EPIDEMIOLOGY OF MUSCULOSKELETAL DISORDERS AMONG COMPUTER USERS: LESSON LEARNED FROM THE ROLES OF POSTURE AND KEYBOARD USE

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   Emory University
INTRODUCTION

More than half of US adults now use a computer at work

Widespread concern that computer users are at increased risk of upper-extremity musculoskeletal disorders

Prevention requires characterization of risk

Early studies compared keyboard users to non-users

Attention is focused on characteristics of computer work that might lead to increased risk
Is computer use associated with musculoskeletal outcomes?

Is the association causal or non-causal?

Review epidemiological evidence of associations between MSD outcomes and:
- computer user posture
- keyboard use intensity (hours/day or hours/week).
CAUSAL vs NON-CAUSAL ASSOCIATION (HILL, 1965)

Strength
Consistency
Specificity
**Temporality**
Biologic gradient
Plausibility
Coherence
Experimental evidence
Analogy

“None of my nine viewpoints can bring indisputable evidence for or against the cause and effect hypothesis…”

AB HILL, 1965
POSTURE AND MUSCULOSKELETAL OUTCOMES AMONG COMPUTER USERS

LITERATURE REVIEW:
Six field-based, observational epidemiologic studies in which measures of operator posture were used as exposure variables in analyses relating computer use to UEMSDs.

Only one study followed a cohort prospectively; the remaining five were of cross-sectional design.
Hunting et al., 1981

**Subjects:** 162 workers using VDTs and 133 comparison subjects

**Exposure:** VDT user posture assessed by direct measurement

**Health outcome:** Discomfort, upper extremity physical examination

**Results:**
- Ulnar deviation >20° was significantly associated with physical examination abnormalities for some categories of VDT work
- Negative association between keyboard height and musculoskeletal discomfort of neck, shoulder, and arms (higher keyboard = discomfort)
- Head rotation angle and head inclination angle discomfort and clinical abnorm.
- Ability to work with hands and forearms supported neck, shoulder, and arm pain
Starr et al., 1985

**Subjects:** 100 video display terminal operators

**Exposure:** VDT operator posture estimated from photographs taken while participants were keying

**Health outcome:** Musculoskeletal discomfort questionnaire

**Results:** Increasingly downward monitor viewing angle discomfort
Sauter et al., 1991

**Subjects**: 40 VDT users

**Exposure**: Direct measurement while the participant was working at his/her VDT workstation

**Health Outcomes**: Musculoskeletal discomfort rating scale

**Results**:

Right arm discomfort was associated with:
- Shoulder flexion (flexion discomfort)
- Relative keyboard height (keyboard height wrt elbow discomfort)
- Right hand ulnar deviation

Left arm discomfort was associated with:
- Relative keyboard height
- Relative document distance (document distance discomfort)
**Faucett and Rempel, 1994**

**Subjects:** 70 newspaper workers

**Exposure:** Direct measurement of VDT workstation configuration and operator posture

**Health outcome:** MSD outcomes were assessed with a questionnaire

**Results**

**Upper torso:**
- Head rotation and keyboard height above elbow height were associated with pain and stiffness severity
- Significant interactions were observed between posture and some psychosocial work factors and some upper torso MSD outcomes

**Upper extremity:**
- Significant interactions were observed between posture and some psychosocial work factors and some UE MSD outcomes
Bergqvist, et al., 1995

**Subjects**: 260 VDT users

**Exposure measures**: “extreme hand positions” and keyboard-elbow height difference

**Health outcomes**: MSD symptoms and clinical examination

**Results:**
- N/S outcomes were significantly associated with “too highly placed keyboard”
- Arm/hand symptoms were non-significantly associated with low keyboard placement
- Arm/hand symptoms (but not diagnoses) were significantly associated with “non-neutral position” of the wrists
- Odds ratios below 1.0 for associations between table “inadjustability” and shoulder disorders and between frequent overtime and neck diagnoses
Marcus et al., 2002

