Frost P, Bonde JPE, et al. Risk of Shoulder Tendinitis in Relation to Shoulder Loads in Monotonous Repetitive Work. Am J Ind Med 2002;41:11-18.

Design: cross-sectional study

Study question: Which, if any, biomechanical factors in the workplace are risk factors for shoulder tendinitis?

Population/sample size/setting:

- 2846 manual workers (1728 women, 1118 men, mean age 39) at 19 workplaces in Denmark, including 4 food processing plants, 3 cardboard industries, and 4 electronic plants
- Workers were recruited in a Danish government study, the Project on Research and Intervention in Monotonous work
- All currently employed manual workers from the workplaces were eligible

Assessment of exposure:

- The principal biomechanical factors of interest were repetition, force, and lack of micro-pauses during the execution of job tasks
    - A micro-pause was defined as occurring when the arm was hanging down or was supported for more than 2 seconds, taking mechanical loads off the shoulder
- Job tasks were classified by ergonomists, who classified tasks as either repetitive or control tasks; jobs classified as repetitive were further assessed with videotapes
- The ergonomists videotaped workers from three different camera angles for at least 10 working cycles or for a minimum period of 10-15 minutes, and the videotapes were also used to estimate force requirements for the job tasks
    - The assessment of force requirements had been tested against EMG measurements in a separate study, and showed "good agreement" with the videotape estimation
    - Force requirements were categorized in terms of the percent of Maximal Voluntary Contraction (MVC)
        - Light was <10% MVC
        - Somewhat hard was 10-29% MVC
        - Hard was 30-49% MVC
        - Very hard was 50-79% MVC
        - Near maximal was >= 80% MVC
- A large number (103) of tasks were defined by the researchers, but these were condensed into 5 task groups for purposes of allocating time-weighted exposure measurements

    - Workers estimated their task distribution during a normal 37 hour work week (55% had only one task during a week, but the other 45% had more than one task)
        - For workers with more than one task, the relative time at each task was multiplied by the level of exposure for that task; these time-exposure products were then added up to yield a time-weighted exposure measurement
        - In this way, different exposure profiles could result in the same time-weighted exposure level estimates
    - Other factors potentially associated with musculoskeletal problems were assessed: psychosocial job characteristics, psychological demands at work, and social support; age, gender, and BMI were recorded as potential confounders
        - An additional potential confounder was pain sensitivity threshold; this was assessed with pain pressure thresholds in the tibia and vastus medialis
        - Leisure physical activity, overhead sports, previous shoulder trauma, and arthritis/connective tissue disorder were also determined

Assessment of shoulder pain and impairment:

- Shoulder pain and impairment were self-reported on four ten-point scales (0-9): worst and average pain in the last 3 months, average pain in the past 7 days, and severity of activity impairment due to pain in the past 3 months
- Three teams of physicians did on site physical examinations according to a defined protocol, who were not informed about exposure and health status
    - Resisted abduction pain, impingement pain, and tenderness at the greater tuberosity were registered, with a maximum score of 36 points
    - A score greater than 12 points was defined as shoulder tendinitis
        - This cutpoint had been previously proven sensitive in identifying persons with clinical signs of shoulder disorder

Analysis of exposure: tendinitis relationships:

- The prevalence of dominant shoulder tendinitis was the main outcome variable
- The workplace main factors of interest were repetitive work, force requirements, and lack of micro-pauses
    - These main factors were adjusted for occupational health center (3 levels for the 3 separate centers), age, age squared, gender, high BMI, low pain threshold, low leisure time activity, overhead sports activity, and arthritis
- A reference group (n=793) had been classed as having non-repetitive jobs and were assumed to have no exposure to the biomechanical factors of interest

- The analyses were done for the 1964 workers whose tasks had been observed by the ergonomic team; 378 workers with missing information were excluded
- There were 88 workers who met the criteria for tendinitis; 58 of these had tendinitis in the dominant shoulder, and 55 (7 in the reference group and 48 in the repetitive work group) were analyzed in a multiple logistic regression model adjusted for the above confounders to produce adjusted odds ratios for tendinitis

