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#### **Special Issue: Epidemiological Studies of Workplace Musculoskeletal Disorders**

**Arun Garg, Sruthi Boda, Kurt T. Hegmann, J. Steven Moore, Jay M. Kapellusch, Parag Bhoyar, Matthew S. Thiese, Andrew Merryweather, Gwen Deckow-Schaefer, Donald Bloswick, and Elizabeth J. Malloy.** *The NIOSH Lifting Equation and Low-Back Pain, Part 1: Association With Low-Back Pain in the BackWorks Prospective Cohort Study.* S. 6-28.

**Objective:** The aim of this study was to evaluate relationships between the revised NIOSH lifting equation (RNLE) and risk of low-back pain (LBP). **Background:** The RNLE is commonly used to quantify job physical stressors to the low back from lifting and/or lowering of loads. There is no prospective study on the relationship between RNLE and LBP that includes accounting for relevant covariates. **Method:** A cohort of 258 incident-eligible workers from 30 diverse facilities was followed for up to 4.5 years. Job physical exposures were individually measured. Worker demographics, medical history, psychosocial factors, hobbies, and current LBP were obtained at baseline. The cohort was followed monthly to ascertain development of LBP and quarterly to determine changes in job physical exposure. The relationship between LBP and peak lifting index (PLI) and peak composite lifting index (PCLI) were tested in multivariate models using proportional hazards regression. **Results:** Point and lifetime prevalences of LBP at baseline were 7.1% and 75.1%, respectively. During follow-up, there were 123 incident LBP cases. Factors predicting development of LBP included job physical exposure (PLI and PCLI), history of LBP, psychosocial factors, and housework. In adjusted models, risk (hazard ratio [HR]) increased per-unit increase in PLI and PCLI ( $p = .05$  and  $.02$ ; maximum HR = 4.3 and 4.2, respectively). PLI suggested a continuous increase in risk with an increase in PLI, whereas the PCLI showed elevated, but somewhat reduced, risk at higher exposures. **Conclusion:** Job physical stressors are associated with increased risk of LBP. Data suggest that the PLI and PCLI are useful metrics for estimating exposure to job physical stressors.

- **Keywords:** epidemiology, ergonomics, occupational cohort, job analysis, risk assessment

**William S. Marras, Sue A. Ferguson, Steven A. Lavender, Riley E. Splittstoesser, Gang Yang. Cumulative Spine Loading and Clinically Meaningful Declines in Low-Back Function. S. 29-43.**

**Objective:** The objective was to assess the role of cumulative spine loading measures in the development of a clinically meaningful decline in low-back function. **Background:** Cumulative spine loading has been a suspected risk factor for low-back pain for many years, yet the measures that characterize risk have not been well delineated. **Methods:** A total of 56 cumulative exposure measures were collected in a prospective field study of distribution center workers. An individual's risk for a clinically meaningful decline in low-back function (true cases) was explored with daily, weekly, and job tenure cumulative exposure measures using univariate and multivariate statistical modeling techniques. True noncases were individuals with no decline in low-back function. **Results:** An individual's risk for a clinically meaningful decline in low-back function (true cases) was predicted well versus true noncases (sensitivity/specificity = 72%/73%) using initial low-back function ( $p(n)$ ), cumulative rest time, cumulative load exposure, job satisfaction, and worker age. **Conclusions:** Cumulative rest time was identified as an important component for predicting an individual's risk for a clinically meaningful decline in low-back function. **Application:** This information can be used to assess cumulative spine loading risk and may help establish guidelines to minimize the risk of a clinically meaningful decline in low-back function.

