Work-related musculoskeletal disorders - exposure assessment and gender aspects

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Work-related musculoskeletal disorders
– exposure assessment and gender aspects

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What doesn´t kill you makes you stronger
– presuming that you get time enough to recover
Emil Nordander, 13 years old

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LIST OF PAPERS

This thesis is based upon the following four papers, which are included at the end and referred to in the text according to their Roman numerals:

I. Nordander C, Ohlsson K, Balogh I, Rylander L, Pålsson B, Skerfving S. Fish processing work: the impact of two sex dependent exposure profiles on musculoskeletal health. Occup Environ Med 1999;56(4):256-64.
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II. Nordander C, Hansson G-Å, Rylander L, Asterland P, Unge Byström J, Ohlsson K, Balogh I, Skerfving S. Muscular rest and gap frequency as EMG measures of physical exposure: the impact of work tasks and individual related factors. Ergonomics. 2000;43(11):1904-19.
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III. Nordander C, Balogh I, Mathiassen S-E, Ohlsson K, Unge J, Skerfving S., Hansson G-Å. Precision of direct technical measurements of physical workload of the shoulders and arms during manual handling. Part I: Surface electromyography of *m. trapezius*, *m. infraspinatus* and the forearm extensors. J Electromyogr Kinesiol 2004;14(4):443-454.
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IV. Nordander C, Ohlsson K, Balogh I, Hansson G-Å, Axmon A, Persson R, Skerfving S. Gender differences in musculoskeletal disorders and physical exposure, despite identical repetitive industrial tasks. Submitted.

ABBREVIATIONS

ACGIH	American Conference of Governmental Industrial Hygienists
A/D	Analogue to Digital
APDF	Amplitude Probability Distribution Function
BMI	Body Mass Index
CI	95% Confidence Interval
CV	Coefficient of Variation
EMG	Surface Electromyography
MSDs	Musculoskeletal Disorders
MVC	Maximal Voluntary Contraction
MVE	Electrical activity at MVC
POR	Prevalence Odds Ratio
RMS	Root mean square
RVC	Submaximal Voluntary Reference Contraction
RVE	Electrical activity at RVE
RR	Relative Risk
SD	Standard Deviation
TLV	Threshold Limit Value
WRMSDs	Work-related musculoskeletal disorders

INTRODUCTION

Pain and discomfort in the neck and upper limbs are widespread in the general population in industrial countries.[1-6] Though not lethal, such disorders often have serious consequences for the individual, in terms of pain and impairment. Indeed, they constitute one of the most common causes for long-term sick leave and early retirement,[7, 8] thus having huge economical implications both for society[9-11] and for the individual.[12, 13] In the general population, musculoskeletal disorders (MSDs) are much more common among females than in males,[14] the reasons for which are unclear.

Work-related musculoskeletal disorders

Several physical factors at work have convincingly been shown to increase the risk for MSDs.[2] These include work tasks that demand high repetitiveness or high force, are performed in constrained or awkward postures or imply lack of recovery time.[15-20] A combination of risk factors further increases the risk. Moreover, psychosocial factors, such as high demands, low control and lack of social support are important risk factors.[16, 21-24] It has been estimated that 17% of workers across the European Union experience pain in the arms or legs, believed to be caused by work,[25] and indeed, the most common kind of work-related disorders are the musculoskeletal ones.[15, 26]

Since a substantial share of the disorders are caused by, or impaired by, working conditions, they are also preventable. To attain such prevention, information about noxious factors is necessary, but not sufficient.[27] Unfortunately, for work-related musculoskeletal disorders (WRMSDs), solid knowledge of what levels (in terms of amplitude, duration and repetitiveness[28]) that cause adverse effects is lacking to a great extent,[16, 29] since many studies have been dichotomous, with one exposed and one referent group, yielding evidence only on the fact that a factor is deleterious at high, and safe at low levels.

WRMSDs are not a homogenous entity, but include several disease conditions,[2] the common denominator of which is pain, and, most often, functional impairment. Of course, different kinds of exposures can be injurious to different structures, through various pathological pathways. High levels of physical exposure at work give rise to muscular fatigue[30, 31] and impaired coordination.[32] Exposure to high force, but still not so high that it exceeds the strength of the tissue, may also lead to micro-ruptures in tendons, muscles, cartilages and connective tissues.[27] Moreover, metabolic changes may occur. If sufficient time for recovery is provided, inherent reparative processes will heal the micro-ruptures, and adaptation, such as improved strength and endurance, will occur. If exposure is repeated with short intervals, however, it may lead to inflammation and degeneration.

There is a profusion of terms used for WRMSDs, some referring to the affected region (like tension neck syndrome), others to the pathology (like rotator cuff tendinitis) and still others to the aetiology (like repetitive strain injury).[4] Some of them appear only as pain and tenderness, while others have histological correlates and can be demonstrated by, *e.g.*, ultrasound. Many pain conditions are not anatomically discrete, but several sites are affected. Not uncommonly, however, they have once begun as pain in one or a few locations.[33]

Muscle pain

Pain arising from the musculo-tendineous structures is the most common kind of WRMSDs.[2, 30, 34] Thus, muscular activation, which is influenced by working postures and movements, as well as weight and shape of handled materials, is of great importance. In the forearm muscles, high levels of exposure due to vigorous gripping are at hand in several occupational settings, and have been shown to constitute an independent risk factor.[20] Hence, to study the relationship between work and disorder, reliable estimates of *postures*, *movements* and *muscular activity* are needed.

In many work tasks of today, though, ergonomic considerations have accomplished reduced force, and the injurious exposure is rather characterised by repetitive contractions, or by sustained tension with insufficient restitution time. Precision demands, as well as mental demands, may give rise to increased muscle tension.[35] Muscles are composed of a large number of long and narrow cells, the muscle fibres. Muscle fibres that are dispersed in the muscle belly are grouped together in motor units; all fibres in one unit being supplied by branches of the same motor neuron, thus activated practically simultaneously. At low-level, long-duration contractions, the level of exerted force is mainly decided by the number of motor units that are activated. Motor units within the same muscle vary substantially in size¸ the smaller ones (*i.e.* with the lowest number of fibres) consisting of type I fibres and the larger ones of type II fibres. As suggested by Henneman,[36] motor units are recruited in an orderly pattern, starting with the smallest ones. Thus, in low-force contractions, only the small ones are active, and as more force is required, larger ones are added.

In 1991 Hägg formulated 'the Cinderella hypothesis' (first up, last to bed) concerning motor units with low recruitment thresholds, which may be active throughout every contraction,[37] thus vulnerable to sustained or repeated contractions with little time for recovery. Sustained tension may lead to depletion of energy and accumulation of metabolites in these fibres.[27] Hence, the intracellular concentration of calcium ions may rise, activating phosholipases that damage cellular membranes,[38] with subsequent leakage of algesic substances; such mechanisms may be involved in neck-shoulder myalgia, as well as in forearm pain in computer work (so called mouse arm).

A number of studies have been carried out in order to verify or discard the Cinderella hypothesis.[39-42] It seems, then, that the recruiting principle is at least partly valid in real work. Some individuals, however, obviously have an ability to rise the recruitment threshold of exhausted fibres (at least for some time), while in others, motor units have been demonstrated to be active through out long-duration work tasks.[42] The type of activity might play an important role, and especially activities with a rather constant force demand seem more dangerous than the more dynamic ones.[41] Even in work tasks with almost uninterrupted muscular activity, however, not all individuals develop complaints, and a protecting factor could be a high ability to substitute exhausted motor units with others. When studying work exposure, such ability cannot be presumed, thus measurements of *the activity of the Cinderella fibres* should be made.

Tendinitis

In muscle contractions, the muscle tendons are exposed to tensile forces. In movements they slide by, and may be pressed against, adjacent structures. For example in the carpal tunnel and under the acromion, the space is very limited and any swelling of the tendon or other structures will increase the contact forces acting on the tendon.[43] The distal part of, *e.g.*, the supraspinatus tendon is poorly vascularised,[44] which hampers regenerative processes and makes the tendon vulnerable to overload, as blood flow is reduced when the muscle is contracted.[45] Especially in work tasks that are performed with lifted arms, circulation will be reduced, and, furthermore, the tendon will be squeezed against the acromion.[46] Degeneration of the tendon is common in these work tasks, sometimes complicated by rupture.[47]

Also common is work-related epicondylitis, probably due to micro-ruptures caused by repetitive high forces in the forearm flexors or extensors. Likewise, de Quervains tendovaginitis (affecting the tendons in the first dorsal wrist compartment) occur after repetitive wrist movements that make the tendons slide in the narrow compartment.[43] Hence, for studies of risk factors for tendinitis, assessment of working *postures of the shoulders*, as well as working *movements of the shoulders and wrists*, are important, in combination with assessment of *muscular activity*, especially in the forearm muscles.

Nervous tissue disorders

Swelling of muscles and tendons, as well as external pressure, *e.g.*, due to poorly designed tools, may cause mechanical pressure on nervous tissues, resulting in tingling, numbness, pain and loss of function in supplied structures, due to impaired circulation. Further, awkward postures and movements, such as excessive wrist extension may cause stretching of the median nerve, resulting in micro-ruptures, inflammation and secondary swelling, increasing the pressure in the carpal canal. Then, also for these disorders, the working *postures* and *movements*, particularly of the wrists, should be assessed.

Gender differences in work-related musculoskeletal disorders

WRMSDs are considerably more prevalent among females, in comparison to males.[48] There are several possible explanations to this gender discrepancy. First, exposure to the above-mentioned risk factors at work may differ. Second, biological differences may entail varying vulnerability to such exposures. Third, conditions outside work, such as family responsibilities, may have an impact, and may be unevenly distributed.[49-52]

To establish what gender-related conditions that influence the development of disorders, and the magnitude of their impact, is important, from a pathomechanistic, as wells a preventive, perspective.

Physical exposure

Physical exposure is an umbrella term for several ergonomic and environmental factors. Hence, it includes noise, lighting, temperature, climate, vibrations and radiation. Concerning most of these, adverse condition may influence the occurrence of WRMSDs (*e.g.* coldness and hand-held vibrating tools).[53] In the following, however, the term physical exposure specifically refers to working postures and movements, as well as exerted forces. The physical exposure at work is determined by the purpose of the job, thus, sight demands, tools, weight of handled materials, time demands, working heights, possibilities to sit down, as well as restraint to a machine, are of great importance. Moreover, organisational factors and design of the work process, such as how much of a product that is completed at each work station, and how work tasks are distributed among workers have great impact. These conditions, and the individual working technique, decide the physical exposure.

