Physical variation – a magic pill in repetitive and constrained work?

Svend Erik Mathiassen
Centre for Musculoskeletal Research, University of Gävle
### Work-related disorders by cause

Percent employed experiencing disorders during last 12 months

<table>
<thead>
<tr>
<th>Cause</th>
<th>Females</th>
<th>Males</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise</td>
<td>1.4</td>
<td>1.1</td>
</tr>
<tr>
<td>Vibrations</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Heat, cold, draft</td>
<td>0.5</td>
<td>0.4</td>
</tr>
<tr>
<td>Substances from plants or animals</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Chemical substances</td>
<td>0.8</td>
<td>0.6</td>
</tr>
<tr>
<td>Stressful postures</td>
<td>8.2</td>
<td>6.1</td>
</tr>
<tr>
<td>Short, repeated movements</td>
<td>2.7</td>
<td>1.9</td>
</tr>
<tr>
<td>Heavy manual handling</td>
<td>4.2</td>
<td>4.1</td>
</tr>
<tr>
<td>Computer work</td>
<td>2.4</td>
<td>1.1</td>
</tr>
<tr>
<td>Harassment</td>
<td>0.9</td>
<td>0.3</td>
</tr>
<tr>
<td>Threats or violence</td>
<td>0.7</td>
<td>0.4</td>
</tr>
<tr>
<td>Mental stress</td>
<td>14.6</td>
<td>7.7</td>
</tr>
</tbody>
</table>

*Work-related Disorders 2014*
ERGONOMICS
Provisions of the Swedish Work Environment Authority, AFS 2012:2

7 § The employer shall ensure that work which is repetitive, closely controlled or restricted does not normally occur…
…Prevention must lead to an augmented Variation in the work, for instance through job rotation, job diversification or breaks

Trends in working life:
• Outsourcing
• Hi-tech-taylorization
• Computerization
• Intensification
• Surveillance
• Temporary jobs
• Less autonomy
• Flexibility in time and space

Less variation
Repetitive work…

“The concept ‘repetitive work’ refers to similar work tasks performed again and again” \textit{Kilbom 1994}

“Motion is the change in joints and change of body parts in space. Repetition is the frequency and the rate of these changes” \textit{Hagberg 1992}

“High repetitive jobs were defined as those with a cycle time of less than 30 seconds or more than 50% of the cycle time involved performing the same type of fundamental cycles” \textit{Silverstein et al. 1986}
Traditional ergonomics

Paradigm:
Less is better

Modern ergonomics

Paradigm:
Load and recovery
A position paper…

*Ergonomics*  
Vol. 52, No. 10, October 2009, 1215–1225

Increased physical work loads in modern work – a necessity for better health and performance?  
Leon Straker* and Svend Erik Mathiassen

*School of Physiotherapy, Curtin University of Technology, Perth, Australia; Centre for Musculoskeletal Research, University of Gävle, Sweden*

What is ‘variation’?…

*Applied Ergonomics*  
37 (2006) 419–427

Diversity and variation in biomechanical exposure: What is it, and why would we like to know?  
Svend Erik Mathiassen

Centre for Musculoskeletal Research, University of Gävle, F.O. Box 7829, SE 901 72 Umeå, Sweden
Load Variation: change across time

- **How much**: [description]
  - range across time
  - dispersion across time (e.g. SD)
  - occurrence of neutral and extreme loads

- **How often**: [description]
  - rate of change
  - jerks (Exposure Variation Analysis)
  - spectral parameters

- **How similar**: [description]
  - soon to appear on a screen in front of you
Exposure Variation Analysis

ERGONOMICX, 1991, VOL. 34, NO. 12, 1455–1468

Quantifying variation in physical load using exposure-vs-time data

SVEND ERIK MATHIASSEN and JOHNN WINKEL
National Institute of Occupational Health, Division of Applied Work Physiology,
S-171 84 Solna, Sweden

Keywords: Exposure; Intermittent; Isometric; Pause; Variation.