- **Keywords:** low-back pain, biomechanics, epidemiology, occupational risk, surveillance

**Arun Garg, Jay M. Kapellusch, Kurt T. Hegmann, J. Steven Moore, Sruthi Boda, Parag Bhoyar, Matthew S. Thiese, Andrew Merryweather, Gwen Deckow-Schaefer, Donald Bloswick, and Elizabeth J. Malloy. The NIOSH Lifting Equation and Low-Back Pain, Part 2: Association With Seeking Care in the BackWorks Prospective Cohort Study. S. 44-57.**

**Objective:** The aim of this study was to investigate the relationship between the revised NIOSH lifting equation (RNLE) and risk of seeking care for low-back pain (SC-LBP). **Background:** The RNLE is commonly used to quantify low-back physical stressors from lifting/lowering of loads in workplaces. There is no prospective study on relationship between RNLE and SC-LBP. **Method:** A cohort of 258 incident-eligible workers from 30 diverse facilities was followed for up to 4.5 years. Job physical exposures were individually measured. Worker demographics, medical history, psychosocial factors, hobbies, and current low-back pain were obtained at baseline. The cohort was followed monthly to ascertain SC-LBP and quarterly to determine changes in physical exposure. Associations between SC-LBP and both the peak lifting index (PLI) and peak composite lifting index (PCLI) were tested in multivariate models using proportional hazards regression. **Results:** SC-LBP lifetime prevalence at baseline was 31.9%, and there were 24 incident cases during follow-up. Factors predicting SC-LBP included job physical exposure (PLI and PCLI), history of low-back pain, age, female gender, and lower body mass index. In adjusted models, risk (hazard ratio [HR]) increased per unit increase in PLI and PCLI ( $p = .03$  and  $.02$ , and maximum HR = 23.0 and 21.9, respectively). Whereas PCLI suggested a continuous increase in risk with an increase in PCLI, the PLI showed elevated, though somewhat reduced, risk at higher exposures (HR = 14.9 at PLI = 6). **Conclusion:** Job physical stressors are associated with increased risk of SC-LBP. Data suggest that both the PLI and PCLI are useful metrics for estimating exposure to job physical stressors.

- **Keywords:** epidemiology, ergonomics, occupational cohort, job analysis, risk assessment

**Sue A. Ferguson, William S. Marras, Steven A. Lavender, Riley E. Splittstoesser, and Gang Yang. Are Workers Who Leave a Job Exposed to Similar Physical Demands as Workers Who Develop Clinically Meaningful Declines in Low-Back Function? S. 58-72.**

**Objective:** The objective is to quantify differences in physical exposures for those who stayed on a job (survivor) versus those who left the job (turnover). **Background:** It has been suggested that high physical job demands lead to greater turnover and that turnover rates may supplement low-back disorder incidence rates in passive surveillance systems. **Method:** A prospective study with 811 participants was conducted. The physical exposure of distribution center work was quantified using a moment monitor. A total of 68 quantitative physical exposure measures in three categories (load, position, and timing) were examined. Low-back health function was quantified using the lumbar motion monitor at baseline and 6-month follow-up. **Results:** There were 365 turnover employees within the 6-month follow-up period and 446 "survivors" who remained on the same job, of which 126 survivors had a clinically meaningful decline in low-back functional performance (cases) and 320 survivors did not have a meaningful decline in low-back functional performance (noncases). Of the job exposure measures, 6% were significantly different between turnover and cases compared to 69% between turnover and noncases. Turnover employees had significantly greater exposure compared to noncases. **Conclusion:** Turnover employees had similar physical job exposures to workers who remained on the job and had a clinically meaningful decline in low-back functional performance. Thus, ergonomists and HR should be aware that high turnover jobs appear to have similar physical exposure as those jobs that put workers at risk for a decline in low-back functional performance.

- **Keywords:** employee turnover, warehousing, low-back injury

**Ming-Lun Lu, Thomas R. Waters, Edward Krieg, and Dwight Werren. Efficacy of the Revised NIOSH Lifting Equation to Predict Risk of Low-Back Pain Associated With Manual Lifting: A One-Year Prospective Study. S. 73-85.**

