**Harris-Adamson C, Eisen EA, Kapellusch J, et al. Biomechanical risk factors for carpal tunnel syndrome: a pooled study of 2474 workers. Occup Environ Med 2015; 72:33–41.**

Design: multicenter prospective cohort study

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Purpose of study: to define the associations between workplace factors such as force and repetition with the occurrence of new cases of carpal tunnel syndrome (CTS)

Population/sample size/setting:

* 2474 workers (1200 men, 1274 women) studied at five NIOSH epidemiological sites in the United States
* Eligible workers were 18 or older and employed at a company where some workers performed hand-intensive activities such as manufacturing or assembling of products such as automobiles or auto parts, appliances, furniture, artificial stone, metal and plastic products, books, textiles, and other products
* Additional settings included some service industries, construction, agriculture, retail trade, and wholesale trade
* Workers who had already been diagnosed with CTS at the beginning of the study were excluded from the study; only workers free of CTS were studied

Assessments of exposures:

* Ten measures of workplace biomechanical exposure were collected for all participants: two measures of hand force, three measures of hand repetition, two measures of hand exertion duty cycle, two measures of wrist posture, and one measure of hand vibration
* Exposure estimates were based on observations of a trained analyst who was unaware of the worker’s health status
  + Information was obtained through observations of workers performing their usual tasks, through interviews with workers and supervisors, through videotape analysis of the tasks, and through measurements of hand force applied to complete each task (such as pinch force and grip force using dynamometers)
* The Borg CR-10 scale was recorded twice for each worker: as estimated by the worker (worker-rated peak hand force) and by the analyst (analyst-rated peak hand force); where a Borg scale >=2 was called forceful
  + Dynamometer readings were also used to estimate force; an exertion was classified as forceful if it involved >= 9 N of pinch force or >= 45 N grip force
* The repetitiveness of tasks was estimated by the analyst using the Hand Activity Level (HAL) scale
* Hand exertion duty cycle was quantified for all exertions (% of time all exertions) and for forceful exertions (% of time forceful exertions)
* Posture was quantified as % of time with the wrist in >= 30 degrees of extension or % of time with the wrist in >= 30 degrees flexion
* Vibration was recorded as a yes/no variable as observed by the analyst
* Three standard approaches were used to summarize the task-level exposures: peak level, typical level, and time-weighted average (TWA)
  + Because these three approaches were highly correlated, only the TWA was used in the analyses of exposure
* Other personal factors were recorded for each worker: age, gender, BMI, race/ethnicity, education, hand dominance, and medical comorbidities such as diabetes, thyroid disease, and rheumatoid arthritis
  + General health was assessed on a five point scale
  + Total years at the current employer was self-reported by the worker

Outcome assessment:

* Incident CTS in the dominant hand was the main study outcome and required (1) symptoms of numbness, tingling, burning, or pain in the median nerve distribution and (2) median mononeuropathy at the wrist as confirmed by electrodiagnostic (EDS) testing
  + Criteria for median mononeuropathy were defined in terms of peak sensory latency, onset sensory latency, motor latency, transcarpal sensory difference, and absence of evidence of ulnar nerve abnormalities
  + If ulnar nerve EDS abnormalities were present, the worker was classified as having a polyneuropathy and was excluded from the counting of CTS cases

Assessment of exposure/outcome associations:

* The main measure of the associations between work factors and CTS was expressed in terms of hazard ratios (HR), which compare time to occurrence of specific events in different groups of patients; a HR of 2.0 means that in a given period of time, twice as many new cases of CTS occur in one group than in a comparison group
* Among the 2474 workers in the study, 179 new cases occurred during 5103 person-years of followup, for an incidence rate of 3.51 per 100 person-years
* For purposes of analysis, the exposure variables were divided into tertiles; the lowest tertile was treated as unexposed, with HR calculated for the middle and for the highest tertile in relation to the unexposed tertile
* The main pertinent findings were as follows:
  + For analyst-rated peak hand force, the HR for the middle tertile was 1.59 (95% confidence interval 1.09 to 2.34), suggesting a 60% increased risk of CTS for this tertile; for the highest tertile, the HR was 2.17 (95% CI 1.38 to 3.43)
  + Similar patterns were observed for the tertiles of worker-rated peak hand force
  + For *forceful* hand repetition rate, the HR for the middle tertile was 1.53 (95% CI 1.05 to 2.25); for the highest tertile, the HR was 1.84 (95% CI 1.19 to 2.86)
    - For *total* hand repetition rate, however, there was no increase of HR with increasing tertiles of exposure
  + The data on duty cycle were similar to the above; the % time for *all* hand exertion was not related to incident CTS, but the % time for forceful hand exertion (9 N pinch grip or 45 N hand grip) was related to CTS; the HR for the middle tertile was 1.46 (95% CI 0.98 to 2.17); for the highest tertile, the HR was 2.05 (95% CI 1.34 to 3.15)
  + The analyst HAL scale did not show a convincing relationship with CTS; the HR was elevated for the middle tertile but not for the highest tertile
  + No associations with CTS were seen for either wrist posture or for vibration
  + A post hoc analysis was carried out to explore whether there was an interaction between repetition rate and force; that is, whether the effect of a high repetition rate depended on the level of force, and whether the effect of force depended on the level of the repetition rate; such interactions did appear in the data
    - If the rate of hand repetition was <=18.1 repetitions/min, the level of analyst-rated peak hand force did not have a clear association with CTS, but if the rate was >18.1/min, analyst-rated peak hand force was associated with CTS (the HR for the middle tertile was 2.78 and for the highest tertile the HR was 2.97)
    - However, the analysis by levels of analyst-rated peak hand force (whether it was greater or less than 3 on the CR-10 scale) did not show an interaction with repetition rate; for both levels of analyst-rated peak hand force, the middle and highest tertiles had the same risk of CTS as the lowest tertile
  + The authors looked for a healthy worker survivor effect; that is, whether workplace exposures appear to be associated with CTS in workers who started their jobs recently but not associated with CTS in workers who have remained on the job longer; this can mean that workers who are vulnerable to the effects of hand force leave employment fairly early, and workers who are less vulnerable remain in employment; if this is the case, workers with less time in employment may show associations with CTS which are not seen in workers with more time in employment
    - This did appear to be the case; for analyst-rated peak hand force, the HR in the highest tertile was 3.37 in workers with less than 3 years on the job; for workers with more than 3 years, the HR for the highest tertile was 1.88