The common trait of many occupations that have been shown to imply a high risk of WRMSDs is repetitive or intensive use of the hands.[43] Apart from hand-forearm exposure, such work tasks also imply static loading on the neck-shoulder muscles, since visual demands require that the head is kept still, often in a forward-bent posture, and that the scapula is stabilised, so that controlled arm and hand motions can performed.

There are several methods available for assessment of the physical exposure. Questionnaires can easily be distributed to large groups of subjects,[17] and subjects can report their average exposure over a longer time period, not restricted to the measurement day, both obvious advantages. Questionnaires, however, suffer one serious weakness: those subjects that already have pain (or, possibly, are beginning to experience discomfort), rate their exposure higher than those who do not, thereby attenuating the dose-response relationship.[54] It has further been shown that subjects are incapable of giving reliable detailed information about the level and frequency of exposure.[55]

Moreover, numerous observational methods are at hand. Such methods are time consuming, especially for jobs that do not consist of just one short-cycled task. They require experienced analysts, and even so, they include a subjective component with shortcomings concerning inter-observer reliability.[17] To distinguish between adjacent angular sectors, as well as to assess speed, is difficult. Finally, scientists risk introducing an information bias, *i.e.* to collect information that is in accordance with their hypothesis.[56]

The most reliable way to assess physical exposure is by technical measurements.[28] Registration can be performed during long periods, with homogenous or heterogeneous work tasks. Registrations of working postures and movements can be expressed in SI units (º and º/s), and can be validated against a gold standard.[57] Further, technical methods are independent of the examiner, thus they are objective.

In assessing physical exposure, different strategies may be applied, depending on the research question. In some cases, the *absolute* exposure (such as total lifted load, or number of motor units active) is aimed at. When focusing on gender differences in the relationship between workload and disorders, however, the physical exposure as related to the capacity (*e.g.* strength or range of motion), the *relative* exposure may be more relevant. Hence, concerning measurements of amplitude of muscular activity, a normalisation to maximal exertions is usually applied.

Assessment of postures and movements

Accelerometer based inclinometers have several advantages. They are light weighted, and with such equipment the worker can move freely inside or outside the workplace, and perform all occurring tasks, a great advantage in occupational epidemiology.[57] They record positions of different body parts, as compared to the line of gravity, and thereby compare well with observational methods, and the conceptual understanding of postures (e.g. head bent forward). Data can be recorded several times per second, which allows calculation movements, and data can be transferred to portable data loggers, allowing long duration registrations.[58]

Goniometers can be attached around a joint, and can register motions in two directions. Like the inclinometers, they can be used in ordinary work, and report data several times per second. Calculation of posture, as compared to a neutral reference position, and movements can be performed.[58-60]

Assessment of muscular activity
In muscular contractions, static, as well as dynamic ones, action potentials propagate along the membrane of the muscle fibre, and their electrical activity can be registered by surface electromyography (EMG).[61, 62] By deriving the amplitude of the signal, and relating it to the electrical activity registered during a maximal voluntary contraction (MVE), or a sub-maximal voluntary contraction (RVE), an estimate of the developed force can be obtained. Such estimates are important measures of physical exposure when exerted force is suspected to constitute a risk of disorders, and they are traditionally presented as the static (10^{th} percentile of the amplitude probability distribution function, APDF), average (50^{th} percentile) or peak (90^{th} percentile) amplitudes. As argued above, however, in many work situations even the static load is very low, and the deleterious exposure seems rather to be related to the duration of muscular activity, and the lack of recovery periods. The traditional way of analysing EMG gives little information about the exposure on low-threshold motor units, which presumably are exposed as long as the muscle is active at all; thus, a more relevant measure is needed.

Veiersted *et al.*[63, 64] have suggested an interesting method for determining very short periods of inactivity (EMG 'gaps'), in the registration, and showed that a high number of gaps per minute were associated with a lower risk of neck-shoulder pain in a one-year prospective study. Other authors have shown that such EMG gaps coincide with a rotation between active motor units,[42] and the EMG gap frequency seems to be a suitable method for selecting high-risk individuals.

An important purpose of exposure assessment, on the other hand, is to discriminate between high-risk and low-risk jobs. For that purpose, the gap-analysis method is less usable, since both work tasks that do not require muscular activation, and tasks that require continuous activation, will show a low gap-frequency. Instead, the gap-analysis method should be further developed, to be usable as an exposure assessment method, thus not only to discriminate between individuals, but to quantify a relevant aspect of physical exposure in different kinds of work. Then, the time proportion ('total gap time'), instead of the frequency, of gaps could give an estimate of the recovery time for low-threshold motor units.[63] Such an approach should be applied and validated in different work tasks, with different physical exposure and varying risk of myalgia.

EMG has been used as an exposure measurement method in numerous studies, and a great inter-individual variability has been shown in subjects performing the same work tasks.[65-67] The variability can be caused by true inter-individual differences in strength and work techniques. Further, when registrations are only made once in each subject, it includes a true intra-individual variability. On the other hand, some of it can be due to a measurement error (related to, *e.g.,* electrode placement or calibration procedures). Thus, as for all measurement methods, knowledge about the analytical quality is important, both for study design and for interpretation of results. One important aspect of the analytical quality is the precision, concerning which surprisingly little is known for EMG, considering the extensive use. For assessment of exposure-response relationships, information about intra-individual variation is important, since a large variation will result in considerable bias, in terms of attenuation of the slope; thus, true relations might be obscured by limitations of the exposure assessment method.

Hence, for shoulder muscles, as well as for forearm muscles, it is important to evaluate the precision of EMG estimates of muscular activity. For *m. trapezius*, data have been reported in two studies, however one from a real work place, where it cannot be excluded that some of the day-to-day variation is due to external variances,[66] and the other one only considering RVE-normalised data.[65] The precision in EMG registrations from *m. infraspinatus* and the forearm muscles has not been studied.

Gender differences in physical exposure

To account for possible differences in physical exposure due to occupation, de Zwart *et al.* evaluated the gender related risk of complaints in the neck and upper limbs, adjusted for occupational class (*i.e.* job-title).[68] They found remaining increased risks for females; thus, they rejected the hypothesis that gender segregation in occupations could explain the excess female morbidity. However, not all workers with the same job-title have exactly the same work-tasks, and it is possible that exposure differs systematically between genders within the same occupation. If so, risk estimates that are adjusted for job-title, may show an effect of gender, which is actually due to exposure differences.[69, 70] To evaluate the results from the study by de Zwart *et al.* [68] it is important to assess and compare the physical exposure of work tasks held by male and female workers with the same job-title.

In addition, even within the same occupation, the same workplace and the same work task, it is possible that males and females are exposed to physical loads at different levels (*absolute* or *relative*). This issue has not been studied, why physical exposure should be quantified in males and females with identical work tasks. Further, in such a setting, to elucidate the gender specific risk of disorders at a certain level of exposure, the occurrence of MSDs should be assessed on males and females separately.

Psychosocial work-environment factors

Also the psychosocial work environment may influence pain development.[22, 71] Psychosocial factors seem to be especially relevant in combination with high physical exposure,[23] and the strongest evidence has been shown for high perceived job stress, contributing to upper extremity disorders. One suggested mechanism is muscle activity aroused by mental or emotional demands, initiating the same processes that are present in low load static work due to physical exposure.[35] An imbalance between job demands and job control is further suggested to impair coping capabilities.[71] Hence, it has been shown prospectively that workers with low decision authority[72] have a high risk of sickness absence due to neck pain.[21] Therefore, when studying the relationships between physical exposure and disorders, data on psychosocial work-environment conditions should be collected.

AIMS

General aim

To clarify the impact of work on the gender difference in occurrence of musculoskeletal disorders, in the neck and upper limbs.

Specific aims

To compare the physical exposure in male and female workers with the same job-title.

To further develop and validate a method to analyse and interpret surface electromyography (EMG), with particular focus on muscular rest.

To evaluate the precision of EMG estimates of muscular activity, in some neck and upper limb muscles.

To objectively quantify physical exposure, in terms of muscular activity, as well as working postures and movements of the head and upper extremities, in male and female workers with identical work tasks.

To compare the occurrence of work-related musculoskeletal disorders of the neck and upper limb, in male and female workers with identical work tasks.

MATERIALS AND METHODS

Subjects

In **Paper I**, the occurrence of MSDs among 206 female and 116 male fish-processing workers were compared. Further, 208 females and 129 males with mobile and varied work served as referents. Participation rates were 92%, 85%, 98% and 100% respectively. Former employees of the fish-processing industries (196 males and 322 females) received a postal questionnaire, for assessment of the 'healthy worker effect'. Fifty-five percent of them responded.

In **Paper II**, 218 female hospital cleaners, 173 female and 103 male office workers were examined concerning MSDs. Among those, EMG was registered during one full working day in 11 cleaners with and 13 cleaners without neck/shoulder disorders. Further, EMG was registered in 8 affected and 12 unaffected female, as well as 5 affected and 8 unaffected male, office workers were registered.

In **Paper III**, six healthy females from the department staff participated.

In **Paper IV**, 83 female and 37 male workers in a rubber manufacturing plant, and 89 female and 68 male workers in a mechanical assembly plant were examined concerning MSDs. The participation rates were 98% for females and 95% for males. A postal questionnaire was sent to 98 male and 120 female former workers, whereof 72% responded. Further, physical exposure during one full working day was registered in 8 males and 9 females in the rubber industry, and in 10 males and 10 females in the mechanical assembly plant.

Individual factors

In **Papers I**, **II** and **IV**, eleven questions concerning habitual muscular tension tendency were included. Analyses were performed using the sum of scores.[73] Further, age, smoking, activities outside work and civil status were recorded.

Work tasks

The main work tasks in fish processing, in **Paper I**, were cod-machine operation, trimming of cod, herring machine operation, packing, supply and removal, and maintenance. The referent female workers were employed in day nurseries, had varied office work, performed home care of elderly or were gardeners. The referent male workers were employed as house caretakers, worked in community parks and gardens or performed maintenance and repair of machines.

The hospital cleaners in **Paper II** mainly performed floor cleaning, but also some cleaning of toilets, dusting and wiping of furniture. The most common work task for office workers was deskwork without a computer; however some keyboard work was registered. For both groups, registrations were also performed during pauses and scheduled breaks.

In **Paper III**, EMG was registered during three different standardised work tasks; materials picking, light assembly and heavy assembly, each repeated on three different measuring days.

