

## **Symposium: Force and Repetition - Relative Contributions to Upper Extremity Disorders and Fatigue**

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Discussants: Arun Garg<sup>c</sup>; Jim Potvin<sup>d</sup>; Carisa Harris-Adamson<sup>a</sup>; Roberta Bonfiglioli<sup>b</sup>; David Rempel<sup>a</sup>

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### **1. Introduction**

Recent prospective studies of production workers have found that workplace risks for distal upper extremity disorders include hand force, exertion rate, and duty cycle. However, the conclusions are not homogeneous. Differences between studies in the contributions of force and repetition will be explored in this symposium with new data analyses, examination of differences in exposure assessment methods and exposure levels. In addition, related findings from psychophysical studies of fatigue will be presented.

Objectives: Attendees should have a better understanding of findings from recent prospective studies on the relative contributions of repetition, force, and duty cycle to distal upper extremity musculoskeletal disorders and fatigue. They should be able to explain and apply the findings to their professional practice or research.

### **2. Arun Garg: Definitions of force and repetition: Associations with upper limb MSDs**

A review of upper limb MSD literature was conducted to present definitions used to quantify force and repetition; present cut points used to classify risk from force and repetition; and discuss advantages and disadvantages of different definitions and classifications. Epidemiological studies have quantified force using electromyography, Borg CR-10 scale, 0-10 visual analog scale, the 5-point Strain Index scale and simply high-low forces. Repetition definitions have included: exertions/min., Hand Activity Level, % of duty cycle, classifying exertions into 5 categories using the Strain Index scale, simply high-low repetitions and "significant exertions". Some definitions of repetition were confounded with force. Practical difficulties in applying these definitions in field studies will be discussed. (Bao et al. 2015)

### **3. Jim Potvin: Findings from psychophysical studies on repetitive upper extremity tasks**

Ergonomists must often estimate maximum acceptable forces or torques for hand intensive tasks. There is a large biomechanical database of strength values to determine acceptable loads for tasks that are done very infrequently. However, there are far less published psychophysical and/or physiological data to guide the determination of acceptable loads for repetitive, submaximal occupational tasks. The purpose of this research was to develop an equation that uses either frequency or duty cycle (DC) to predict maximum acceptable efforts (MAE) relative to maximum strength. Based on 75 tasks, from eight psychophysical studies of the upper extremities, maximum acceptable efforts (MAE) were calculated. While there was a poor relationship between MAE and frequency, the relationship was much stronger between MAE and DC. The resulting equation took the form:  $MAE = 1 - DC^{0.24}$  and it fit the experimental MAE very well ( $r^2 = 0.89$ , RMS difference = 7.0% MVC). The MAE equation now allows for a scaling of the much more prevalent strength database, to estimate acceptable load limits for repetitive tasks. In contrast, there was a much weaker relationship between frequency and MAE, demonstrating the importance of using duty cycle, which combines duration and frequency, when designing repetitive tasks to avoid muscle fatigue. (Potvin 2012)

**4. Carisa Harris-Adamson: The association of force and repetition with wrist tendinosis among blue-collar workers in the San Francisco study**

Workers (N=413) at four industries were followed for up to 28 months to identify incident cases of hand wrist tendinosis. Self-report, direct measure, observer-rated measures were used to quantify force and repetition. Video analysis determined the percent time (% time) in heavy pinch (>1 kg-force) or power grip (>4 kg-force), the overall repetition rate, and forceful repetition rate. A proportional hazards model was used to assess the relationship between exposures and incidence of wrist tendinosis with adjustment for personal factors and other exposures. There were 26 incident cases of wrist tendinosis during the follow-up. Normalized peak force showed an increase risk of developing wrist tendinosis for medium (HR=2.20; 95%CI: 0.70-6.96) and high (HR=3.36; 95%CI: 1.01-11.18) exposure groups with adjustment for repetition. Total repetition rate HRs for medium and high groups were 0.67 (95%CI: 0.22-2.06) and 0.83 (95%CI: 0.27- 2.59). Workplace factors most associated with wrist tendinosis were time-weighted measures of force. (Harris et al. 2011)

**5. Roberta Bonfiglioli: Findings on carpal tunnel syndrome from the prospective Italian cohort study on manual workers**

The role of repetition (hand activity level – HAL) and manual force (normalized peak force – nPF), in the development of carpal tunnel syndrome (CTS) was studied in a cohort of industrial workers using the ACGIH TLV for HAL model. Cases were based on symptoms and positive nerve conduction studies. Poisson regression models including age, gender, BMI, and presence of predisposing pathologies were conducted to estimate incidence rate ratios (IRR). 2,982 subjects had complete information at baseline and at least one follow-up. We observed 147 cases of CTS in 9,390 person-years. HAL predicted the incidence of CTS (IRR for unitary increase 1.26, 95%CI 1.12–1.42); only marginal evidence was observed for nPF (IRR for unitary increase 1.12, 95%CI 0.98–1.28). When HAL and nPF were modeled together, HAL was still associated with the outcome (IRR 1.26, 95%CI 1.10–1.43), while no increased risk of CTS was observed for nPF (IRR 1.01, 95%CI 0.88–1.16). Our findings support the hypothesis that preventive efforts should target (fast) steady motions/exertions. (Bonfiglioli et al. 2013)

**6. David Rempel: Work-related factors associated with carpal tunnel syndrome: Analysis of pooled prospective data from 2532 workers**

Five research groups in the US participated in the NIOSH Consortium study which pooled data from their prospective studies of production workers to evaluate workplace risk factors for carpal tunnel syndrome (CTS). Individual workplace exposure measures of were collected by observation and video analysis for each task and included various measures of hand force, repetition, and duty cycle. 2474 participants, without CTS or polyneuropathy at enrolment, were followed up to 6.5 years (5102 person-years) and there were 182 incident cases of CTS. After adjustment for covariates, analyst (HR=2.17; 95% CI: 1.38-3.43) and worker (HR=2.08; 95% CI: 1.31-3.39) estimated peak hand force, video based forceful repetition rate (HR=1.84; 95% CI: 1.19-2.86), and percent time in forceful hand exertions (HR=2.05; 95% CI: 1.34-3.15) were associated with increased risk of CTS. Associations were not observed between total hand repetition rate or percent duration all hand exertions and CTS. In this study, measures of forceful hand exertion were associated with incident CTS but measures of total hand repetition rate were not (Harris-Adamson et al. 2015).

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