**Objective:** The objective was to evaluate the efficacy of the Revised National Institute for Occupational Safety and Health (NIOSH) lifting equation (RNLE) to predict risk of low-back pain (LBP). **Background:** In 1993, NIOSH published the RNLE as a risk assessment method for LBP associated with manual lifting. To date, there has been little research evaluating the RNLE as a predictor of the risk of LBP using a prospective design. **Methods:** A total of 78 healthy industrial workers' baseline LBP risk exposures and self-reported LBP at one-year follow-up were investigated. The composite lifting index (CLI), the outcome measure of the RNLE for analyzing multiple lifting tasks, was used as the main risk predictor. The risk was estimated using the mean and maximum CLI variables at baseline and self-reported LBP during the follow-up. Odds ratios (ORs) were calculated using a logistic regression analysis adjusted for covariates that included personal factors, physical activities outside of work, job factors, and work-related psychosocial characteristics. **Results:** The one-year self-reported LBP incidence was 32.1%. After controlling for history of prior LBP, supervisory support, and job strain, the categorical mean and maximum CLI above 2 had a significant relationship (OR = 5.1–6.5) with self-reported LBP, as compared with the CLI below or equal to 1. The correlation between the continuous CLI variables and LBP was unclear. **Conclusions:** The CLI > 2 threshold may

be useful for predicting self-reported LBP. Research with a larger sample size is needed to clarify the exposure-response relationship between the CLI and LBP.

- **Keywords:** Revised NIOSH lifting equation, lifting index, manual lifting, low-back pain, prospective study, job strain

**Matthew S. Thiese, Kurt T. Hegmann, Eric M. Wood, Arun Garg, J. Steven Moore, Jay M. Kapellusch, James Foster, Tom Greene, Greg Stoddard, Jeremy Biggs, and BackWorks Study Team. Low-Back Pain Ratings for Lifetime, 1-Month Period, and Point Prevalences in a Large Occupational Population. S. 86-97.**

**Objective:** This manuscript systematically quantifies multiple measures of low-back pain (LBP) prevalence by pain rating in a large, multisite cohort of workers. **Background:** Published LBP prevalence rates vary. Studies rely on one measure of LBP and none report prevalence stratified by pain rating. **Method:** Cross-sectional analyses of baseline data from a multicenter prospective cohort study were performed to evaluate differences in lifetime prevalence, 1-month period prevalence, and point prevalence of LBP. Workers were from 28 different employment settings in 4 diverse U.S. states. All workers completed computerized questionnaires and structured interviews. LBP prevalence measures were stratified by pain ratings. **Results:** A total of 828 subjects had complete health data at baseline. Lifetime prevalence, 1-month period prevalence, and point prevalence for any LBP ( $\geq 1/10$ ) were 63.4%, 44.0%, and 20.8% respectively. Prevalence of LBP decreased with increasing pain ratings. As an example, using a threshold of LBP  $\geq 3/10$  pain, prevalence measures were 61.0%, 37.6%, and 16.7% respectively. A threshold of LBP  $\geq 5/10$  had prevalence measures of 51.2%, 22.9%, and 9.9% respectively. Age, systolic and diastolic blood pressure, high cholesterol, high blood pressure, and tobacco use were statistically significantly related to lifetime prevalence of LBP. **Conclusion:** Lifetime LBP prevalence, 1-month period prevalence, and point prevalence stratified by pain ratings demonstrate a wide variation of prevalence measures of LBP and self-reported pain ratings. Higher pain rating thresholds yield lower prevalence measures and may impact assessments of risk factors. Differences in pain ratings may allow for focused surveillance within an occupational cohort.

- **Keywords:** epidemiology, risk factors, cohort, ergonomics, cross-sectional study design

**Jay M. Kapellusch, Arun Garg, Kurt T. Hegmann, Matthew S. Thiese, and Elizabeth J. Malloy. The Strain Index and ACGIH TLV for HAL: Risk of Trigger Digit in the WISTAH Prospective Cohort. S. 98-111.**