In the rubber manufacturing plant, in **Paper IV**, rubber-sealings were produced. The workers attended vulcanization machines, which, with a cycle time of about 1 minute, should be opened and emptied. The sealings were then inspected and trimmed. In the mechanical assembly plant, brake regulators were produced on an assembly line with six different workstations, each station had a cycle time of about 25 s. In both plants, males and females worked side-by-side and changed places with each other according to a job-rotation schedule.

Exposure assessment

Exposure profile

Based on an observation method, Ergonomic Workplace Analysis (EWA),[74] questionnaire and videotape recordings, each work task was classified according to the weight of the materials handled, the cycle time and the degree of constrained neck postures. Then, for the *absolute* physical exposure, a three-dimensional diagram was constructed. Through interviews with every currently employed worker, the total proportion of time spent in each workload cell, by all females and all males was calculated and presented graphically (**Paper I**).

Postures and movements

In **Paper IV**, working postures and movements of the head, upper back and upper arms were registered by inclinometers that were attached to the forehead, the cervicothoracic spine and both upper arms.[57] Wrist angles and movements were registered bilaterally by flexible biaxial electrogoniometers (Biometrics Ltd, Gwent, UK).[59] For both methods, a sampling frequency of 20 Hz was applied, and data were collected on portable data loggers.

Muscular activity

In **Papers II, III** and **IV**, EMG was registered bilaterally from *m.trapezius*. Further in **Papers III** and **IV**, muscular activity from *m.infraspinatus* and the forearm extensors was registered. Surface electrodes (Ag/AgCl), with a centre-to-centre distance were used, and placed over the descending parts of *m.trapezius*, 2 cm lateral to the midpoint on the lines between the seventh cervical vertebra and the lateral acromions, and over the muscle bellies of *m.infraspinatus,* as well as of *mm.extensor carpi radialis longus* and *brevis*. The signals were anti-aliasing filtered, amplified, analogue to digital (A/D) converted at 1024 Hz, amplified and stored on portable data loggers. Off line, digital filtering at 30-400 Hz was applied, and the root mean square (RMS) values were calculated.

EMG was normalised to the activity obtained during maximal voluntary contractions (MVC); the highest registered level for the maximal voluntary electrical activity (MVE) was selected. Further, in Papers II and III, submaximal reference contractions (RVC) were performed for *m.trapezius* and *m.infraspinatus*; the electrical activity registered was denoted RVE. The noise level was registered at complete rest, and subtracted from the registration. The EMG amplitudes were expressed as the 10th, 50th and 90th percentiles of the APDF, in percentages of MVE and, when applicable, RVE.[75]

In Papers II, III and IV, the proportions of time below 0.5 %MVE and, when applicable, 3 %RVE, *i.e.* the 'muscular rest' were derived, as were the mean numbers of downward crossings of these levels *i.e.* the 'gap frequency' in Paper III. In Paper II, to optimise inter-individual sensitivity of the gap frequency, thresholds of 1 %MVE and 5 %RVE were used for this measure.[76]

Psychosocial work environment

In Paper I, data on psychosocial work environment conditions were collected by a questionnaire-based interview. The following five areas were evaluated: influence on and control over work, relations with the supervisor, stimulation from the work itself, relations with fellow workers and physical and psychosocial work load.[77]

In Paper IV, a Swedish version of the Job Content Questionnaire was applied for measurements of job demands, job control and job support. In addition to the separate dimensions, the quotient between job demands and job control was calculated.[24, 72, 78]

Response assessment

Questionnaire

The Nordic questionnaire on musculoskeletal symptoms from different body regions, during the last 12 months and the last 7 days, was used in Papers I, II and IV.

Physical examination

A standardised physical examination was performed on all workers. The maximal possible number of findings was 110 for neck/shoulders and 130 for elbows/hands. If relevant, predefined diagnoses were set.[79] The reliability, in terms of the inter-observer agreement, of the method has recently been evaluated (Nordander *et al.* to be published). Four examiners each examined 19 male and 20 female subjects. For each subject and each observer, the total number of positive findings, grouped into four categories; 'mobility', 'tenderness at palpation', 'specific tests' (*e.g.* Phalen's test) and 'strength', were recorded. Further, the presence of at least one diagnose in neck/shoulders, as well as in elbows/hands, was decided. The kappa-values (κ) for each pair of observers are shown in **Table 1**. In **Papers I**, **II** and **IV**, the examinations were performed by observer A and C. Between these, as for most other comparisons the inter-observer agreement was generally good, with κ 0.7-0.9. Concerning strength, considerably lower agreement was shown. With the present criteria for diagnoses, strength is only relevant for the nerve entrapment diagnoses, which are uncommon, thus the poor agreement between observers did not significantly influence the results.

Statistical methods

In **Papers I** and **IV**, the prevalence odds ratio (POR) was used as the effect measure, mainly because, in a logistic model, the POR can be adjusted for several

Table 1. Reliability, of physical examination, as calculated by kappa-statistics (κ)between pairs of four different observers, each examining the same 19 males and 20 females. Sum of findings, grouped into categories, and the presence of at least one diagnosis, in neck/shoulders or elbows/hands.

Observer			**B** κ	**C** κ	**D** κ
A	Category	Mobility	0.81	0.79	0.68
		Tenderness	0.86	0.90	0.86
		Specific tests	0.81	0.77	0.76
		Strength	0.17	-0.01	0.04
	Diagnosis	Neck/shoulders	0.79	0.79	0.65
		Elbows/hands	0.65	0.65	-0.04
B	Category	Mobility		0.78	0.60
		Tenderness		0.90	0.73
		Specific tests		0.76	0.77
		Strength		0.33	0.43
	Diagnosis	Neck/shoulders		0.71	0.56
		Elbows/hands		1.00	-0.06
C	Category	Mobility			0.55
		Tenderness			0.75
		Specific tests			0.71
		Strength			0.58
	Diagnosis	Neck/shoulders			0.71
		Elbows/hands			-0.06

covariates, which is an advantage to the relative risk (RR).[80] Hence, in **Papers I** and **IV,** the risk estimates were adjusted for age, and several other factors were tested as possible confounders. At low prevalences, POR can be considered an approximation of RR, at higher ones the PORs are higher than the RRs. A high prevalence may reflect a high incidence, long duration of disorders, or both.

In **Paper III**, for different EMG variables, variance components between days (within subjects) and between subjects were derived, using a restricted maximum likelihood algorithm in a general linear random effects model. The corresponding standard deviations (SD) were derived, and since these were clearly dependent on mean load, the variation was expressed as coefficients of variation (CV).

RESULTS WITH COMMENTS

Male and female workers with the same job-title

Musculoskeletal disorders

Fish-processing industry work entails a high risk of disorders as compared to varied and mobile work, for males as well as females (**Paper I**). Hence, the age and sex-adjusted PORs for diagnoses in neck/shoulders was 3.5 (95% confidence interval; CI = 2.3-5.3) and for elbows/hands 3.5 (1.6-7.7). Further, among the fish-processing workers, females had a greater occurrence of MSDs, as compared to males, concerning complaints during the last seven days, as well as diagnoses, in the neck and upper extremities (**Table 2**). For low back and lower extremities, no statistically significant differences were shown, though twice as many females complained about foot and ankle symptoms.

The risk estimates were higher for complaints than for diagnoses. Moreover, when comparing the males in the fish-processing industry to those with other work, significant differences were shown at the physical examination (POR 3.6; CI 1.6-8.0 for neck/shoulders) but not in the questionnaire based interview (POR 1.3; 0.7-2.3). This was interpreted as a tendency among male fish-processing workers to underreport their disorders, which was named the 'Tarzan effect'.

Physical exposure

The exposure profile (Figure in **Paper I**), which estimated the *absolute* physical exposure, revealed that, for the males, most of the total working time was found at two extremes. Hence, 26% of the time entailed work with low physical exposure, performing mobile work, with no or very light materials handling, and 34% of the time repeatedly lifting loads heavier than 25 kg. Several males handled a total daily weight of 10 – 15 tons. Further, 15% of the time was spent with a high degree of constrained neck postures, handling weights of 1-5 kg, with cycle times below 5 s.

Table 2. Age adjusted prevalence odds (POR) ratios for 206 females *vs.* 116 males in the fish-processing industry, concerning complaints during the past 7 days as well as diagnoses at a physical examination. (Adopted from **Paper I**, Table 1)

	Females *vs.* males	
	POR	95% CI
Complaints		
Neck/shoulders	2.9	1.9 – 4.7
Elbows/hands	2.8	1.6 – 4.7
Diagnoses		
Neck/shoulder	1.9	1.1 – 3.2
Elbows/hands	1.8	0.7 – 4.5

Among the female fish-processing workers, on the other hand, as much as 63% of the total working time was spent with a high, or a very high, degree of constrained neck postures. The materials handled weighed below 1 kg, and the cycle times were shorter than 10 s. During 6% of the total working time, weights heavier than 25 kg were handled. The female exposure profile did not contain any work involving work cycles longer than 1 min, or non-cyclic work.

Great efforts were made to classify the subjects into different exposure categories, however this was not possible, because the workers rotated frequently between work tasks.

Psychosocial work environment.

Workers in the fish-processing industry reported a much poorer psychosocial work environment than referent workers (**Paper I**). Among the fish-processing workers, the perceived conditions were worse in females, than among males, concerning all aspects except relations with fellow workers, especially obvious for climate and stimulation at work.

Individual factors

The female fish-processing workers reported a high muscular tension tendency, as compared to females in other work (median 3.0 *vs.* 2.0.) Males with and without fish-processing work reported a low muscular tension tendency (median 1.0). Smoking was more common among female fish processing workers (52%), than in males in both groups (31%), and in females with other work (23%).

Measurement of muscular rest by EMG

In **Paper II**, EMG was analysed regarding the time proportion with an EMG signal below 0.5 %MVE. Then, in hospital cleaners who had a high risk of neck/shoulder myalgia (32% had tension neck syndrome at the physical examination), the median value of muscular rest was 1.0 (range 0.0-13) % during the main work task, cleaning (which constituted 52% of the total registration time). The corresponding figure for female office workers (with a considerably lower prevalence of tension neck syndrome; 11%) was 13 (0.0-33) %, and for male office workers (tension neck syndrome in only 3%) 10 (2.6-56) %, during their main work task, deskwork (54% of total registration time). The alternate threshold of 3 %RVE showed almost identical figures, thus the transformation factor was adequately selected. Since muscular rest could differentiate between work tasks with high and low risk of muscular disorders, it was considered suitable for exposure assessment.