Exposure Variation Analysis – first step

Arm elevation (°)

Time of day

8:00 9:00 10:00 11:00 12:00 13:00 14:00

83 1 11111

a.m. Mathiassen & Winkel 1991
Exposure Variation Analysis – second step

<table>
<thead>
<tr>
<th>%time</th>
<th>0-1</th>
<th>1-3</th>
<th>3-7</th>
<th>7-15</th>
<th>&gt;15</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;15</td>
<td>2.3</td>
<td>1.3</td>
<td>0.0</td>
<td>2.0</td>
<td>0.0</td>
</tr>
<tr>
<td>15-30</td>
<td>2.6</td>
<td>8.7</td>
<td>1.8</td>
<td>0.0</td>
<td>4.1</td>
</tr>
<tr>
<td>30-45</td>
<td>3.8</td>
<td>1.8</td>
<td>3.1</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>45-60</td>
<td>7.7</td>
<td>3.6</td>
<td>1.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>60-75</td>
<td>9.5</td>
<td>11.5</td>
<td>1.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>75-90</td>
<td>6.6</td>
<td>19.4</td>
<td>7.2</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>&gt;90</td>
<td>1.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Exposure Variation Analysis – the figure

% time vs. sequence duration (min)

'how much'

'how often'

Angle interval (deg) vs. sequence duration (min)
"How much":
- range across time
- dispersion across time (e.g. SD)
- occurrence of neutral and extreme loads

"How often":
- rate of change
- jerks (Exposure Variation Analysis)
- spectral parameters

"How similar":
- cycle time
- cycle-to-cycle variability
- non-linear metrics
Muscles with similar action (Palmerud et al. 1995)

Compartments in muscle
(Mathiassen&Winkel 1990, Falla&Farina 2007)

Motor units in compartment
(Westgaard&deLuca 1999, Thorn et al. 2002)
Ten workers have the same job –

Four get disorders, six remain healthy...

Rapport 2016:1
Fysisk variation och belastningsbesvär i arbetet

Mathiassen & Lewis 2016
Three ways of changing job variation

- changing contents or conditions in individual tasks in the job
  - give people a sit-stand station
- changing the time-line and proportions of current tasks in the job
  - manipulate sit-stand time schedule
- adding new tasks to the job
  - add a non-office task to the job

What does science say about the effectiveness of those approaches…

… in changing variation in physical loads

… in having an effect on well-being and health
Three ways of changing job variation

• changing contents or conditions in individual tasks in the job
• changing the time-line and proportions of current tasks in the job
• adding new tasks to the job

Changing variation: change a task
Changing variation: change a task

• Changed contents

Changed precision in pipetting
Srinivasan et al. 2015

Changing variation: change a task

• Changed conditions

Line vs. batch assembly
Dempsey et al. 2010
Changing a task – can it change variation?

<table>
<thead>
<tr>
<th>Initiative</th>
<th>n</th>
<th>result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changed equipment</td>
<td>4</td>
<td>yes</td>
</tr>
<tr>
<td>Changed contents</td>
<td>3</td>
<td>maybe</td>
</tr>
<tr>
<td>Changed conditions</td>
<td>6</td>
<td>maybe</td>
</tr>
</tbody>
</table>

Three ways of changing job variation

• changing contents or conditions in individual tasks in the job
• changing the time-line and proportions of current tasks in the job
• adding new tasks to the job
Changing variation: change the time-line of tasks

- Effective only if tasks differ in load

Diversity

Mathiassen 2006
Diversity:
the extent to which tasks differ in load

Almost no diversity

Some diversity

Combination: increased variation

Changing variation:
change the time-line of tasks

Different distribution

Different proportions
Changing variation: change the time-line of tasks

• Re-distribution of tasks (maintained task proportions)

No empirical studies
Changing variation: change the time-line of tasks

• Changed proportions of tasks

Only simulations
Barbieri et al. 2015

Tasks in an office

Four kinds of work:
45% Computer work
34% Sit, no computer
11% Stand, no computer
10% Break

Relative min-min variation in muscle activity (trapezius)

Mix, max variance 1.64
Current job 1.44
Only computer 1.00

Barbieri et al. 2015
Changing the time-line of tasks – can it change variation?