**Objective:** The objective of this study was to investigate the association between job physical exposure (JPE) and incidence of flexor tendon entrapment of the digits (FTED). **Background:** FTED, commonly known as trigger digit, is associated with age, gender, and certain health disorders. Although JPE has been suggested as a risk factor for FTED, there are no prospective cohort studies. **Method:** A cohort of 516 workers was enrolled from 10 diverse manufacturing facilities and followed monthly for 6 years. Worker demographics, medical history, and symptoms of FTED were assessed. JPE was individually measured using the Strain Index (SI) and American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value for hand activity level (TLV for HAL). Changes in JPE (assessed quarterly) and symptoms (assessed monthly) were recorded during follow-up. FTED was defined as demonstrated triggering on examination. **Results:** Point prevalence of FTED at baseline was 3.6%. During follow-up there were 23 incident FTED cases (left and/or right hands). The incident rate for first

occurrence of FTED from enrollment was 1.38 per 100 person-years. Risk factors were JPE, age, gender, diabetes mellitus, carpometacarpal osteoarthritis, and rheumatoid arthritis. In multivariate models, the SI showed strong association with risk of FTED when treated as a continuous variable and marginal association when dichotomized (SI > 6.1). TLV for HAL showed a statistical trend of increasing risk of FTED using the ACGIH limits, but no association as a continuous variable. **Conclusions:** Both JPE and personal risk factors are associated with FTED development. The SI and TLV for HAL are useful tools for estimating JPE.

- **Keywords:** epidemiology, ergonomics, tenosynovitis, tendovaginitis, job analysis, musculoskeletal disorders

**Fredric Gerr, Nathan B. Fethke, Linda Merlino, Dan Anton, John Rosecrance, Michael P. Jones, Michele Marcus, and Alysha R. Meyers. A Prospective Study of Musculoskeletal Outcomes Among Manufacturing Workers: I. Effects of Physical Risk Factors. S. 112-130.**

**Objective:** To better characterize associations between physical risk factors and upper-extremity musculoskeletal symptoms and disorders, a prospective epidemiologic study of 386 manufacturing workers was performed. **Background:** Methodological limitations of previous studies have resulted in inconsistent associations. **Method:** An individual, task-based exposure assessment strategy was used to assess upper-extremity exertion intensity, repetition, and time-in-posture categories. Participants recorded time spent performing daily work tasks on a preprinted log, which was then used to calculate time-weighted-average exposures across each week of follow-up. In addition, a weekly Strain Index (SI) risk category was assigned to each participant. Incident musculoskeletal symptoms and disorders were assessed weekly. Proportional hazards analyses were used to examine associations between exposure measures and incident hand/arm and neck/shoulder symptoms and disorders. **Results:** Incident symptoms and disorders were common (incident hand/arm symptoms = 58/100 person-years (PY), incident hand/arm disorders = 19/100 PY, incident neck/shoulder symptoms = 54/100 PY, incident neck/shoulder disorders = 14/100 PY). Few associations between separate estimates of physical exposure and hand/arm and neck/shoulder outcomes were observed. However, associations were observed between dichotomized SI risk category and incident hand/arm symptoms (hazard ratio [HR] = 1.73, 95% confidence interval [CI] = [0.99, 3.04]) and disorders (HR = 1.93, 95% CI = [0.85, 4.40]). **Conclusion:** Evidence of associations between physical risk factors and musculoskeletal outcome was strongest when exposure was estimated with the SI, in comparison to other metrics of exposure. **Application:** The results of this study provide evidence that physical exposures in the workplace contribute to musculoskeletal disorder incidence. Musculoskeletal disorder prevention efforts should include mitigation of these occupational risk factors.

- **Keywords:** manufacturing workers, musculoskeletal, risk factor, epidemiological study, occupational health

**Alysha R. Meyers, Fredric Gerr, and Nathan B. Fethke. Evaluation of Alternate Category Structures for the Strain Index: An Empirical Analysis. S. 131-142.**