Gap frequency, on the other hand, showed no difference between the two work tasks; hence it cannot be recommended as an exposure measure.

Both measures displayed a wide inter-individual variation. For the cleaners, some of the variance was explained by Body Mass Index (BMI) and age, with lower values of muscular rest for older subjects with a high BMI than for slimmer and/or younger ones (**Paper II**, Table 3, Figure 2). Surprisingly, among the office workers, low values of muscular rest were registered in subjects with a low subjective muscular tension tendency. Gender, strength, smoking, job strain, employment time or musculoskeletal symptoms had no impact on either EMG measure.

Precision of EMG

The between-days (within-subject) variability for the MVE-normalised values was, 8% for *m. trapezius*, 15% for *m. infraspinatus* and 33% for the forearm extensors, in the work task 'heavy assembly'. This work task showed the lowest variability, partly as an effect of the fact, that it had the highest mean value, which reduced CV.

As RVE-normalisation accounts for strength, it reduced the between-subjects variation from 16% to 15% for *m. trapezius*, and from 58% to 27% for *m. infraspinatus* in 'heavy assembly'. For the forearm extensors, no RVE-normalisation was applied.

In the forearm extensors, higher between-days variability was shown for MVE-normalised values, 33% in 'heavy assembly', than for non-normalised ones, 16%. Hence, a variation was introduced by the normalisation method, which should be further evaluated and improved.

Concerning muscular rest and gap frequency, low mean values were found for most work tasks and muscles (around 1 %time). As an effect of this, even though the SDs were small, the CVs were more than 100% for several work tasks and muscles. 'Materials picking' however, entailed higher values of muscular rest in *m. trapezius (*mean 10 %time*)*, resulting in CV 34%, **Figure 1**.

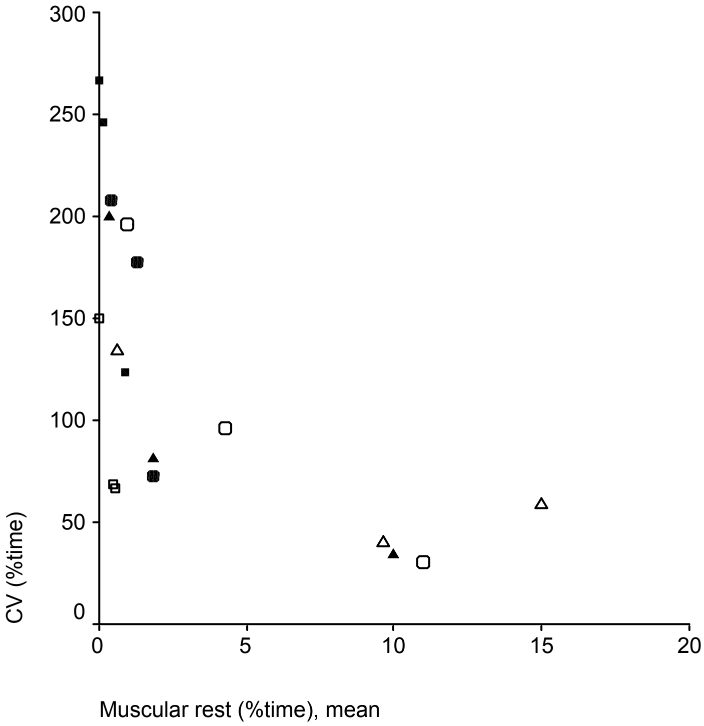


Figure 1. Precision, CV, *vs.* mean values of muscular rest, for the between-days (within-subjects) variation in six females. Three different work task; 'materials picking', 'light assembly' and 'heavy assembly', were repeated on three different days (Paper III). ▲ = *m. trapezius*, right, △ = *m. trapezius*, left, ● = *m. infraspinatus*, right, ○ = *m. infraspinatus*, left, ■ = forearm extensors, right, □ = forearm extensors, left.

Male and female workers with identical work tasks

Musculoskeletal disorders

Though males and females performed identical work tasks, disorders in the neck and upper extremities were twice as common among females (**Paper IV**). Hence, the age-adjusted POR for complaints during the past 7 days was 2.3 (CI 1.3-3.8) for neck/shoulders, and 2.4 (1.4-4.0) for elbows/hands. Corresponding figures for diagnoses at the physical examination was 1.9 (1.1-3.6) and 2.1 (0.6-7.9). For low back and lower extremities, no differences between the genders were found.

Physical exposure

The registered levels of muscular activity, as well as working postures and movements, was highly similar in the rubber manufacturing plant and the mechanical assembly plant; hence the data were pooled.

No major gender differences were shown concerning working postures of the head, upper arms and wrists. On the other hand, females showed a higher upper arm velocity, especially at the 90th percentile (though not statistically significant), and 40% higher wrist/flexion extension velocities at the 50th percentile. An association between wrist flexion/extension mobility and the corresponding range of motion during work was found (Paper IV, Figure 2).

Higher *relative* levels of muscular activity were registered in females than among males, particularly for peak force (90th percentile). For *m. trapezius ,* the difference was 50%, and for the forearm extensors 44%, MVE-normalised values. Moreover, females showed 45% less muscular rest in the forearm extensors as compared to males, while for *m. trapezius,* no gender difference in muscular rest was shown.

Psychosocial work environment

No differences were found between male and female workers, concerning the explored dimensions of perceived psychosocial work environment. Further, no correlation was found between the quotient (job demands to job control) and the total number of findings at the physical examination.

Individual factors

Females spent much more time on household work, and somewhat less time on exercise and relaxation than males. To some extent could be because the females were older, thus more of them had family responsibilities (58% of the females and 44% of the males had children at home). Smoking was somewhat more common among females than in males (35% vs. 29% daily smokers). Parenthood and smoking were tested as possible confounders, inclusion of these in the model did not additionally influence the risk estimates. The median values for reported muscular tension tendency were 2.5 in females and 1.0 in males; $p < 0.001$. This tendency was associated with the number of findings registered at the physical examination.

GENERAL DISCUSSION

Methodological issues

Selection

Since exposure, as well as disorders, are recorded in real occupational settings, in **Papers I**, **II** and **IV**, several sources of selection bias need to be considered. The employers were well aware that the work tasks were strenuous, hence, there was a possibility that they selected strong and previously unaffected subjects. In fact, in the mechanical assembly department in **Paper IV**, all subjects were examined by the occupational health service prior to employment, with special focus on musculoskeletal complaints. Concerning strength, we saw no obvious selection: in all studied groups, there were strong, as well as weak, subjects.

Moreover, in cross-sectional studies, there is a risk of a healthy workers effect,[81] implying that those who develop disorders are more liable to change jobs, or receive a sick pensioning, while healthy workers stay in the work place. A healthy workers selection will bias the risk estimate towards the null. Further, if the healthy workers selection differs between males and females, it could introduce a bias changing the risk relationship between the genders.[69] In **Papers I** and **IV**, healthy workers selection was assessed by mailed questionnaires to subjects who had left employment during some years before the study. Then, in **Paper IV**, females twice as often as males reported that they had suffered from pain in the neck or upper limb during employment. Further, in both studies, it was twice as common among females as in males to have left employment due to such disorders. This is in accordance with the main results of the studies, showing an about double frequency in females for neck/shoulders, as well as elbows/hands, complaints. Hence, it is not plausible that the difference in risk between genders is neither exaggerated nor attenuated by a healthy workers effect.

On the other hand, in **Paper IV**, men had shorter employment time, and one might thus speculate that they have greater possibilities to find another job, if they consider the present one risky. Further, an 'un-healthy workers effect' will occur if workers with WRMSDs have trouble getting a new employment, even though they are well aware that the present one makes them worse. In Sweden, workers protection laws, stating that the workers who have been employed last shall be the first to leave in a cut-down situation, will enhance this phenomenon. Leaving a long employment for a new one is hazardous, especially for subjects that have WRMSDs.

Further, selection bias may occur when some of the subjects who are invited to the study, refrain participation. Hence, in **Paper I**, 15% of the males and 8% of the females in the fish-processing industry refused to participate. Unfortunately, no data were collected to judge whether these workers differed from those included.

In **Paper IV**, the problem was very small, since all but 2% of the females and 5% of the males participated in the interview and the physical examination; it is thus unlikely that the conclusions have been biased. Concerning the questionnaire, however, only 83% of the males and 80% of the females could be reached, partly because some of them were on sick leave. Thus, to some extent, the relationship to non-occupational determinants may have been biased. Concerning the former workers, it is quite possible that subjects who did not experience any complaints during their employment did not bother to return the questionnaire. It is, however, less likely that this phenomenon should differ between males and females, thus the conclusions are probably not biased.

Some of the workers were selected for exposure recordings in order to assess the group means. By not measuring on everybody, an additional possibility for selection bias was introduced, if these subjects differed from the rest of the group in the way that they performed the work tasks. Hence, in **Papers II** and **IV** there was a risk that interested and ambitious workers volunteered for measurements. Subjects with, as well as without, complaints were included, though, and they were observed during the whole measurement day, without any obvious deviation from other workers being detected.

In **Paper III**, the main focus of the study was the reproducibility of the EMG method, why the between-days variability in EMG recordings was assessed. To avoid large inter-individual differences in reproducibility, *e.g.* due to recurrent pain, the subjects were carefully selected. The study design allowed a parallel assessment of the between-subjects variability. These variabilities would probably have been larger, if the subjects had differed more concerning length, weight, strength and pain status.

Information

Response assessment
In the structured interviews, where the examiners, by asking questions to the subject, filled out a questionnaire, there was a risk of observer bias, since knowledge about gender was inevitable. Likewise, since the examinations were performed at the work-sites, to optimise participation rates, it was also obvious to the observer where each subject worked. Letting the subjects fill out the questionnaires themselves would have excluded any bias introduced by the examiner, but would have introduced a risk of drop out (as seen for the questionnaire in **Paper IV**) or misinterpretation of the questions.

A possible source of information bias is if males, or females, are more reluctant to report symptoms. Indeed, in **Paper I**, there was a larger difference between male and female workers in the interview than in the physical examination. Hence, 70% of the males that reported neck/shoulder complaints during the past seven days fulfilled the criteria for a diagnosis at the physical examination. For females, the corresponding figure was somewhat lower, 62%. Thus, probably, some males with less severe symptoms omitted to report them ('the Tarzan effect'). The questionnaire thereby showed a larger difference between males and females, than was found by the physical examination (which in this sense may be considered more objective). This phenomenon was, however, not found in **Paper IV**.

