (2014)	Height Weight Muscle strength ROM Muscle activation	Assess the effect of lifting height and weight lifted on shoulder muscle mechanical loads.	Repeated trial design Motion, force, and activation as measured using three-dimensional camera analysis, force sensors on instrument handle, and EMG. Measurements were taken during the initial maximum test and sagittal lifting movements using different heights and box weights.	Healthy male participants $N = 15$	Shapiro–Wilk test Two-way repeated-measures ANOVA Mean calculated	Box weight and height of lift significantly affected the Lifting Index. Supraspinatus and infraspinatus decreased in muscle force when changing height from shoulder to eye levels. Subscapularis force increased when changing height from shoulder to eye levels.

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Appendix D. Research Studies of Shoulder Biomechanics (*Continued*)

Author	Variables	Research Questions or Hypotheses	Design/Methods	Sample/Setting	Measurement	Findings
Fuller et al. (2009)	Shoulder height repetitive activity Fatigue, posture, and ROM	What whole-body effects do shoulder fatigue have?	Pre- and posttest study of whole-body fatigue with induced arm fatigue. Whole-body kinematic, kinetic, and EMG characteristics were recorded.	Convenience sample of healthy young adults $N = 14$	*t* tests used, and the *p* value set at $p < .05$.	Shoulder elevators fatigue quicker than other muscles with activities at our above shoulder height. Medial and lateral movements adapted the most with fatigue. Also, fatigue increased shoulder flexion.
McDonald et al. (2016)	Muscle strength Joint ROM Muscle fatigue Perceived exertion Demographics	Evaluate the immediate and prolonged kinematic and muscular responses to muscle fatigue during repetitive work.	The shoulder was assessed using EMG and three-dimensional motion analysis. After a standardized fatigue protocol, participants completed four tasks representative of industrial setting (drill, handle pull, handle push, cap rotation) every minute for 60 minutes.	Right-hand-dominant males with no history of upper extremity pathology $N = 12$	*t* tests was used, and the *p* value set at $p < .05$. Repeated-measures ANOVAs Mean calculated	Shoulder flexion decreases and abduction increases to compensate for muscle fatigue. Compensation is worse after first 4–8 minutes but improves average time. Anterior and posterior deltoids show fatigue after the initial protocol but were able to return within the postfatigue protocol. Significant motion and muscle changes in push-and-pull tasks seen throughout the entire postfatigue protocol.

Note. ANOVA = analysis of variance; EMG = electromyography; MVC = maximum voluntary contraction; ROM = range of motion.