**Objective:** The purpose of this study was to develop alternative Strain Index risk classification categories. **Background:** Strain Index scores are usually categorized into four Strain Index "risk categories." The "original" risk categories were developed in the meat-packing industry and may not be fully applicable to other industries. **Method:** Daily Strain Index scores were estimated among 276 manufacturing workers participating in a

cohort study of occupational risk factors for hand-arm musculoskeletal symptoms. Each score was categorized using the original method and a new method based on quartiles of Strain Index score values among symptomatic participants. Models examining associations between original Strain Index risk categories and incident hand-arm symptoms were compared to models examining associations between the alternative Strain Index risk categories and incident hand-arm symptoms. **Results:** Compared to the respective referent categories, a twofold or greater increase in the risk of incident hand-arm symptoms was observed for the highest original Strain Index risk category ( $HR = 2.06$ , 95% CI = [1.08–3.92]) and for the second highest alternate Strain Index risk exposure category ( $HR = 2.21$ , 95% CI = [1.26–3.85]). Although significant associations between Strain Index risk category and incident hand-arm symptoms were observed for both Strain Index categorization methods, model fit statistics favored the alternate approach. **Conclusion:** Results from this study suggests that the Strain Index risk category structure may need to be tailored to specific populations. **Application:** If verified, results from this study provide a better way to identify hazardous manufacturing jobs and target them for exposure reduction.

- **Keywords:** epidemiology, cohort study, ergonomics, musculoskeletal symptoms, Strain Index

**Carisa Harris-Adamson, Doohee You, Ellen A. Eisen, Robert Goldberg, and David Rempel. *The Impact of Posture on Wrist Tendinosis Among Blue-Collar Workers: The San Francisco Study.* S. 143-150.**

**Objective:** The objective was to evaluate the effect of wrist posture on incidence of wrist tendinosis in a prospective cohort of blue-collar workers. **Background:** Previous studies have identified awkward wrist posture as a risk factor for wrist tendinosis, though the magnitude of the relationship is unclear. **Method:** Workers ( $N = 413$ ) at four industries were followed for up to 28 months with questionnaires and physical examinations every 4 months. Individualized exposure assessments of wrist posture were based on video analysis to determine the wrist extension/flexion angle for up to four tasks. Posture measures were calculated while in "heavy pinch" ( $> 1$  kg force), "heavy power grip" ( $> 4$  kg force), and across "all grips." A proportional hazards model estimated the relationship between time-weighted average posture measures and incidence of dominant-side wrist tendinosis. **Results:** In a model based on tertiles of exposure, adjusted for age, gender, hand force, and repetition of exertions, risk of tendinosis more than doubled in the highest category ( $HR = 2.69$ , 95% CI = 1.01–7.21) across all grips. The relative risk was highest during heavy pinch ( $HR = 5.03$ , 95% CI = 0.74–34.05), though not statistically significant. Increased median wrist extension while in heavy power grip was protective ( $HR = 0.24$ , 95% CI = 0.06–0.94). **Conclusion:** In this study of production workers, median wrist flexion of more than  $7^\circ$ , across all grips, was associated with an increased risk of tendinosis. The protective findings on median wrist extension during power grip deserve further investigation. Work tasks and tools should be designed to prevent sustained wrist flexion, especially during tasks involving forceful pinch.

- **Keywords:** wrist, tendinosis, tendinitis, tendonitis, tendonopathy, posture, prospective, exposure response, incidence

**Z. Joyce Fan, Barbara A. Silverstein, Stephen Bao, Dave K. Bonauto, Ninica L. Howard, and Caroline K. Smith. *The Association Between Combination of Hand Force and Forearm Posture and Incidence of Lateral Epicondylitis in a Working Population.* S. 151-165.**