Concerning response assessment by physical examinations, all methodological aspects are discussed below, under the heading 'Assessment of musculoskeletal disorders by physical examination'.

Exposure assessment

Measurements of exposure were made in an identical way for males and females. The measuring equipment has a total weight of approximately 3 kg, and since females generally are weaker than males, they may experience it as relatively heavier. However, this will hardly influence neither the working postures and movements, nor the activity the muscles of interest. Measurements would be biased, if subjects changed their usual way of working during the measurement day, maybe to make the work appear more demanding, *e.g.* by taking fewer pauses, or by working in other postures. However, since the equipment was carried for a full working day, it seemed that the workers more or less forgot that it. Further, any such effect would probably not differ between genders.

An obvious pit-fall would be, if exposure were not registered from representative work tasks, or on days that were either especially stressful or calm. By measuring whole working days, on varying days for different individuals, most of these problems have been avoided, though. On the other hand, in **Paper IV**, there was a 'healthy workers selection' within the workplace, as some workers who had previously worked on the production lines no longer were able to do so, due to WRMSDs. Instead, some of them did preparation of materials, or inspection and trimming of products. These tasks were, in general, less force demanding, but just as repetitive, and were performed with as little muscular rest as the line work tasks. However, as the workers performed them when disorders had already occurred, they have not been presented in **Paper IV**.[81]

Further, the reliability of the methods for assessing exposure, as well as response, are most important, since methods with low precision may conceal a true relationship between the two, and systematic errors may bias the slope, either upwards or downwards.

In **Paper I**, an observational method was used for exposure assessment.[74] It has proven to be a good tool to point out hazardous working conditions of various kinds. However, in assessment of repetitive work, it is not detailed enough, since the highest grade is given to work tasks with cycle times below 30 s, while some of the tasks in the fish-processing industry had cycle times of 2, 3 and 5-10 s. Based on information from the observational method, as well as from the structured interview, an exposure matrix was constructed, which has several advantages. First, it combines force and hand activity level, as suggested by several authors.[20, 53, 82] Secondly, visual demands due to the hand-intensive work are considered. Third, since an interview of the worker is involved, it is not a snapshot of the exposure, but an integrated assessment over the past months is obtained. Since the tasks were classified in different load cells, independent of workers, concerning this method, no gender related differences in exposure assessment can be suspected.

The inclinometry and goniometry measurement methods have been carefully evaluated and have shown excellent qualities. Concerning the inclinometry, the between-days reproducibility in manual work was SD 3° (Hansson *et al.* to be published), and it has been shown that the angular error of the system is small.[57] The reproducibility of goniometry recordings in manual work was assessed in the study presented in **Paper III**, and for the 50th percentile of the flexion/extension velocity the between-days variation was 5-8% for the different work tasks (Balogh *et al.* to be published). Moreover, the goniometers' inherent crosstalk in rotation has no significant influence on the results.[59, 60]

All methodological aspects of EMG are discussed below, under the heading 'EMG'.

Regarding gender differences in WRMSDs, there are several potential confounders and effect modifiers, which are discussed under the heading 'Gender aspects'.

EMG

Quality

For *m. trapeziu,s* the MVE level is typically about 1,000 µV, for *m. infraspinatus* and the forearm extensors, it is only about 500 µV, probably because these muscles are smaller, why higher gain settings are used. For *m. trapezius* and *m. infraspinatus* a noise level of about 1.5 µV is registered, for the forearm extensors about 0.5 µV, as an effect of the higher gain setting. For *m. infraspinatus*¸ even though the signal is high-pass filtered at 30 Hz, there is a residual effect of the heart activity, which probably explains the higher noise. Then, for *m. trapezius*, the threshold defined for muscular rest (0.5 %MVE, after subtraction of the noise level),[63, 76] on average corresponds to about 5 µV; for *m. infraspinatus* and the forearm extensors about 2.5 µV. The reason for not using 0 µV as the threshold is that some stochastic noise is present, even after subtraction of the average noise level. Considering that the higher gain settings for the smaller muscles will reduce also the stochastic noise, there is reason to believe that the threshold adequately

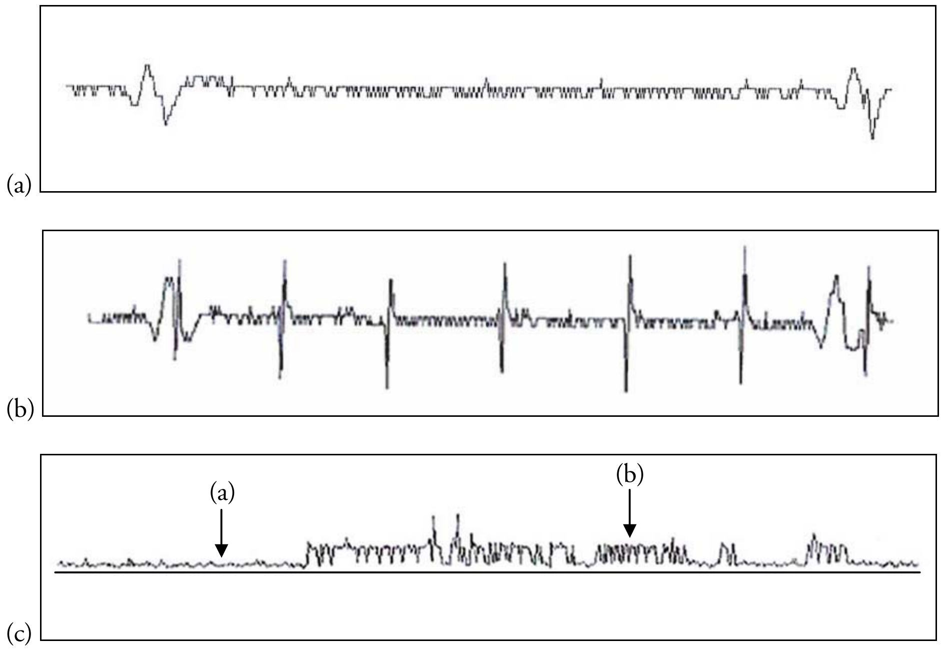


Figure 2 An EMG recording from *m. trapezius* during sleep. Panel 2a shows a 1.25 s long section of A/D converted raw EMG, where only electrical noise and heart activity are registered. In panel 2b, one motor unit with a firing rate of 6 Hz is active. Then, the RMS-converted EMG of a 5 min 20 s long registration shows that the activity from a single motor unit (2.3 µV RMS) can be clearly distinguished from the system noise (0.6 µV RMS).

exceeds the noise. As shown in **Figure 2**, it is possible to detect the activity of a single motor unit by surface EMG.

The recorded EMG depends on the thickness and the electrical properties of the subcutaneous fat layer.[83] Hence, subjects with a high BMI have a low MVE, which may significantly reduce the signal-to-noise ratio, as well as the threshold defined for muscular rest, at least for *m. trapezius.* Then, if the stochastic noise occasionally exceeds the threshold, spuriously low values of muscular rest will be obtained. In fact, in **Paper II**, cleaners with high BMI showed a low muscular rest, possibly explained by such a phenomenon. To avoid the influence of BMI, defining the threshold independent of a reference contraction could be a possibility. Other researchers have used a threshold of 10 µV for all subjects,[84] which, however, might be unnecessarily high; hence, further evaluation should be made. Still, the effect of BMI is small, as compared to differences in the time proportion of muscular rest that have been shown between different occupational groups.

Finally, in **Paper III**, the upper limit of the imprecision of the method *per se* was evaluated. A problem is, then, that the day-to-day variation also includes the slightly different work-technique from day-to-day for the individuals. Thus, the subject with the smallest day-to-day variation (6% for *m. trapezius* and 9% for the forearm extensors, may give a better estimate of the methodological variation than the group average (8% and 33% respectively). For the forearm extensors, obviously some variation was introduced by the normalisation method, and alternate ways for electrode placements and reference contractions should be evaluated, to reduce this. Still, the imprecision was rather small, as compared to differences shown between groups with different work tasks.

Level of muscular activity

EMG is a valuable tool in assessing physical exposure at work (**Paper IV**). EMG amplitude increases with exerted force, hence EMG can be used to get an estimate of the exposure in this respect.[85] For static contractions and large muscles, like *m. trapezius*, there is a linear relationship between the EMG signal and the exerted force up to about 30% of MVC; above that level, the EMG signal increases faster than the force. For smaller muscles, the relationship seems to be more linear over the full range.[86] However, there are limitations, as, in addition to force, several factors may influence the EMG level.[87] Hence, in dynamic contractions, the force-EMG relationship may change. The muscle may slide under the electrode, changing its relative position, and the muscle may become thicker, or thinner. Also, different recruitment patterns may be involved.[88] Further, in fatigued muscles the amplitude will rise due to motor unit recruitment and a slower conduction velocity.[86] However, in the situations studied in this thesis, such circumstances probably have less impact than the physical demands of the work tasks. A great advantage is, that EMG can also register the level of contraction in stabilising muscles, co-contractors or antagonists. Such muscular activity is not observable by eye, and does not alter the external force; still it may be relevant in a pathomechanistic perspective.

Concerning the relationship between the level of muscular activity and disorders, most likely, the strength of the subjects is relevant. Then, EMG offers a possibility to directly account for this, by normalisation to MVC. Especially when comparing genders, this is an advantage (**Paper IV**). Additionally, normalisation adjusts for the above-mentioned effect of the subcutaneous tissues.

Muscular rest

EMG offers a possibility to quantify the time proportions of muscular activity and rest (**Papers II**, **III** and **IV**).[89, 90] This aspect is most relevant to the risk of myalgia, thus EMG is a useful and important tool to be used in the field for assessment of dose-response relationships. In the pathomechanistic perspective, EMG has additional advantages. Thus, in addition to the demands for movements and force exertion, several other factors have been shown to influence this relationship: Mental and emotional loads may induce low-level activity in *m. trapezius*, with a low second-to-second variability.[35] This kind of activity may be especially deleterious, since motor unit substitution probably occurs more readily in muscular contractions of varying load levels.[41] Also, anticipation to perform a movement, as in precision-demanding tasks or computer-mouse operations, as well as stabilising contractions, as in the shoulder muscles during hand/arm movements, will cause muscular tension without movements.[27]

Originally, time periods without muscular activity (gaps) were registered to study differences between subjects.[63, 64, 89] Then, there was an association between EMG gap frequency and the occurrence of disorders, (not always present[91]). In **Paper II**, no such relationship was found. However, assuming that the occurrence of EMG gaps gives an indication of motor unit recruitment, the gap frequency is only relevant in working conditions that offer an extremely low time proportion of muscular rest. In other situations, adequate muscular recovery will be available, and will not require an ability to rotate between motor units.

