Webinar: Ergonomic Methods to Assess Complex Jobs – Cumulative Effects of Multiple Sub-tasks

Risk is determined based on the balance of load versus capacity

- Most assessment tools assess a single task, and many are based on maximum effort
    - PROBLEM: Most jobs include multiple tasks that are very different

<u>Structure of Tissues</u>

- Passive: Connective tissue (fibrous vs elastic)
    - Mechanics of the tissue can be explained through a stress/strain curve based on a single type of load (Figure 1)
        - Elastic region = ability for the tissue to recover via healing mechanisms
        - Plastic region = permanent tissue damage
    - NIOSH action limit based on cadaveric spine testing (Figure 2)
        - Variability in mean values within and between studies
        - Action limit threshold is set at 3400N, but it doesn't mean that every spine is going to result in damage after 3400N
            - There is a continuum of risk based on individual factors, but this is the cut-off value in which we base decisions on

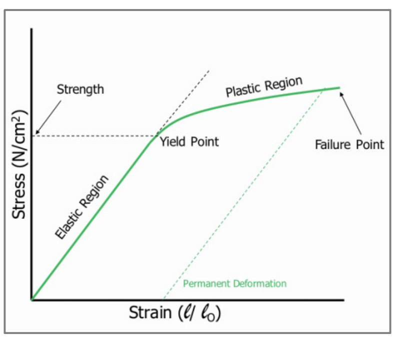

Figure 1: Passive tissue stress/strain curve

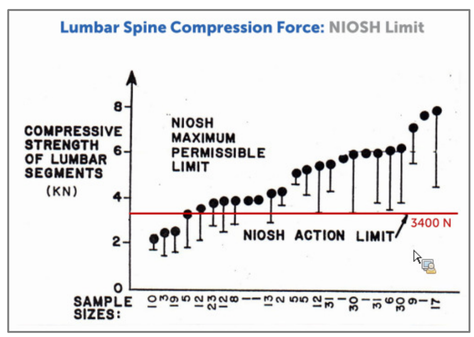

Figure 2: Compressive strength of cadaveric spines

- Mechanics of the tissue based on repetitive loading
    - Increasing repetition rate results in reduction in acceptable forces (Figure 3)
    - Sub-maximal loading over time without adequate recovery time reduces tissue tolerance and can lead to injury (Figure 4)

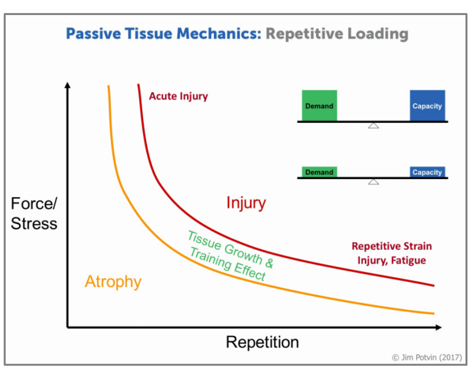

Figure 3: Force-repetition curve

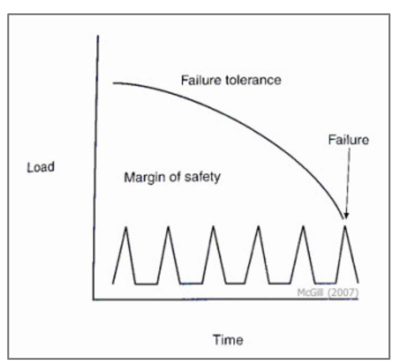

Figure 4: Repetitive loading over time

- Cumulative tissue loading
    - PROBLEM: Current ergonomic assessment tools assess individual tasks and not the cumulative effect of all tasks
    - Example: All individual tasks are below the NIOSH compression limit, but is the cumulative exposure to these tasks acceptable? (Figure 5)