**Objective:** The objective of this prospective study is to investigate the exposure-response relationships between various workplace physical exposures of force, repetition, and their combination assessed at an individual level with lateral epicondylitis (LE). **Background:** Workplace upper extremity musculoskeletal disorders (UEMSDs) are prevalent, disabling, and expensive. LE is one of the major UEMSDs in active workers. **Method:** We used detailed health history, symptoms, and physical examination for identifying incidence and detailed exposure assessment to capture work tasks of each worker and to measure quantitative mechanical workload. We used counting process style input of proportional hazards regression for modeling cumulative incidence that accounts for changed exposure estimates during the follow-up period when respondents change jobs. **Results:** The incidence rate of LE on the dominant side was 4.91 per 100 person-years. Adjusted for age and gender, the combined effect of forearm pronation  $\geq 45^\circ$  for  $\geq 40\%$  of time and time spent with forceful exertion, including any power grip (hazard ratio [HR] = 2.8, 95% confidence interval [CI] = [1.35–5.77]), lifting for  $\geq 3\%$  of time (HR = 2.50, 95% CI = [1.19–5.24]), and duty cycle for forceful exertion for  $\geq 10\%$  (HR = 2.25, 95% CI = [1.09–4.66]), were significant predictors of dominant side LE, whereas neither the awkward posture nor the forceful exertion alone was significant. Older workers with jobs requiring a high percentage of time working with force in combination with awkward postures of forearm were more likely to predict LE. **Conclusion:** This study shows the evidence of the etiologic role of strenuous manual tasks in the occurrence of LE.

- **Keywords:** forceful exertion, awkward posture of forearm, lateral epicondylitis, incidence

**Bradley Evanoff, Angelique Zeringue, Alfred Franzblau, and Ann Marie Dale. Using Job-Title-Based Physical Exposures From O\*NET in an Epidemiological Study of Carpal Tunnel Syndrome. S. 166-177.**

**Objective:** We studied associations between job-title-based measures of force and repetition and incident carpal tunnel syndrome (CTS). **Background:** Job exposure matrices (JEMs) are not commonly used in studies of work-related upper-extremity disorders. **Method:** We enrolled newly hired workers in a prospective cohort study. We assigned a Standard Occupational Classification (SOC) code to each job held and extracted physical work exposure variables from the Occupational Information Network (O\*NET). CTS case definition required both characteristic symptoms and abnormal median nerve conduction. **Results:** Of 1,107 workers, 751 (67.8%) completed follow-up evaluations. A total of 31 respondents (4.4%) developed CTS during an average of 3.3 years of follow-up. Repetitive motion, static strength, and dynamic strength from the most recent job held were all significant predictors of CTS when included individually as physical exposures in models adjusting for age, gender, and BMI. Similar results were found using time-weighted exposure across all jobs held during the study. Repetitive motion, static strength, and dynamic strength were correlated, precluding meaningful analysis of their independent effects. **Conclusion:** This study found strong relationships between workplace physical exposures assessed via a JEM and CTS, after adjusting for age, gender, and BMI. Though job-title-based exposures are likely to result in significant exposure misclassification, they can be useful for large population studies where more precise exposure data are not available. **Application:** JEMs can be used as a measure of workplace physical exposures for some studies of musculoskeletal disorders.

- **Keywords:** carpal tunnel syndrome, job exposure matrix, O\*NET, prospective cohort study, ergonomics

**Fredric Gerr, Nathan B. Fethke, Dan Anton, Linda Merlino, John Rosecrance, Michele Marcus, and Michael P. Jones. A Prospective Study of Musculoskeletal Outcomes Among Manufacturing Workers: II. Effects of Psychosocial Stress and Work Organization Factors. S. 178-190.**

**Objective:** The aim of this study was to characterize associations between psychosocial and work organizational risk factors and upper-extremity musculoskeletal symptoms and disorders. **Background:** Methodological limitations of previous studies of psychosocial and work organizational risk factors and musculoskeletal outcomes have produced inconsistent associations. **Method:** In this prospective epidemiologic study of 386 workers, questionnaires to assess decision latitude ("control") and psychological job demands ("demand") were administered to study participants and were used to classify them into job strain "quadrants." Measures of job stress and job change were collected during each week of follow-up. Incident hand/arm and neck/shoulder symptoms and disorders were ascertained weekly. Associations between exposure measures and musculoskeletal outcomes were estimated with proportional hazard methods. **Results:** When compared to the low-demand/high-control job strain referent category, large increases in risk of hand/arm disorders were observed for both high-demand/high-control (hazard ratio [HR] = 4.49, 95% confidence interval [CI] = [1.23, 16.4]) and high-demand/low-control job strain categories (HR = 5.18, 95% CI = [1.39, 19.4]). Similar associations were observed for hand/arm symptoms. A strong association was also observed between the low-demand/low-control job strain category and neck/shoulder disorders (HR = 6.46, 95% CI = [1.46, 28.6]). Statistically significant associations were also observed between weekly stress level and weekly job change and several musculoskeletal outcomes. **Conclusion:** Associations between psychosocial risk factors and work organizational factors and musculoskeletal outcomes were large and in the hypothesized direction. **Application:** Prevention of occupational musculoskeletal disorders may require attention to psychosocial and work organizational factors in addition to physical factors. Methods to control adverse effects of psychosocial and work organizational risk factors should be explored.