Subjects: 632 newly hired computer users

Exposure measures: direct measurement at time of enrollment

Health outcomes: symptoms and examination confirmed disorders

Results:

Neck/Shoulder outcomes: Lower risk associated with (significant or near significant):
- Inner elbow angle $>121^\circ$
- Greater downward head tilt
- Placement of the keyboard $>17$ cm from the edge of the desk
- Presence of armrests on the participants chair
- J key below elbow height
- Absence of telephone shoulder rest

Hand/Arm outcomes: Lower risk associated with:
- Horizontal location of the “J” key $>12.5$ cm from the edge of the desk
- Use of a keyboard with the “J” key $<3.5$ cm above the table surface
- Radial wrist deviation of $<5^\circ$ while using a mouse
## POSTURE AND NECK/SHOULDER MSD OUTCOMES

<table>
<thead>
<tr>
<th>Study</th>
<th>N</th>
<th>keyboard ht. below elbow ht.</th>
<th>armrest or ability to rest arms</th>
<th>downward head tilt</th>
<th>head rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hunting et al., 1981</td>
<td>295</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Starr et al., 1985</td>
<td>100</td>
<td>-</td>
<td>n.a.</td>
<td></td>
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<tr>
<td>Sauter et al., 1991</td>
<td>40</td>
<td>n.a.</td>
<td>n.a.</td>
<td></td>
<td>-</td>
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<tr>
<td>Faucett &amp; Rempel, '94</td>
<td>70</td>
<td>n.a.</td>
<td></td>
<td></td>
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<tr>
<td>Bergqvist et al., 1995</td>
<td>260</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td></td>
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<tr>
<td>Marcus et al., 2002</td>
<td>632</td>
<td></td>
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<td></td>
<td>-</td>
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</table>
## POSTURE AND HAND/ARM OUTCOMES

<table>
<thead>
<tr>
<th>Study</th>
<th>Sample size</th>
<th>Keyboard ht below elbow ht</th>
<th>Ulnar deviation</th>
<th>Radial deviation</th>
<th>Wrist extension</th>
<th>Wrist flexion</th>
<th>Keyboard thickness</th>
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<tbody>
<tr>
<td>Hunting et al., 1981</td>
<td>295</td>
<td>n.a.</td>
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<td>n.a.</td>
<td>n.a.</td>
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<td>Starr et al., 1985</td>
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<td>Sauter et al., 1991</td>
<td>40</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
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<tr>
<td>Faucett &amp; Rempel, 94</td>
<td>70</td>
<td>or **</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
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<tr>
<td>Marcus et al., 2002</td>
<td>632</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

* while using mouse
** depending on interaction term
WHY AREN’T THE RESULTS CONSISTENT?

CROSS SECTIONAL STUDY DESIGN

Associations may be observed between musculoskeletal illness and postures that were assumed after the illness onset (suggested by Bergqvist)

HETEROGENEITY OF EXPOSURE ESTIMATION AND HEALTH OUTCOME ASSESSMENT

INCOMPLETE CONTROL OF CONFOUNDING

  e.g., psychosocial stress
WHY AREN’T THE RESULTS CONSISTENT?

LIMITED PRECISION OF POSTURE ESTIMATION

How representative is one measure of posture?

Ortiz et al. (1997) performed a repeated measures study of postural variability between and within computer users.

For wrist, elbow, shoulder, and neck postures, variability was significantly greater between users than within users.

Ortiz et al. concluded that a single measure of posture can distinguish postures between participants in an epidemiological study.

-however-

Repeated measures would increase the precision of posture estimation and would improve power to detect posture effects.
WHY AREN’T THE RESULTS CONSISTENT?