<table>
<thead>
<tr>
<th>Initiative</th>
<th>n</th>
<th>result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changed distribution</td>
<td>0</td>
<td>?</td>
</tr>
<tr>
<td>Changed proportions</td>
<td>(1)</td>
<td>doubtful</td>
</tr>
</tbody>
</table>

Three ways of changing job variation

• changing contents or conditions in individual tasks in the job
• changing the time-line and proportions of current tasks in the job
• adding new tasks to the job
Changing variation: add a new task

... diversity needed!

Changing variation: add a new task

• New task for the individual

Current and alternative tasks in office work
(Barbieri et al. 2015)
Tasks in an office

Barbieri et al. 2015

Current job, 10% computer replaced by cleaning
Mix, max variance
Current job
Only computer

Relative min-min variation in muscle activity (trapezius)

Barbieri et al. 2015
Changing variation: add a new task

- Re-distribution within the organisation

Job rotation!

Job rotation: the basic idea

Move available dispersion in product cycle exposure\(^1\):

from between subjects…

\[ \text{Load} \]

…to within subjects

\[ \text{Load} \]

… diversity needed!

\(^1\): cf. Bao et al. 1996
"They rotate every 30 minutes!"

Changing variation: add a new task

- Re-distribution within the organisation
  Rotation between assembly tasks
  (Möller et al. 2004)
Adding a new task – can it change variation?

<table>
<thead>
<tr>
<th>Initiative</th>
<th>n</th>
<th>result</th>
</tr>
</thead>
<tbody>
<tr>
<td>New task for the individual</td>
<td>4</td>
<td>maybe</td>
</tr>
<tr>
<td>Re-distribution within organisation</td>
<td>3</td>
<td>maybe</td>
</tr>
</tbody>
</table>

Three ways of changing job variation

- changing contents or conditions in individual tasks in the job
- changing the time-line and proportions of current tasks in the job
- adding new tasks to the job
What does science say about the effectiveness of those approaches…

… in changing variation in physical loads

… in having an effect on well-being and health

ERGONOMICS
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…Prevention must lead to an augmented Variation in the work,
for instance through job rotation, job diversification or breaks
Variation in isometric contractions

Endurance (min)

Mathiassen 1993

Three ways of changing job variation

- changing contents or conditions in individual tasks in the job
- changing the time-line and proportions of current tasks in the job
- adding new tasks to the job
Effect of increased variation: change a task

- Changed contents

Passive breaks vs. pause gymnastics at an office
van den Heuvel et al. 2003
### Increasing variation by changing the task – does it have an effect?

<table>
<thead>
<tr>
<th>Initiative</th>
<th>n</th>
<th>Effect?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changed equipment</td>
<td>0</td>
<td>?</td>
</tr>
<tr>
<td>Changed contents</td>
<td>8</td>
<td>doubtful*</td>
</tr>
<tr>
<td>Changed conditions</td>
<td>0</td>
<td>?</td>
</tr>
</tbody>
</table>

*only studies of different types of breaks

### Three ways of changing job variation

- changing contents or conditions in individual tasks in the job
- changing the time-line and proportions of current tasks in the job
- adding new tasks to the job
Effect of increased variation: change the time-line of tasks

• Re-distribution of tasks
  (maintained task proportions)

Different distributions of breaks in office work
Boucsein & Thum 1997

Effect of increased variation: change the time-line of tasks

• Changed proportions of tasks

Increased break allowance in assembly work
Mathiassen & Winkel 1996
Increasing variation by changing the time-line of tasks – does it have an effect?

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Effect?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changed distribution</td>
<td>3</td>
<td>unclear</td>
</tr>
<tr>
<td>Changed proportions</td>
<td>8</td>
<td>maybe*</td>
</tr>
</tbody>
</table>

* only studies of added breaks

Limited effect of more breaks…
Why?