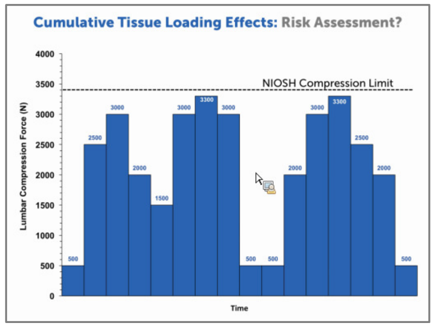

Figure 5: Example of individual task-based NIOSH assessments

- Active: Muscle tissue
    - Muscle fatigue is a temporary decrease in force/power capacity of skeletal muscle
        - Resulting from repetitive/prolonged efforts
        - Can exist even if a submaximal target force can still be achieved
        - Fatigue is not an event, but a process
    - Muscle tissue
        - Made up of a series of fascicles controlled by motor units, which are innervated by motor neurons
        - Each motor neuron innervates the same type of muscle fibres (fast vs slow twitch)
        - Motor recruitment:
            - Small, slow twitch (low threshold) are activated first and shut off last (Cinderella fibres – activated the entire time)
                - Typically fatigued with cumulative exposure due to inadequate recovery time
            - Increasing % MVC recruits intermediate and then large, high threshold motor units; high threshold cannot be maintained for long durations
    - Endurance time
        - Holding a contraction over time (amount of force that can be sustained over time)
        - Increasing the effort required reduces the time is can be sustained
            - Not a linear trend
            - Not directly applicable to many work tasks due to variability in demands
    - Fatigue recovery
        - Rohmert rest allowances for sustained/intermittent contractions
        - Unknown effect of aging on recovery from fatigue – research required
    - Prolonged repetitive tasks
        - Fatigue can cause progressive tissue damage as well as altering muscle coordination and technique
            - May result in injury, decreased quality/productivity, etc.

<u>Current Assessment Methods for Cumulative Exposure</u>

- Metabolic equations (Garg et al., 1978)
    - Sum of kcals required for each sub-task
- NIOSH Composite Lifting Index (CLI)
    - Incorporates assessment of the cumulative impact of several lifting tasks
- Cumulative spine compression and shear
    - 3D Match software (Callaghan)
        - Force & posture analysis of sub-tasks based on a video
    - Lumbar motion monitor (Marras)
        - Directly measures spine kinematics

<u>Recent Technology and Ergonomic Tools that Assess Multiple Subtasks</u>

- Cumulative Passive Tissue Loading
    - Cumulative Lifting Index (CULI) for the Revised NIOSH Lifting Equation (Garg & Kapellusch, 2016)
        - Modified the NIOSH CLI – continuous function for Frequency Multiplier (FM)
        - Conclusion: CULI partially addressed the underestimation of physical exposure using the time-weighted average approach, and overestimation of exposure using the peak exposure approach
- Passive Tissue Fatigue Failure (Gallagher & Schall, 2016)
    - Predicting failure using the Palmer-Miner rule (dividing # of cycles completed by # of cycles to failure)
        - Incorporates varying tasks performed at different % MVC for different durations
- Metabolic cost
    - Wearable technology
        - HR chest wrap or watches
        - Good sense of daily activity through steps
        - Garments to measure respiration, skin temperature (ex. Hexoskin, Montreal)
    - Increases in manual material handling for 'just-in-time' manufacturing
        - Wearable technology can streamline collection of data for ease of sampling data
- Recommended Cumulative Rest Allowance (RCRA) (Potvin)
    - Maximal acceptable effort for repetitive tasks (Potvin, 2012)
        - Assumes no contraction can be held indefinitely
    - ACGIH TLV released the 'Upper Limb Localized Fatigue: TLV(R)' (Figure 6)
        - Assumes a 6.6% contraction indefinitely

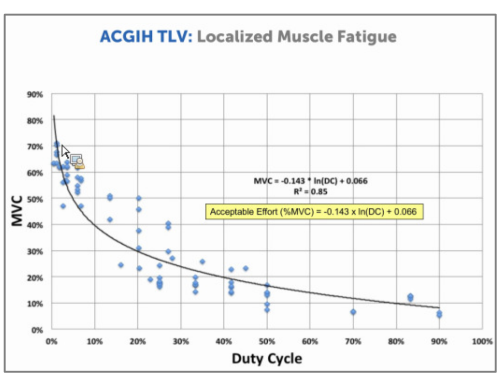

Figure 6: ACGIH TLV – Upper Limb Localized Fatigue

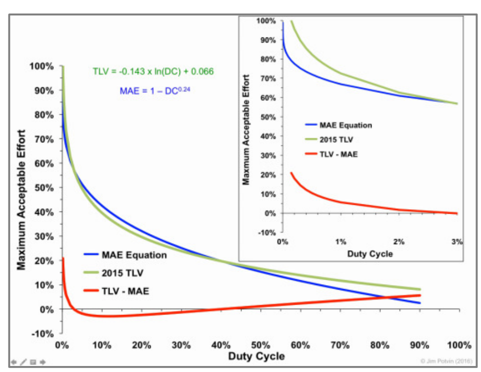

Figure 7: Comparison of MAE to ACGIH TLV

Assessment Tools Combining Multiple Subtasks

- Root-Mean-Quartic Equation
  - Combining different tasks requiring different %MVC
    - Allows assessment of different rotation schedules or work allocations
  - Weighted average of effort with MAE equation
  - Limitations identified with calculation
- Practical Fatigue Evaluation Model to Boost Productivity (Gibson): RCRA Method
  - Rearranged MAE equation to use holding time to predict recovery time
  - Outputs rest required in seconds/cycle
  - More conservative than Rohmert rest allowances
  - Gives a better sense of cumulative risk
    - *Jim Potvin shared excel spreadsheet of tool for trial*

Motion Capture & Posture Prediction

- SantosHuman Inc. software
- Task simulation builder – Jack software
- Wearable technology – motion capture
  - Validation studies being completed on Xsens, Perception Neuron