

Is it the peak that matters or is it the cumulative exposure?

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Introduction

Musculoskeletal disorders (MSDs), including low back pain, carpal tunnel syndrome, tenosynovitis and certain myalgias are considered to have strong work-related components. Many measures of “ergonomic exposure” in the workplace have been used in determining their work-relatedness. There are many possible injury mechanisms that could be responsible for the development of these disorders at work. Some are clearly due to a high peak load, rupture of the interspinous ligament (due perhaps to a fall) or end plate failure in a lumbar motion unit while some are the result of longer term processes such as the development of myalgia in the trapezius. Inspection of some recent reviews shows that exposure measures used in epidemiological studies of musculoskeletal disorders fall into groups such as force, posture, repetition, static load, and vibration (1, 2). It should be noted that this discussion of the importance of peak and average exposures is also present in environmental and occupational health sciences where the most common metric of exposure is the Time-Weighted Average (TWA).

This paper addresses the findings from physiological and epidemiological sources as to the importance of peak and cumulative exposure on the development of musculoskeletal disorders and makes some suggestions on exposures to include in the study of MSDs.

Acute and chronic injury mechanisms

A starting point for the discussion is the injury mechanism for MSDs, also called cumulative trauma disorders. Table 1 shows examples of postulated mechanisms.

Acute and chronic exposure measures

Table 1 would suggest that exposure measurement strategies be matched to injury mechanisms and include both cumulative and acute measures (3). The exposure descriptors least well developed are those describing the time variation pattern of the exposure. It is from this time variation pattern that the highest value (peak) or some measure of average or cumulative exposure originates. The average value can often be taken as a surrogate of cumulative exposure; the average value times the length of shift or employment is cumulative exposure. If the basic exposure variable is force then peak exposures have units of N, as do average exposures, however cumulative exposures have units of N.s. In the case of posture peak exposures have units of degree as do average exposures, however cumulative exposures have units of degree.s or using a cumulative probability approach, the % of time with exposure greater than 45 degrees. Table 2 shows examples of common exposure measures

Table 1: Examples of Disorders Caused by Peak and Cumulative Exposure (Putative mechanism in brackets)

Tissue	Injury Caused by Single Peak Force	Injury Caused by Repeated Force
Muscle	Z line disruption/muscle tear (Single eccentric contraction)	Muscle pain with ragged red and moth eaten fibres (Cinderella Hypothesis)
Joint	-	Osteoarthroses
Lumbar Motion Unit	-Interspinous ligament rupture (Fall on buttocks) -End plate fracture (Single high compressive load)	Disc herniation (Continuous or repeated load in flexed posture)
Nerve	-	Sensory and motor loss, (Entrapment/elevated compartment pressure)

Table 2: Examples of Peak and Cumulative Ergonomic Exposure Measures

Basic Exposure Category	Peak Variable	Average/Cumulative Variable
Force	Maximum load lifted	Average load or cumulative load per shift/employment
Posture		(%) time limb flexed greater than 45°
Joint angle	Peak limb flexion	
Velocity	Max angular velocity	Average angular velocity
Acceleration	Max angular acceleration	Average angular acceleration

Epidemiological evidence

Although not explicitly denoted by peak or cumulative, many studies use both types of exposure measures. Both peak and cumulative exposures have been shown to be related to the development of MSDs, (1). Unfortunately, there are few studies where both have been measured and where a comparison of their relationships to musculoskeletal health outcomes can be compared. Norman and colleagues did measure both peak and cumulative exposures to the low back simultaneously and showed that both were related independently to risk of reporting low back pain (4) and the same may hold true for upper limb disorders (5).

Summary and conclusions

Both peak and cumulative exposures appear to be important and independently related to WMSDs. Investigators studying work-relatedness of MSDs and evaluating hazards in workplaces should ensure that their exposure strategy includes both peak and cumulative/average measures appropriate to the disorders studied/expected.

References

1. Hagberg, M., et al., and Kourinka, I. and Forcier, L. (eds). *Work-related Musculoskeletal Disorders (WMSD): A Handbook for Prevention*, Taylor and Francis, London, 1995.
2. Bernard B.P., (ed.) *Musculoskeletal disorders and workplace factors: A critical review of epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back*. Cincinnati OH: Department of Health and Human Services, National Institute for Occupational Safety and Health, 1997.
3. Moore et al., (1991). Quantifying Exposure In Occupational Manual Tasks With Cumulative Trauma Disorder Potential. *Ergonomics*, 1991, 34(12):1433-1453.

4. Norman, R. et al. (1998) A comparison of peak vs. cumulative physical work exposure risk factors for the reporting of low back pain in the automotive industry. *Clinical Biomechanics*. 13:561-573.
5. Sjøgaard, G. et al (2000) The role of muscle activity and mental load in the development of pain and degenerative processes at the muscle level during computer work. *European Journal of Applied Physiology* 83: 99-105.

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Preface

This book contains the extended abstracts to the X2001 Conference on Exposure Assessment in Epidemiology and Practice in Göteborg, Sweden, June 10-13, 2001. The excellent work performed by the contributing scientists has made this book a first-class, up-to-date, state of the art review on what is known about exposure assessment today.

The outstanding scientific quality of the extended abstracts was secured through the work of five international programme committees. The chairmen for the committees were: Chemical, Patricia Stewart; Ergonomic, Alex Burdorf; Physical, Ulf Bergqvist; Psychosocial, Annika Härenstam and Biological, Jean-Francois Caillard.

Financial support to the conference and thereby to the publishing of this book was made possible by contributions from The National Institute for Working Life, Stockholm, Sweden; The Swedish Council for Working Life and Social Research, Stockholm and Volvo. Without the excellent skills of the organizing committee - Ulrika Agby (administration and layout), Ann-Sofie Liljenskog Hill (administration) and Christina Lindström Svensson (administration) - the production of this book would not have been possible.

We want to express our gratitude to the contributing authors, session chairmen and to the participants who presented papers and contributed in the discussions, for making X2001 an outstanding meeting.

Göteborg in June 2001

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