Results:

- For repetitive work overall, the odds ratio was 3.12
    - For low frequency repetitive work (1-14 movements/min) the odds ratio was 2.93
    - For higher frequency repetitive work (15-36 movements/min), the odds ratio was 3.29
- For high force (more than 10% of MVC), the odds ratio was 4.21
    - For repetitive work and low force (<10% of MVC), the odds ratio was not statistically significant
- For combinations of force and repetitive work, high frequency and high force had an odds ratio of 4.82
- For high frequency and lack of micro-pauses, the odds ratio was 3.53
- For high force and lack of pauses, the odds ratio was 4.48

Authors' conclusions:

- Workers in manual repetitive tasks with increased force requirements have an increased risk of shoulder tendinitis
    - Repetitive jobs without forceful loads appear to have no increased risk of shoulder tendinitis
    - Lack of recovery time in combination with high force demands is an important risk factor for shoulder tendinitis
- The cross-sectional design of the study may underestimate the baseline risk, since current workers represent a survivor population from which workers who left the workforce are not represented
- The time-weighted assessment of exposure assigns equivalent exposure to workers with short periods at a high task exposure and long periods with a lower task exposure; precautions may be warranted in interpreting risk estimates based on time-weighted exposures

Comments:

- While ergonomists used videotape to assess task exposures, making them independent of self-report, assessment of exposure did require self-report for the time spent in the tasks for which the ergonomists had assessed the level of exposure

- Figure 1 represents a relation between median shoulder movements per minute and the percent of weekly time in job tasks
    - There is little to no explanation of the polynomial regression (which included a cubic term); it may be simpler to say that the more shoulder movements per minute, the less time per week was spent at that level of repetition intensity
    - The fitted curves appear to have two bends or humps; this is the kind of curve for which a cubic term would be expected in a polynomial regression, but there is no convincing explanation of how the curves were constructed from the data
- Table II displays the numbers of workers per exposure category, the number of incident cases of shoulder tendinitis, the percent of workers with new tendinitis, a crude odds ratio, an adjusted odds ratio, and a 95% confidence interval for the adjusted odds ratio
    - From the text, it appears that all eleven potential confounders were retained in the logistic regression model for each time an exposure variable was analyzed
    - However, the adjusted and crude odds ratios do not differ very much for most exposures, suggesting that there was minimal confounding of the exposure-tendinitis relationship
    - It is a general principle of logistic regression that the estimates of the odds ratio become unstable if too many variables are retained in the model in relation to the number of "events" for the exposure whose effect are being estimated
        - For example, the odds ratio for "low frequency and high force" in Table II had only 4 cases of tendinitis being compared to 7 cases in the reference group; the regression model is seriously "overloaded" for this and for several other exposure categories
    - A consequence of keeping all eleven confounders in the logistic model is that the 95% confidence intervals may be wider than they ought to be, and might have been narrower if fewer unnecessary variables had been retained in the model each time the logistic model was fitted
- It was not feasible to measure exposure in the reference group, and it was assumed that there was zero exposure in that group; if there was at least some forceful or repetitive shoulder movement in the reference group, this would tend to yield a conservative estimate of the odds ratios for the exposed groups
    - This suggests that the odds ratios are not likely to be inflated estimates of the effects of exposure
- Similarly, as the authors note in the discussion, a healthy worker survivor effect, which loses workers who dropped out of work for any reason, also would tend to lead to a conservative, not an inflated, odds ratio for exposure and tendinitis

- The amount of repetitive movement associated with tendinitis is difficult to estimate, since “repetitive work” has an elevated odds ratio, and both groups of repetitive work, 1 to 14 and 15 to 36 movements per minute, separately have elevated odds ratios, and one movement per minute is probably not appropriately combined with 14 movements per minute

Assessment: Adequate for evidence of these exposure-tendinitis associations: force requirements in which more than 10% of maximum voluntary contraction are regularly exerted, in combination with a lack of brief pauses (2 seconds) between motions, or with frequency greater than 15 movements per minute, increase the risk of tendinitis three to fourfold.