Other aspects of exposure assessment by EMG

The imprecision of EMG, as evaluated in **Paper III** in a laboratory setting, was small compared to the intra-individual variation registered in a field setting, where all workers performed the same standardised work task; for *m.trapezius* 8% *vs.* 66% and for *m.infraspinatus* 15% *vs.* 51% for the MVE-normalised 50th percentiles.[67] Accordingly, among the hospital cleaners in **Paper II**, the corresponding figure for *m.trapezius* was 58%. Hence, as in most exposure measurements, the analytical error is small as compared to the imprecision resulting from variation between subjects and days.[92]

In **Paper IV**, to reduce variation a possible strategy would be to measure several times in each subject. This would, however, be extremely resource demanding, and instead a group based exposure assessment strategy was applied. Then, since different subjects were measured on different days, some of the between days variation was handled. Further, the average exposure estimated from a sample of subjects could be applied to the rest of the workers who performed the same work-tasks, which improves the power of the study.

Assessment of musculoskeletal disorders by physical examination

The physical examination includes judgement by the examiner, *e.g.* of what is normal and what is increased tenderness. In **Paper I**, one examiner examined all males, another one all females. Hence, if the examiners differed systematically in their assessment, the results would be biased. As reported in the materials and methods section, their inter-observer agreement is, however, good, and – more important – there was no systematic tendency for the examiner who assessed the musculoskeletal status on the female workers to make higher ratings. In **Papers II** and **IV**, the two examiners (the same ones as in **Paper I**) randomly examined males and females.

WRMSDs are not either-or-conditions, with obvious starting points and then present for ever after. They come and go, and they vary in intensity so that the same disorder can be everything from just noticeable, to making the person unable to continue to work.[93] The assessment WRMSDs by physical examination can be done by several methods, none of them qualifying for the title gold standard. Which method to choose depends, *i.a.*, on the intent of the study. Hence, for workers compensation claims, treatment or prevention, different extents of specificity are appropriate. Further the severity of disorders in the groups to be examined is important. Then, in epidemiology, the criteria for diagnosis must not be so rigorous that they are almost never fulfilled, and not so loose that most subjects fulfil them. Different research groups have used various diagnostic criteria; hence, unfortunately, the prevalences reported in different studies are not comparable.

In **Papers I**, **II** and **IV**, the same method (Lund) was used, with a good inter-observer reproducibility, as reported in the materials and methods section.[79] Concerning the neck/shoulder region, the diagnostic criteria were suitable for showing significant differences between groups. However, for the elbows/hands regions, this was not the case, as few subjects fulfilled the criteria, even in groups were subjective complaints were common. Rigorous criteria were used, especially

Table 3. Diagnoses defined at physical examination, by the criteria applied in **Papers I**, **II** and **IV** (Lund), and those suggested by Sluiter *et al.*,[94] on 277 subjects (105 males and 172 females in **Paper IV**).

	Lund (%)	Sluiter *et al.* (%)
At least one neck/shoulders diagnose	29	14
Tension neck syndrome	17	n.a.
Cervicalgia	2	n.a.
Radiating neck pain	n.a.	7
Rotator cuff tendinitis	12	11
Acromioclavicular syndrome	10	n.a.
At least one elbows/hands diagnose	5	18
Epicondylitis	5	5
Cubital tunnel syndrome	0	3
Radial tunnel syndrome	0	n.a.
Peritendinitis	0	0.4
De Quervains' disease	n.a.	7
Carpal tunnel syndrome	0.4	8
Guyon's canal syndrome	0	1
Over-used hand syndrome	1	n.a.

n.a. Not applicable

concerning nerve entrapments. An alternate method has recently been suggested by Sluiter *et al.*, with the purpose to facilitate a more uniform data collection about WRMSDs.[94] Most of the signs explored are included in both methods; thus recalculation of the material in **Paper IV** allows a comparison (**Table 3**). If Sluiter *et al.*'s criteria would have been used; the age-adjusted PORs for females *vs.* males would have been 2.2 (CI 0.9-5.0) for neck/shoulders, and 1.9 (0.9-3.9) for elbows/hands diagnoses, instead of 1.9 (1.1-3.6) and 2.1 (0.6-7.9), respectively. Thus, the confidence interval for neck/shoulders would have been wider, and for elbows/hands, narrower, while the risk estimates would be approximately unchanged. An important advantage of the Lund method is that it includes the diagnose 'tension neck syndrome', since neck/shoulder myalgia is by far the most common WRMSD.[34] A combination of the two methods would improve the usability.

Gender aspects

A model to be used for a discussion of interaction between gender/sex and the sequence work to WRMSDs is outlined in **Figure 3**.

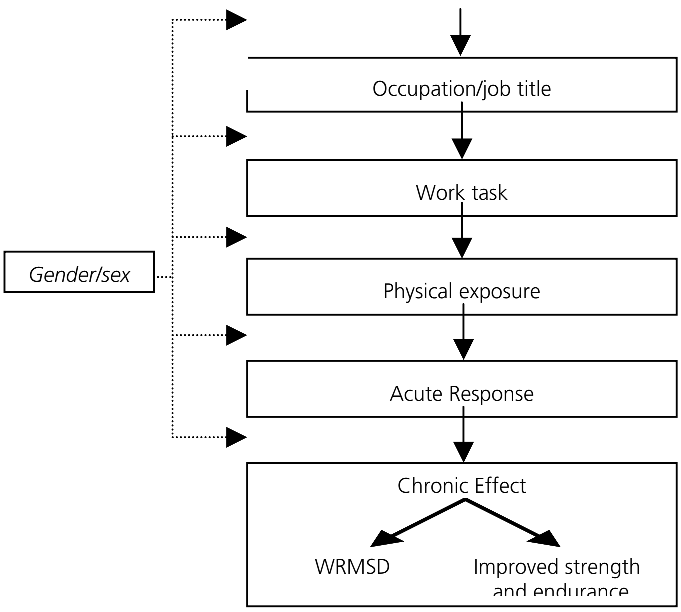


Figure 3. An exposure-effect model for work-related musculoskeletal disorders (WRMSDs). Modified from Winkel and Mathiassen.[28]

In Sweden, 2.2 million males and 2.0 million females were in gainful employment 2002. Among those, 26% of the males and 10% of the females had manufacturing work. Corresponding figures for building work was 10% and 1%, teaching 5% and 16% and institutional, as well as non-institutional, care 5% and 28%, respectively.[95] Hence, on the labour market as a whole, males and females are not evenly distributed among available *occupations*. Traditionally, females perform jobs that were earlier carried out in the home, like taking care of the children, the elderly and the sick. Also, cleaning and sewing are typical female jobs. Contrary, jobs that require forceful exertions and heavy lifting traditionally are performed by males. Thus, on a population level, there are great differences in physical exposure between genders.

Further, once in an occupation, gender has an impact on *work tasks*, as shown in **Paper I**, and corroborated by several studies.[96, 97] Hence, female workers more often than males are assigned repetitive, monotonous work tasks, which imply a higher risk of WRMSDs. Accordingly, in a Swedish survey, 37% of the males and 45% of the females performed repetitive work more than half of the working day.[98] Apart from implying a higher physical exposure, these work tasks also mean poorer psychosocial work conditions, especially in terms of lack of control.

As concerns the *physical exposure* in a specific work task, apart from demands connected to the purpose of the task, an interaction between the subject and the work demands, such as working technique and reaching distance, will decide the true personal exposure. It is possible, that males and females perform the same work task in different ways. Females are, on average, shorter than males, and thus, probably more often work with their hands above she shoulder level. Such effects can be avoided by making the work place easily adjustable. Indeed, in **Paper IV**, no such difference was shown. Further, females have larger wrist mobility (**Paper IV**), and seem to be able to perform hand-intensive tasks faster than males. The viscoelastic properties of tendon structures differ between the sexes; women have significantly lower stiffness than men,[99] possibly enhancing mobility. Interestingly, it has been reported that female fish filleters in France worked much faster than male workers with the same work task in Quebec.[56] Thus, the ability to work fast is exploited by the employer, even though nothing indicates that females are less susceptible than males to such conditions. Additionally, as shown in **Paper IV**, even when males and females perform the same work tasks at the same work speed (*i.e.* cycle time), females show a higher wrist flexion/extension velocity.

As to force exertions, in **Paper IV** the *relative* muscle workload was higher in females than among males, especially for the forearm extensors. In that study, the work tasks were quite force demanding, most certainly implying an elevated risk of disorders. Females showed a higher occurrence of disorders than males, which, presumably, to a large extent can be explained by the discrepancy in *relative* physical exposure. Corresponding results have been shown for male and female military recruits, in whom strenuous exercise resulted in MSDs in females, but not in males.[100]

Acute responses to physical exposure may be pain and fatigue. Then, women have lower pressure pain thresholds than men,[101] and show a greater response to chemically induced muscle pain[102], which may be relevant for the development of myalgia, as algesic substances are released into the tissue after tissue damage, as well as after long duration static contractions. On the other hand, there is no clear gender difference in muscular fatigability when matching for strength and force exertion.[103-106]

Concerning *chronic effects*, whether or not exertions at work, will result in an MSD, or – alternatively – contribute to improved strength and endurance, may be determined by other factors at, or outside, work. Then, psychosocial factors are known to influence the risk of disorders, especially when high levels of physical risk factors are present.[23] Repetitive tasks often imply a poor psychosocial work environment, especially concerning decision authority. Thus, in **Paper I**, females experienced a poorer psychosocial work environment than males, and this fact may have contributed to their elevated risk of disorders. On the other hand, in **Paper IV**, all workers performed repetitive work tasks and 95% reported low control.[107] No gender differences were found concerning work demands, work control or social support.

Another important aspect is the possibility to recover after work.[108] Females often shoulder the main responsibility (mental, as well as physical) for household duties and childcare; thus, their total workload (from paid and unpaid work) is larger than among males.[48] This is reflected in elevated physiological arousal after work, which has been shown as higher norepinephrine excretion.[109] Accordingly, in **Paper IV**, males and females with identical work situations reported very different situations at home. Thus, it was much more common among females than in males to perform household work more than 10 h per week. This may explain some of the higher prevalence of MSDs among females, by confounding or – more likely – by effect modification. Notably, in a recent study, the influence of work and family demands on upper body MSDs, was evaluated by multiple regression; when these factors were included, no gender gap remained.[48] No evidence was found for a larger vulnerability for women. Further, parenthood had a significant negative influence on time for exercise and relax in females, but not among males, in accordance with **Paper IV**.