- **Keywords:** psychosocial, work organization, musculoskeletal disorder, prospective study, epidemiology

**Kurt T. Hegmann, Matthew S. Thiese, Eric M. Wood, Arun Garg, Jay M. Kapellusch, James Foster, Jeremy Biggs, Hannah Edwards, Jacqueline Wertsch, and Richard Kendall. Impacts of Differences in Epidemiological Case Definitions on Prevalence for Upper-Extremity Musculoskeletal Disorders. S. 191-202.**

**Objective:** The aim of this study was to systematically evaluate prevalence based on variations in case definitions used for epidemiological studies of musculoskeletal disorders (MSDs). **Background:** Prior studies of MSDs have mostly relied on a single case definition based on questionnaires. **Method:** In a multicenter prospective cohort study, we systematically collected data to evaluate impacts of differences in case definitions of MSDs on prevalence of three common musculoskeletal disorders: (a) shoulder tendinosis, (b) lateral epicondylalgia, and (c) carpal tunnel syndrome. Production workers were from 21 employment settings in three diverse U.S. states and performed widely varying work. All workers completed laptop-administered structured interviews, two standardized physical examinations, and nerve conduction studies (NCS). Case definitions included symptoms only, and symptoms plus physical examinations and/or NCS. **Results:** A total of 1,227 subjects had complete health data at baseline. The prevalence for shoulder tendinosis is 23.0% if only glenohumeral pain is used for a case definition, compared with 8.0% if a combination of pain plus a positive supraspinatus test is used. The prevalence for lateral epicondylalgia varied on the basis of lateral elbow pain (12.0%), pain plus tenderness on palpation (9.9%), or pain plus tenderness on palpation plus resisted wrist or middle finger extension (3.5%). Carpal

tunnel syndrome prevalence varied on the basis of tingling or numbness in a median nerve-served digit (29.9%) or tingling or numbness plus NCS abnormalities consistent with carpal tunnel syndrome (9.0%). **Conclusion:** Variations in epidemiological case definitions have major impacts on prevalence of common MSDs. Wide-ranging differences in prevalence may have impacts on purported risk factors that need to be determined.

- **Keywords:** epidemiology, rotator cuff tendinitis, lateral epicondylitis, carpal tunnel syndrome, ergonomics

**Thomas R. Waters, Leslie A. MacDonald, Stephen D. Hudock, and Donald E. Goddard. Provisional Recommended Weight Limits for Manual Lifting During Pregnancy. S. 203-214.**

**Objective:** The National Institute for Occupational Safety and Health (NIOSH) Revised Lifting Equation (RNLE) was adapted to derive recommended weight limits (RWLs) for pregnant workers and to develop corresponding guidelines for clinicians.

**Background:** In the past three decades there has been a large increase in the number of women employed outside the home and remaining in the workforce during pregnancy. Practical authoritative guidelines based on accumulated evidence are needed to inform allowable work activity levels for healthy pregnant workers. **Method:** Empirically based lifting criteria established by NIOSH to reduce the risk of overexertion injuries in the general U.S. working population were evaluated for application to pregnant workers. Our evaluation included an extensive review of the literature linking occupational lifting to maternal and fetal health. Decision logic and supporting literature are presented, along with computational details. **Results:** Provisional RWLs for pregnant workers were derived from the RNLE, along with guidelines for clinicians. The guidelines advise against pregnant workers lifting below midshin and overhead. **Conclusion:** Based on our review of the available evidence, we present lifting thresholds that most pregnant workers with uncomplicated pregnancies should be able to perform without increased risk of adverse maternal and fetal health consequences. Except for restrictions involving lifting from the floor and overhead, the provisional guidelines presented are compatible with NIOSH lifting recommendations adopted in the early 1990s for the general working population.