NON-INDEPENDENCE OF POSTURAL VARIABLES

Upper limb postures are clearly biologically related to each other

Multivariable analyses that include multiple related postural measures may have estimation problems

If postures and musculoskeletal outcomes are modeled individually, associations may be confounded by the effects of postures not included in the model

Principal components analysis of the posture exposure variables
EFFECTS OF DAILY OR WEEKLY COMPUTER USE INTENSITY ON MSD OUTCOMES AMONG COMPUTER USERS

15 studies identified in which daily or weekly hours of computer use was examined as a risk factor for MSD outcomes

One prospective, 14 cross sectional
### KEYBOARD USE INTENSITY (HOURS/WEIGHT OR HOURS/DAY) AND MSD OUTCOMES

<table>
<thead>
<tr>
<th>Study</th>
<th>N</th>
<th>Neck/shoulder outcomes</th>
<th>Hand/arm outcomes</th>
<th>Location not specified</th>
<th>Comments</th>
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<tbody>
<tr>
<td>Canadian Labour Congress, 82</td>
<td>1742</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>Lower risk in highest category</td>
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<td>Sauter et al. 1983</td>
<td>333</td>
<td>n.a.</td>
<td>-</td>
<td>n.a.</td>
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<tr>
<td>Knave et al., 1985</td>
<td>550</td>
<td>n.a.</td>
<td>n.a.</td>
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<tr>
<td>Rossignol et al., 1987</td>
<td>1545</td>
<td>n.a.</td>
<td>n.a.</td>
<td></td>
<td>7 h/d vs 0 h/d</td>
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<tr>
<td>Fahrbach and Chapman, 1990</td>
<td>205</td>
<td>n.a.</td>
<td>n.a.</td>
<td></td>
<td>Possible confounding by gender</td>
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<tr>
<td>Sauter et al., 1991</td>
<td>539</td>
<td>n.a.</td>
<td>-</td>
<td>n.a.</td>
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<tr>
<td>Bergqvist et al., 1992</td>
<td>134</td>
<td>n.a.</td>
<td>-</td>
<td></td>
<td>&lt;5h/wk vs. &lt;30h/wk vs. &gt;30h/wk</td>
</tr>
<tr>
<td>Bernard et al., 1994</td>
<td>1000</td>
<td>-</td>
<td>n.a.</td>
<td></td>
<td>Possible threshold?</td>
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<tr>
<td>Faucett and Rempel, 1994</td>
<td>150</td>
<td></td>
<td>n.a.</td>
<td></td>
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<tr>
<td>Bergqvist et al., 1995</td>
<td>353</td>
<td>-</td>
<td>-</td>
<td></td>
<td>Sig. interaction with other expos.</td>
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<td>Polanyi et al., 1997</td>
<td>1007</td>
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<td>Evans and Patterson, 2000</td>
<td>170</td>
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<td>Katz et al., 2000</td>
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<td>College seniors</td>
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<tr>
<td>Marcus et al., 2002</td>
<td>632</td>
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<td>n.a.</td>
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<td>Prospective</td>
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<tr>
<td>TOTAL</td>
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<td>3</td>
<td>6</td>
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CONCLUSIONS

KEYBOARD USE AND MSD OUTCOMES

Greater consistency among studies

Hand/arm outcomes appear to be more consistently associated with keyboard use than neck/shoulder outcomes
REASONS FOR REMAINING INCONSISTENCY

Selective survival bias in cross sectional studies (can even observe paradoxical associations)

Cause-effect reversal bias

Information bias – exposure self-reported by persons with and without symptoms
AREAS WHERE KNOWLEDGE IS INCOMPLETE

Shape of the dose response relationship

Effect modification (interaction) with other exposure variables
CONCLUSIONS

CAUSAL ASSOCIATIONS BETWEEN COMPUTERS AND MSDs?
(STRENGTH, CONSISTENCY, TEMPORALITY)

POSTURE
Appears to be an independent risk factor for MSDs among computer users
Most consistent for relative keyboard height, head rotation, (resting of arms?)
Effect magnitude is not large

COMPUTER USE INTENSITY
Hours keying appears to be a risk factor for MSDs among computer users
Effect magnitude is at least moderate
Is effect greater for hand/arm than for neck/shoulder?