Several studies have shown an effect of age on WRMSDs,[110-112] and, since the females in **Paper IV** were older than the males, adjusting for age significantly reduced the PORs. Age entails declining tissue strength, thus it is an effect modifier for the relationship between exposure and disorders.[113] There might be a sex difference concerning this aspect (*e.g.* if the tissue strength declines faster in post-menopausal women). It is also possible, that there are biological differences concerning tissue repair, which may be accentuated after menopause.[114] However, in **Paper IV**, stratification for age did not significantly affect risk estimates for females *vs*. males. Moreover, most often high age implies long exposure time (cumulative dose), which influences the occurrence of disorders. In **Paper IV**, after adjusting for age, no significant independent effect of employment time was found, probably because the two were tightly connected.

A serious *chronic effect* is altered pain perception. Capsulated nociceptors, and free nerve endings, diffusely distributed in, *i.a.*, the muscles,[115] that do not normally react to mechanical stimuli, may become sensitised by algesic substances (peripheral sensitisation).[116] They may thereafter react to low levels of chemical or mechanical inputs, and even low levels of muscle activity, as well as light touch, may become painful.[117] Further, muscle pain may induce neuroplastic changes at the spinal and medullar level (central sensitization), where after spontaneous pain and hyperalgesia may occur, may spread, and may become chronic.[118] Concerning such processes, the sex difference in response to pain provoking factors could be relevant. Moreover, it has been suggested, that females are at greater risk for developing hyperalgesia in multiple regions secondary to pain experienced during labour or painful gynaecological conditions.[119]

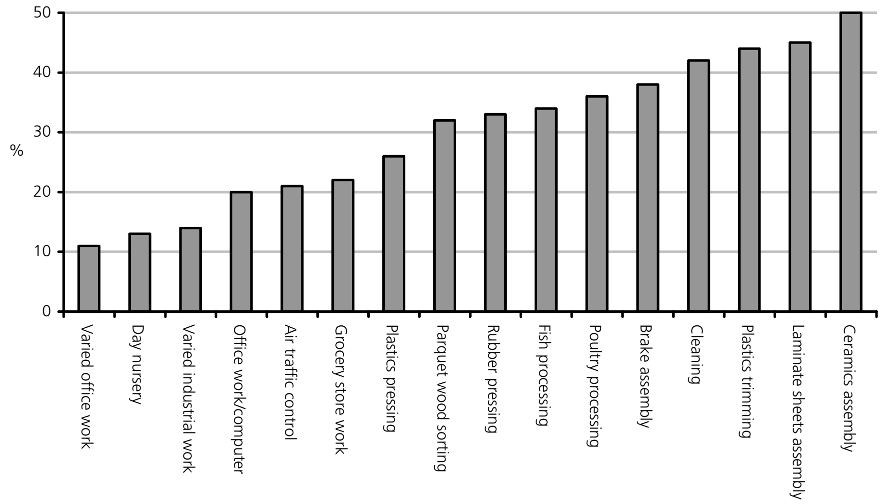
Finally, smoking has been reported to elevate the risk for MSDs,[5, 120] and in **Papers I** and **IV**, smoking was more common among females than in males, thus it was a potential confounder. However, in the logistic regression models, smoking did not significantly change the age-adjusted risk estimates.

Hence, even when the *relative* workload is equal, there are several biological and cultural conditions that may differ between genders, and may influence the outcome. Whether any of these has a substantial influence on the risk at a certain exposure level is, however, not clear, and should be further evaluated by comparing the gender-specific risks at several exposure levels.

Work-relatedness of disorders?

When forming an opinion on whether a certain disorder is work-related or not, it is important to remember, that even if females do run a higher risk than males to develop WRMSDs at a certain exposure level, gender is not the sole cause in an individual case; work has a profound influence. Hence, concerning diagnoses by physical examination in **Papers I** and **IV**, the age-adjusted POR neck/shoulder diagnoses in female fish-processing workers *vs.* other female workers was 3.2. **Figure 4** shows the prevalence of neck/shoulder diagnoses in females, defined by the method used in **Papers I**, **II** and **IV**, in different work tasks, with varying degree of repetitiveness. There is no reason to suspect that the groups differ significantly concerning conditions outside work, and they have approximately the same average age and employment time.

Figure 4. Prevalence of neck/shoulder diagnoses among female workers in different occupational groups, generally more repetitive work to the right. [67, 79, 110, 111, 121-123 and to be published]



For groups with varied work, the prevalence is about 12%, for those with very repetitive work about 45%. If the former prevalence is assumed to be a ‘background’, the latter groups have a relative risk (RR) of about 3.8, and an aetiological fraction [(RR-1)/RR] about 75%, *i.e.* one out of three of the females in the groups with repetitive work had developed a WRMSD. An average for female groups with repetitive work seems to be about 35%. In the aforementioned Swedish survey (see Gender aspects), 17% of the 2 million female workers reported that they performed repetitive, monotonous work tasks more than 75% of the working day,[98] If these are as repetitive as for the examined groups, about 80,000 females, in Sweden alone, may suffer from preventable MSDs!

Correspondingly, among the males in repetitive work reported in Paper IV, the prevalence of neck/shoulder diagnoses was 18%, while in males in mobile and varied work, Paper I, it was only 8%; hence, the aetiological fraction was 55%. In work tasks with higher wrist/flexion velocities, and/or higher *relative* muscular loads, it can be suspected to be even higher.

In judgement of worker’s compensation claims, for several WRMSDs female gender *per se* is often considered an independent risk factor, and the physical exposure at work is not recognised as causal, which hampers the possibilities for females to get economic compensation for their impairments. However, even if the background prevalence of MSDs is higher among females than in males, jobs that entail an aetiological fraction above 50% should entitle to compensation for injured workers.

Recently, a literature survey showed elevated risks for males, as compared to females, to develop back disorders from lifting, and for females, in comparison to males, to have neck/shoulder disorders because of awkward arm postures.[124] However, in that review, exposure levels were not considered. To further explore possible effect-modifying properties of gender, gender-specific exposure-response relationships should be described. It is then not necessary to study the male and female workers in the same setting, as long as the exposure, and the occurrence of disorders, are adequately assessed, and potential confounders and effect-modifying factors considered.

In such an approach, an exposure-response relationship is outlined in **Figure 5**. So far, the material is, however, too small to draw conclusions about the association between exposure and response, as well as on differences or similarities between the genders. The diagram should be extended with data from several groups, especially males performing work tasks that imply low levels of muscular rest. Further, for some of the groups, the confidence intervals are large, due to a low number of subjects.

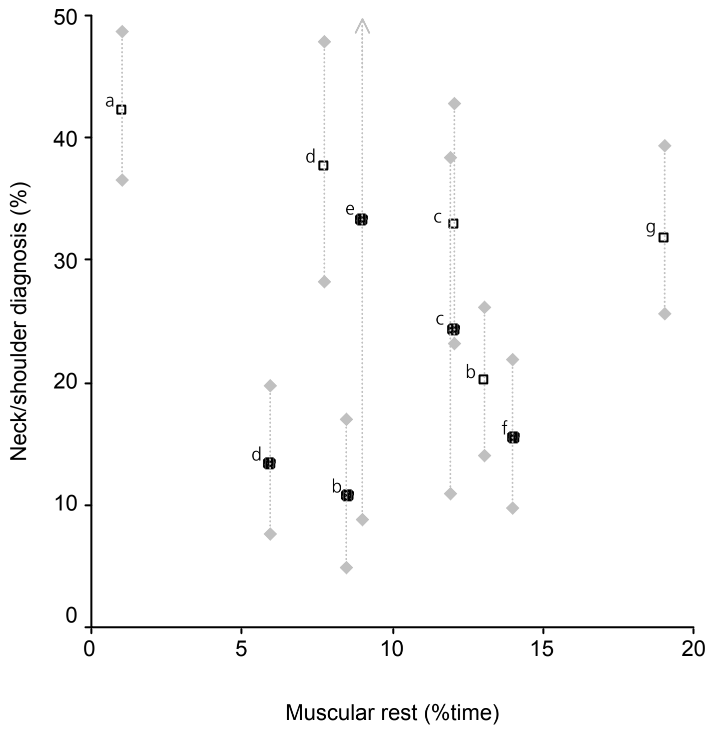


Figure 5. Proportion of subjects with at least one diagnose in the neck/shoulder region at physical examination (with 95% confidence intervals) *vs.* the group mean of muscular rest in *m. trapezius* (right side). ● = males, □ = females, a = cleaning (**Paper II**), b = office work (**Paper II**), c =rubber pressing (**Paper IV**), d = mechanical assembly (**Paper IV**), e = Computer-Aided Design (N= 15), f = mixing of rubber chemicals (N=77), g = parquet wood sorting (N=151).[125 and to be published]

Practical implications

The risk for WRMSDs in monotonous, repetitive work has been known for decades,[126] yet such work tasks are still common. In fact, the present trend is a return to the classical Tayloristic production line. Then, a combination of slim organisations with the lowest possible number of employees, and a production running without disruptions, causes high demands on workers. Preventive actions are urgent. Then, a system based approach, involving collaboration between the occupational safety and health authorities, the employers and the employees, has been suggested,[127] but has not been sufficiently fruitful. Regulations on ergonomic work conditions have been given by the Swedish Work Environment Authority in 1998.[128] They contain valuable advice on prevention of WRMSDs; however, they are only used to a limited extent. The rules are imprecise, thus it is hard for the labour inspector to substantiate that the rules are broken. Hence, as for other hazards at work, firm exposure limits should be defined.[129]

Of course, physical activity cannot, and should not, be avoided. Instead, regular physical activity is a health-promoting factor. Thus, unlike other occupational hazards, such as asbestos or vinyl chloride, a complete ban or a minimisation of activity is not a fruitful way of prevention. Hence, exposure limits must be based on sound scientific evidence on the exposure-response relationships.[29, 43] Once these are solidly described, political judgements can be made as to what levels of risk to be tolerated, balancing the economical consequences, on a macro level, against the benefits of reduced risk. For example, extended versions of diagrams as the one in Figure 5 could be used and a lowest tolerated percentage of muscular rest, or a highest tolerated mean wrist flexion/extension velocity, for the whole working day, could be decided. Whichever limit is chosen for repetitive work, the preventive effect will be larger for females than for males, since they are currently more exposed.