**Application:** Implementation of these provisional guidelines could protect millions of female workers in the workplace from fetal and maternal lifting-related health problems.

- **Keywords:** manual lifting, occupational hazard, pregnancy, recommendations

**Helena Miranda, Laura Punnett, Rebecca J. Gore, and the ProCare Research Team. Musculoskeletal Pain and Reported Workplace Assault: A Prospective Study of Clinical Staff in Nursing Homes. S. 215-227.**

**Objective:** This study examined prospectively the effect of workplace violence on musculoskeletal symptoms among nursing home workers. **Background:** Previously we reported a cross-sectional relationship between physical assaults at work and musculoskeletal pain. This follow-up provides stronger evidence of the effect of workplace violence on musculoskeletal outcomes within the same workforce over two years. **Method:** Nursing home workers who responded to three consecutive annual surveys formed the study cohort ( $n = 344$ ). The outcomes were any musculoskeletal pain, widespread pain, pain intensity, pain interference with work and sleep, and co-occurring pain with depression. The main predictor was self-reported physical assault at work during the 3 months preceding each survey. Prevalence ratios (PRs) were assessed

with log-binomial regression, adjusting for other workplace and individual factors. **Results:** Every fourth nursing home worker, and 34% of nursing aides, reported persistent workplace assault over the 2 years. Among respondents assaulted frequently, two thirds experienced moderate to extreme musculoskeletal pain, and more than 50% had pain interfering with work and/or sleep. Baseline exposure to assault predicted pain outcomes 1 year later. Repeated exposure was associated with a linear increase over 2 years in the risks of pain intensity, interference with work, and interference with sleep; co-occurring pain and depression had an adjusted PR of 3.6 (95% CI = 1.7–7.9). **Conclusion:** Workplace assault, especially when repeated over time, increases the risk of pain that may jeopardize workers' ability to remain employed. **Application:** More effective assault prevention would protect and support the workforce needed to care for our increasing elderly and disabled population.

- **Keywords:** depression, epidemiology, health care, multisite pain, musculoskeletal, sleep, work ability, workplace violence

**Mark Cote, Anne Kenny, Jeffrey Dussetschleger, Dana Farr, Ashok Chaurasia, and Martin Cherniack. Reference Values for Physical Performance Measures in the Aging Working Population. S. 228-242.**

**Objective:** The aim of this study was to determine reference physical performance values in older aging workers. **Background:** Cross-sectional physical performance measures were collected for 736 manufacturing workers to assess effects of work and nonwork factors on age-related changes in musculoskeletal function and health. **Method:** Participants underwent surveys and physical testing that included bioelectrical impedance analysis, range-of-motion measures, exercise testing, and dynamic assessment. **Results:** Physical characteristics, such as blood pressure and body fat percentage, were comparable to published values. Dynamic and range-of-motion measurements differed from published normative results. Women had age-related decreases in cervical extension and lateral rotation. Older men had better spinal flexion than expected. Predicted age-related decline in lower-extremity strength and shoulder strength in women was not seen. Men declined in handgrip, lower-extremity strength, and knee extension strength, but not trunk strength, across age groups. There was no appreciable decline in muscle fatigue at the trunk, shoulder, and knee with aging for either gender, except for the youngest age group of women. **Conclusion:** Normative values may underestimate physical performance in "healthy" older workers, thereby underappreciating declines in less healthy older workers. Work may be preservative of function for a large group of selected individuals. A "healthy worker effect" may be greater for musculoskeletal disease and function than for heart disease and mortality. **Application:** Clinicians and researchers studying musculoskeletal function in older workers can use a more specific set of reference values.

- **Keywords:** aging workforce, physical performance, dynamic function