Authors’ conclusions:

* The incidence of CTS was 3.51 per 100 person-years
* The risk of CTS increased with higher levels of peak hand force, whether it was analyst-rated peak hand force or worker-rated peak hand force
* Both worker and analyst-rated peak hand force were associated with CTS, and either scale is satisfactory for purposes of workplace surveillance
* No association was observed with wrist position, but the workers in the cohort did not require much wrist flexion or extension, and very little time was spent with the wrist flexed or extended more than 30 degrees
* The workers who spent between 11% and 32% of their work time in forceful hand exertion had a 46% increase of the rate of CTS, and those who spent more than 32% of their time in forceful hand exertion had twice the risk of CTS compared to those with less than 11% of the time in forceful hand exertion
* There was a scarcity of data for some of the higher levels of forceful repetition exposure, and the confidence intervals for these higher levels become wide and uncertain
* The interaction between analyst-rated peak hand force and repetition rate suggests that workers may tolerate forceful exertion at low levels of repetition better than they do at higher levels of repetition
* The healthy worker survivor effect seen in the data suggest that workers who develop CTS are likely to drop out of the workforce in the first few years of employment; this suggests that the effects of forceful repetition are likely to be underestimated rather than overestimated in this study
* There may be some limitations in the data due to the fact that the five participating study centers did not use identical methods of measuring exposure data, which is likely to lead to underestimation of the effects of workplace exposures on CTS
* Repetition alone was not seen to be an important risk factor for CTS unless it was accompanied by forceful pinch or hand grip

Comments:

* The ascertainment of exposure and of CTS status are measured with greater precision than in most other studies of CTS in the workplace, and its design as a cohort study is an important strength
* Some of the methodology for the study was not reported in the article, but was reported elsewhere (Kapellusch 2013); for example, the measurement of force by dynamometer was reported there but not in the methods section of this article
* The levels of force can be expressed conveniently in terms which can be applied in the evaluation of work-relatedness; 45 N of hand force is 10 pounds, and 9 N of pinch force is 2 pounds
  + The data were not disaggregated separately into hand force and pinch force, and it is not clear whether one is more influential than the other for increasing the risk of CTS
* The middle tertile of analyst-rated peak hand force was between 2.5 and 4 on the CR-10 scale, and the highest tertile was >4 (the worker rated force not greatly different)
  + This is somewhat subjective, if the CR-10 scale of 2 is “easy,” 3 is “moderate,” and 4 is “somewhat hard”
  + It may be preferable to apply the findings from the video analyses of forceful hand repetition rate in Table 3 for purposes of translating the findings into useful information
    - That is, the middle tertile of forceful hand repletion rate has an estimated adjusted HR of 1.53 for rates between 2.6 and 9.6 per minute
    - This could be expressed as saying that the risk of CTS increases by approximately one half when the worker has between 3 and 9 repetitions per minute of hand grip of 10 pounds or pinch grip of 2 pounds
    - Similarly, there is approximately an 84% increase in the risk of CTS when there are 10 or more repetitions per minute involving 10 pounds of hand grip of 2 pounds of pinch grip
* It is important to note that the reason that the authors did not find an association with hand posture is that there was too little variation in the population with respect to hand flexion and extension, and no inferences should be made that hand posture is irrelevant to CTS
* The analysis of statistical interactions between analyst-rated peak hand force and total hand repetition was reported as having been done post hoc; this need not lead to its dismissal
  + Kapellusch 2013 reported that the study planned an analysis of interaction between high force and high repetition
  + The levels of force planned in Kapellusch were not exactly those in the current study, since Kapellusch planned to use CR-10 cutoffs of >=2 and >=4, while the current study used CR-10 cutoffs of 3
  + However, since the information obtained from the analyses by tertiles of exposure essentially do show an interaction (force makes a difference when repeated frequently but not when repeated infrequently), the analyses for the interactions are consistent with the main analyses and do not have to be reported as separate phenomena
* It should also be remembered that the healthy worker survivor effect is likely to mean that the estimates of forceful repetition are somewhat conservative and are probably not overestimated for most workers in industry

Assessment: high quality cohort study supporting good evidence that the risk of CTS in the workplace is affected by forceful repetition, that the risk of CTS increases by one half when workers use 2 pounds of pinch force or 10 pounds of hand force between 3 and 10 times per minute, and that the risk increases by approximately 84% when these forces are applied more than 10 times per minute

Reference:

Kapellusch J, Garg A, Bao S, et al. Pooling job physical exposure data from multiple sites in a study of carpal tunnel syndrome. Ergonomics 2013;56:1021–37.