By relating exposure to strength, it is also possible to set limits in terms of *relative* physical exposure, considering the lower capacity of females in comparison to males. An excellent example is a threshold limit value (TLV) given by the American Conference of Governmental Industrial Hygienists (ACGIH),[53] which is partly based on an exposure-response relationship for repetitiveness.[130] Then, for various levels, different *relative* hand peak-forces are tolerated. ACGIH suggests, as one way to assess peak force, the use of EMG, thus focusing on forearm extensor and flexor muscle. However appealing, the TLV has one major limitation; it is designed for monotask jobs performed four hours a day. In accordance with TLVs for other work environment hazards, instead a limit for the 8-h time weighted average should be defined.

To describe the exposure-response relationship, and for enforcement and surveillance of exposure limits, as well as assessment of effects of preventive measures, objective and reliable exposure assessment methods are indispensable.

This poses a major objection to another proposal for maximum tolerated ergonomic workload: the OCRA index.[82] Data on dose-response relationships have been presented,[131] and appropriate use of the index would have a preventing effect. However, as ACGIH's TLV, it includes a subjective component in counting the number of 'technical actions' per time unit. Then, direct technical measurements have great advantages; the exposure assessment becomes more pregnant than when more subjective methods are applied.[53, 82]

All of the exposure-assessment measurements described in this thesis could be used for further research and legislation to prevent WRMSDs. However, for practical reasons, a few must be selected. Then, pathomechanistic, as well as usability aspects, should be considered. As discussed above, concerning neck/shoulder myalgia, time for complete muscular rest is important, and can be assessed by EMG (**Papers II**, **III** and **IV**). Further, forward flexion of the head, as well as elevation of the upper arms, are of great importance and can be reliably assessed by inclinometry (**Paper IV**). Concerning elbow/hands disorders, a combination of wrist goniometry and EMG from the forearm extensors would give a solid base (**Papers III** and **IV**).

GENERAL CONCLUSIONS

In workers with the same job-title, females performed highly repetitive work tasks with a high degree of constrained neck postures, males heavier, but much more varied, ones.

A method to extract, from surface electromyography (EMG) recordings, the time proportion of inactivity of muscle fibres (muscular rest) was further developed and tested. Such information discriminated better than the traditional "static load" of EMG, between workers with high and low prevalence of myalgia.

Estimates of muscular activity in *m. trapezius* by EMG have a high precision in repetitive manual work. As regards *m. infraspinatus* and, in particular, the forearm extensors, the variation was somewhat larger, probably because of less adequate normalisation. In the work studied, which was essentially without pauses, the precision of muscular rest was lower.

Even in workers with identical work tasks, some aspects of the physical exposure differed considerably between genders. Hence, EMG showed that the peak load in the forearm extensors (related to a maximal voluntary contraction) was higher among females than in males, accompanied by less muscular rest. Further, by objective assessment of wrist movements, females had higher flexion/extension velocity.

Also in the groups where females and males performed identical work tasks, the former had a much higher prevalence of MSDs in the neck and upper limbs than the males.

It is likely that a substantial share of the excess morbidity among females can be explained by higher physical exposure at work.

ISSUES FOR FUTURE RESEARCH

For the threshold for muscular rest, alternative definitions, independent of MVC, should be evaluated, and the influence of BMI should be considered, to optimise the discrimination between motor unit activity and noise.

To reduce the variance introduced by normalisation of EMG from the forearm extensors, various normalisation procedures should be evaluated. Then, different maximal (and sub-maximal) exertions, *i.e.* handgrip and resisted dorsiflexion, as well as various electrode positions should be applied.

The dose-response relationships between different parameters of objectively assessed physical exposure and WRMSDs should be adequately described. The methods described in this thesis are suitable for data collection, and assessments should be made in several male and females groups with various physical exposure. Concerning females, measurements on subjects with varied work should be made, and concerning males, groups with high repetitiveness should be examined. For both genders, work requiring low as well as high forces should be assessed at various levels of repetitiveness.

To investigate the possible effect of sex (biological factors) and gender (biological and cultural factors combined) on the risk of WRMSDs at various physical exposures, the gender-specific dose-response curves should be compared, taking possible confounders and effect-modifiers, such as activities and recovery outside work, into consideration.

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SVENSK SAMMANFATTNING

Värk i leder och muskler tillhör de vanligaste orsakerna till långtidssjukskrivningar och förtidspensioneringar. En betydande del av dessa tillstånd är orsakade av belastningsergonomiska faktorer i arbetslivet, och kan således förebyggas. Arbetsrelaterade besvär i nacke, axlar och armar är betydligt vanligare bland kvinnor än bland män. Orsakerna till detta är ofullständigt kända. Arbetsmarknaden är könssegregerad så till vida att män och kvinnor till stor del finns i olika yrken. I studier där man tagit hänsyn till yrkestitel kvarstår emellertid överrisken för kvinnor. Flera kända riskfaktorer finns, låsta eller obekväma arbetsställningar, repetitivt och/eller kraftkrävande arbete samt brist på återhämtning. Kombinationer av dessa ökar risken ytterligare. Det är tänkbart att exponering för dessa riskfaktorer skiljer mellan könen, även inom grupper med samma yrkestitel.

Exponeringen för fysiska riskfaktorer utvärderades systematisk för 206 kvinnliga och 116 manliga arbetare med samma yrkestitel, fiskberedare. Stora skillnader påvisades mellan könen. Två tredjedelar av det arbete som utfördes av kvinnor var högrepetitivt, med arbetscykler kortare än 10 sekunder. Det medförde hög eller mycket hög låsningsgrad av arbetet, på grund av synkrav. För männen förekom sådant arbete endast 15 % av tiden, i övrigt var deras arbete betydligt mer varierat. Däremot utförde männen i högre utsträckning tunga lyft. När man korrigerar för yrkestitel missar man denna skillnad i fördelning av riskfaktorer mellan könen, och kan dra felaktiga slutsatser om samband mellan kön och sjukdom.

För att på ett objektivt sätt kvantifiera förekomst och nivå av arbetsställningar, arbetsrörelser och muskelaktivitet krävs pålitliga mätmetoder. I avhandlingen utvärderas elektromyografi (EMG) för mätning av muskelaktivitet. Via elektroder på hudytan registreras elektriska signaler från underliggande muskler. Då en viktig faktor är återhämtningstid för muskelceller, i situationer där låggradig men långvarig muskelaktivitet föreligger (t.ex. vid datorarbete). Då muskelcellerna aktiveras i en förutbestämd ordning är, sannolikt, vissa av dem utsatta för belastning varje gång muskeln används. För att kvantifiera återhämtningstiden för dessa behövs en mätmetod som kan uppskatta när hela muskeln vilar. En sådan metod, ”muskulär vila”, har vidareutvecklats och prövats. Den visade sig väl kunna skilja mellan arbeten med hög (städning) och låg (varierat kontorsarbete) risk för muskelbesvär i nacke/skulderregionen.

EMG används dessutom, sedan länge, för att ge en uppskattning av nivå på muskelaktivitet under arbete. För att ta hänsyn till skillnader i underhudsfett, vilket dämpar signalen från muskeln, föregås mätningen av normalisering mot en referenskontraktion, submaximal eller maximal. Stora skillnader påvisas, trots detta, ofta mellan individer, även då samma arbete utförs. Detta kan bero på skillnader i styrka eller arbetsteknik, men kan också vara ett metodfel. EMGmetodens precision har varit dåligt känd. EMG mättes därför på sex kvinnor som upprepade tre olika arbetsuppgifter vid tre tillfällen. För kappmuskeln var variationen mellan dagar (inom individ) 8 %, ett litet metodfel i förhållande till påvisade skillnader mellan individer. Fortfarande kan en viss skillnad i arbetsteknik mellan dagar ha förelegat, och metodfelet är sannolikt ännu mindre. För underarmens sträckmuskulatur var variationen något större, 33 %, vilket sannolikt berodde på variation införd i samband med normalisering. Denna behöver därför förbättras.

För att studera arbetsuppgiftens betydelse för utveckling av sjukdom i nacke och armar undersöktes 172 kvinnor och 105 män, som utförde exakt samma arbetsuppgifter, i en gummiindustri och i en monteringsindustri. Arbetet var såväl repetitivt och kraftkrävande som synkrävande. Även i detta arbete påvisades en fördubblad förekomst av besvär bland kvinnor.

Med ovannämnda metoder för mätning av muskelaktivitet, samt med inklinometri och goniometri för mätning av arbetsställningar och arbetsrörelser i huvud, överarmar och handleder, kvantifierades den fysiska belastningen hos 18 män och 19 kvinnor. Då påvisades en betydande skillnad i muskelaktivitet, i förhållande till styrka. Den *relativa* belastningen var 50 % högre i kappmuskeln och 44 % högre i underarmens sträckmuskulatur, i jämförelse med männen. Dessutom hade kvinnor 45 % mindre muskulär vila i underarmsmuskulaturen, och 40 % högre rörelsehastighet i handleden, på höger sida.

Då bristfälliga psykosociala förhållanden på arbetsplatsen visats öka risken för smärttillstånd i muskler och leder, inhämtades information om sådana via frågeformulär. Inga skillnader påvisades mellan män och kvinnors upplevelse beträffande någon av dimensionerna krav, kontroll och socialt stöd i arbetet.

Kvinnor utför oftare än män arbete som medför en förhöjd risk för muskel- och ledbesvär. Detta gäller såväl mellan som inom yrken och arbetsplatser. När män och kvinnor utför samma arbetsuppgifter blir den *relativa* fysiska belastningen högre för kvinnor, om man tar hänsyn till styrka. Med hänsyn till de överrisker som påvisats för ensidigt repetitivt arbete i förhållande till rörligt och varierat arbete (3-4 ggr), är det troligt att en betydande del av översjukligheten hos kvinnor kan förklaras av högre fysisk belastning i arbetet.

För att ytterligare belysa risken för besvär vid olika nivåer av exponering bör så kallade exponerings-responssamband beskrivas, separat för män och kvinnor. Detta kommer dessutom att ge möjlighet till fördjupad förståelse för betydelsen av faktorer som är knutna till kön, biologiska såväl som sociala, för uppkomsten av sjukdom. Det kommer också att öka möjligheterna till en striktare regleringar av arbetsmiljön, i form av kvantitativa hygieniska gränsvärden för belastnings-ergonomiska faktorer. Ett sådant gränsvärde skulle få störst preventiv effekt för kvinnor, eftersom dessa för närvarande är mer exponerade.

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