- Only few percent of the working day is changed
- Spontaneous breaks diminish
- Exposure during breaks is similar to that during work
Three ways of changing job variation

• changing contents or conditions in individual tasks in the job
• changing the time-line and proportions of current tasks in the job
• adding new tasks to the job

Arvidsson et al. 2006
Job rotation in US manufacturing

Jorgensen et al. 2005:
• 43% of companies reported using ‘job rotation’
  - Main objective: reduce incidence/cost of WRI
  - Main benefits:
    - increased skills
    - reduced incidence of WRI

Effect of increased variation: add a new task

• Re-distribution within the organisation
  More administrative tasks in car assembly
  (Christmansson et al. 1999)
Increasing variation by adding a task – does it have an effect?

<table>
<thead>
<tr>
<th>Initiative</th>
<th>n</th>
<th>Effect?</th>
</tr>
</thead>
<tbody>
<tr>
<td>New task for the individual</td>
<td>4</td>
<td>maybe*</td>
</tr>
<tr>
<td>Job rotation</td>
<td>9</td>
<td>doubtful</td>
</tr>
<tr>
<td>Rationalisation</td>
<td>4</td>
<td>maybe</td>
</tr>
</tbody>
</table>

*only studies of breaks vs no breaks

"...In conclusion, the evidence for positive effects of increasing the level of variation is scarce. The number of studies on variation is limited, while in most studies the findings were not controlled for the amount or intensity of work."
Job rotation

Ergonomics, 2015
Vol. 58, No. 1, 18–32, http://dx.doi.org/10.1080/00140139.2014.961566

Effects of job rotation on musculoskeletal complaints and related work exposures: a systematic literature review
Pricilla C. Leider, Julitta S. Benschmar, Monique H.W. Frings-Dresen and Henk F. van der Meulen
"Coronel Institute of Occupational Health, Academic Medical Center, University of Amsterdam, Amsterdam, The Netherlands; "Arbeids-, Duurzame Gezondheid & Veiligheid Stichting Construction Industry, Harderwijk, The Netherlands"

"... In conclusion, there is currently inconsistent evidence for positive or negative effects of job rotation on musculoskeletal complaints and exposure related to musculoskeletal complaints"

Job rotation

Applied Ergonomics 58 (2017) 386–397

Review article
Job rotation designed to prevent musculoskeletal disorders and control risk in manufacturing industries: A systematic review
Rosimeire Simprimi Padula, Maria Luiza Caires Comper, Emily H. Spares, Jack I. Dennerlein
"Department of Physical Therapy, School of Biological Sciences, Universidade Gua de São Paulo, São Paulo, Brazil;
Department of Social and Behavioral Sciences, Harvard T.H. Chan School of Public Health, Boston, MA, United States;
Department of Environmental Health, Harvard T.H. Chan School of Public Health, Boston, MA, United States;
Department of Physical Therapy, Movement, and Rehabilitation Sciences, Tufts University School of Health Sciences, Northeastern University, Boston, MA, United States"

"... Currently, weak evidence exists supporting job rotation as a strategy for prevention and control of musculoskeletal disorders"
The big picture

• Lack of knowledge about the relative significance of “how much”, “how often” and “how similar”

• Lack of studies documenting both changes in variation and its effects

• Lack of knowledge about long-term variation in load, and its effects

The big picture

• Lack of knowledge about other matters than breaks and what’s in them

• Lack of good studies of job rotation (all workers included, control group, sufficient follow-up)

• No studies with a gender perspective

• No studies with an age perspective
Variation – a magic pill? We still don’t know the answers…

Which tasks can be effectively combined into a job with increased variation so that both short- and long-term outcomes will be beneficial.

What is the optimal temporal structure of changes between such tasks in a short- (hours, days) and long-term (weeks, months, years) perspective.

The perfect job?
Thank you!
Papers and reports referred to in the presentation


Additional reading


Ciccarelli M, Straker L, Mathiassen SE, Pollock C: Posture variation among office workers when using different information and communication technologies at work and away-from-work. Ergonomics 57 (2014): 1678-1686


